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A REPORT ON THE MASS WASTING (LANDSLIDE) HAZARDS IN THE URBAN AND URBANIZING AREAS OF THE CITY AND BOROUGH OF JUNEAU, ALASKA

General Stability Characteristics

Land form in the Juneau area is in a dynamic stage of geomorphic development. The area is geologically young and is actively rising due to faulting and uplift. Recent glaciation (less than 10,000 years ago) has over-steepened the slopes and withdrawl of the 5,000 to 6,000 feet of ice which existed over the area during the Pleistocene Epoch has caused an isostatic rebound or uplift, presently occuring at the rate of 1.3 cm per year (Miller, 1971, p. 83).

Bedrock is composed predominantly of interbedded slate, phyllite (a more highly altered form of slate) and andesite (volcanic flow rock) which have undergone extensive metamorphism. Bedrock strike in the area is to the northwest, approximately parallel to the Gastineau Channel with a variable dip to the northeast at 30° to 75°. Two major joint surfaces or planes of breakage in the rock dominate the slopes above the Juneau urban and urbanizing areas. One strikes perpendicular to the slope and dips northwestward at 55° to 80°. The other strike is parallel to the slope and dips southwestward in the same direction as the slope gradient at about 65° (Miller, 1971, p. 24).

These joint surfaces, in combination with the strike and dip of the bedrock have resulted in a ready production of platy fragments and large blocks of rock which become loosened and unstable on the slopes and move downward, primarily under the force of gravity, accumulating as talus or colluvium on the slopes below.

Controlling Factors

These geologic conditions have produced the following slope and soil characteristics which control the inherent instability of the slopes in the Borough area.

Oversteepening of the slopes, due to glacial erosion and active uplift, have produced gradients far above the stable angle of the materials on them. For soil materials of the type found on the slopes in the Juneau area (Tolstoi-McGilvery stony silt loam)[1] these stable slope angles may

[1] Soils of the Juneau Area, Interim Report by Dale B. Schoephorster and Clarence E. Furbush, U.S.D.A. Soil Conservation Service, Palmer, Alaska.

range from 28^{o} to 37^{o}, but probably lie near the upper end of the range. Measured slope angles in the field have averaged around 40^{o} and have gone as high as 70^{o} on the upper slope.

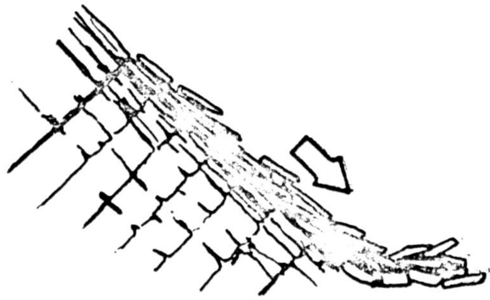
Slope soils are youthful, shallow (usually less than 2 feet), and coarse-grained with little cohesion or internal binder to hold them together. Densities are low, averaging 79.6 pounds/f^{3}. These are colluvial soils produced by mechanical weathering and gravity accumulation of local materials on the slope.

While the bedrock dips into the slope, the dominant jointing has produced planes of breakage or weakness parallel to or inclined in the same direction as the slope and independent of the bedding. Miller (1971), has hypothesized that such parallel jointing is primarily due to stress release, or release of pressure of the overlying ice with withdrawal of continental glaciers from the area. These joints provide zones of weakness along which both mechanical and chemical weathering can take place producing colluvial soil materials and unstable rock units. The joint surfaces also provide excellent planes of failure for overlying colluvial materials and potential sliding surfaces for fragments and blocks of rock.

Fragments of slate and phyllite, which dominate the colluvial soil matrix, are characteristically hard, platy and high in mica content. When accumulated on the slope, they tend to orient parallel to the slope in a shingled fashion (overlapping) (Figure 1) producing small, discrete failure planes where fragments overlap. These planes are low in frictional resistance due to the smooth surfaces and the occasional lubricating effect of the mica weathering to clay, thus greatly decreasing overall stability of the colluvial soil.

FIGURE 1

--Diagramatic cross-section of a slope showing the shingling effect of overlapping slate and phyllite fragments.



Gullies and V-notch channels in the bedrock, produced by differential erosion along fractures and joints, occur frequently on the slope. These serve to concentrate run-off from the slope and frequently channel snow and earthslides onto the lower slope. They also function as areas of temporary accumulation for debris, both organic and soil, produced by earth sliding higher up on the slope. These debris deposits may be temporarily stabilized behind natural dams in the channels, created by jammed logs and rocks, but ultimately reach the bottom of the slope as massive earth flows when the dams fail. This is a frequent cause of destructive earthslides in the Juneau area.

Contributing Factors

Important contributing factors to the relative stability on the slope include vegetation cover and the climatic conditions prevalent in the area.

Vegetation cover exerts its influence mainly through tree rooting effects on soil stability. Tree roots exert a dominantly stabilizing influence through:

a) the anchoring effect of roots growing through the shallow soil and into joints and cracks in the bedrock beneath;

b) intertwining with adjacent root systems to provide a more-or-less continuous long fiber binder to the soil mass over broad slope areas;

c) the spreading of long lateral roots across zones of weakness and into more stable areas; and,

d) the buttressing effect of tree root masses holding the soil up-slope in place.

Vegetation cover and tree rooting can also function to decrease slope stability by:

a) loosening of soil and rock by the waving of trees in the wind and more drastically by tree blow-down;

b) the wedging and loosening of blocks of rock and fragments from cliffs and open rock slopes; and,

c) the damming of channels and gulleys by limbs, trunks and root masses, producing concentrations of debris in the channel which may fail during periods of high run-off.

The relative stability of the slopes in the Borough area is strongly affected by local weather conditions. Juneau weather is characterized by frequent intense rainfalls of fairly long duration, during the months of September, October, November and December. Storms with rainfall in excess of 2 inches in 24 hours are a yearly occurrence and storms with rainfall in excess of 4 inches in 24 hours have a predicted five-year recurrence interval (Miller, p. 163). Heavy snowfall at higher elevations is also common and serves to store precipitation for delayed release and high melt-water run off during warming periods. Winters are generally moderate with frequent periods of melting and freezing and strong winds result from large pressure gradients produced between opposing air masses and gravity drainage from the Juneau Icefield.

ese dominating weather characteristics produce frequent saturation of il masses on the slope and within gullies with resulting temporary in- eases in weight of the soil mass and active pore-water pressure develop- nt due to high rainfall, snow-melt or a combination of both. Active ost wedging of bedrock fragments and blocks by diurnal freeze and thaw d to the unstable conditions on the slope by loosening individual bed- ck units and mobilizing rock debris. Wind-throw or blow-down also ilizes soil and rock material on the slope through the ripping-up of ts and dislodgement of the soil mass.

incipal Processes Operating on the Slope

h these natural factors operative on the slope, soil mass wasting, the down-slope movement of rock, soil and organic debris, primarily gravity, stands out as the dominant process of slope erosion and re- tion in the Juneau area.

pes with gradients above the stable angle of the materials on them rresponding to the angle of internal friction[2] for the slope soils in s area) must be considered as highly unstable under the best of con- ions and any disrupting influence, whether a natural catastrophic nt such as an earthquake or storm, or the activities of man is a po- tial initiator of renewed mass wasting activity.

inant mass wasting processes on the Juneau area slopes can be divided o three groups:

Soil creep, or the slow, almost imperceptible down slope movement of rock and soil by small increments of slipping, sliding and rolling is everywhere present on the slopes. This is a natural process and the principal process in colluvial soil formation and movement. It can be recognized on the slopes in the Juneau area by re-curved trees, "cat-steps"[3], small slumps and short soil and debris slides on the open slope. Movement is due mostly to the application of gravitational stress in increments great enough to cause small movements but not great enough to cause massive failure.

Rockfalls, rockslides and rock avalanches are also common in the Borough area and have been identified as frequent initiators of major earthslides. Probably most of the massive earthslides that have occured in the area prior to Juneau settlement resulted from initial failure of sections of the upper slope due to rockslides and rock avalanches. These may be initiated by hydrostatic pressure between and along bedding and joint planes, by the loosening action of alternate freeze and thaw cycles which lift individual blocks and fragments and greatly reduce their frictional resistance or by earthquake vibrations. Velocities are usually high and movement

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le of internal friction-an expression of the degree of friction or erlocking between individual soil grains. The angle is directly re- ed to the degree of frictional resistance of the soil mass.

t-steps"-narrow, generally backward tilted micro-terraces on steep hill- es produced by slumping.

ranges from free-fall to sliding, bounding and rolling rock. The rock that initially falls or slides may start as one block or several but repeated impact generally causes it to disintegrate as it moves downslope producing a rock avalanche. If enough soil and organic material become incorporated, a debris avalanche or debris flow may result.

c) Debris slides, debris avalanches and debris flows constitute the most important mass wasting processes active in the Juneau area. These are landslides produced by translational failure of the shallow residual or colluvial soils above an impermeable bedrock surface. The soils are essentially cohesionless and range in depth from several inches to four or five feet. Movement may be triggered by surface loading, increase in soil water levels or removal of the mechanical support of the soil mass downslope. Velocities of movement are variable, probably ranging from as high as 40 ft./sec., to as low as 5 ft./sec. Velocities are highest on the steep portions of the slope and within channels and decrease rapidly at the slope base as energy is dissipated through increased internal friction in the slide mass and impact with trees, brush and other obstructions. Several eyewitness reports of landslides in the Juneau urban area describe houses moving downslope more or less intact following impact indicating that many of these slides are moving at a relatively slow rate of speed by the time they reach the urbanized zone.

Rockfalls, rock slides, rock avalanches, debris slides, debris avalanches a[illegible] debris flows will collectively be called landslides in the remainder of th[illegible] report.

Volume of material moved or size of landslide depends on a number of variables including width and depth of failure zone, length of slope on which the landslide developed and the amount of debris accumulated in failure channels. A landslide which occured in 1936 on the slope above the Juneau Cold Storage Plant, piled up against the building approximately 10 feet above the level of South Franklin Street. The estimated volume of this landslide is approximately 1,248 cubic yards. At an assumed density of 79.6 pounds per cubic foot [4], this is a total weight of 1,341 tons. As a comparison, the estimated volume and weight of one of the massive landslides which occured before Juneau settlement (the landslide deposit on which the old Home Hotel was situated) is 66,000 cubic yards at a total weight of 66,825 tons.

Small debris avalanches and debris flows occur yearly throughout the Boro[illegible] area, on open slopes and within gullies and channels on the slope. These are rarely observed or noted since they usually flow a short distance and are temporarily stabilized behind trees, logs or stumps on the slope or jammed within the channels. The ultimate effect, however, is frequently the accumulation of large masses of earth, rock and organic debris in the

[4] This is the average undisturbed soil density and in actuality slide density could be considerably higher although it is highly variable dependi[illegible] on the amount of organic debris included in the slide mass.

channels which may fail as large scale destructive debris avalanches.

Larger debris avalanches and flows are usually the result of massive failures of rock and soil on the upper slope or failure of accumulated debris deposits in the gullies.

MECHANICS OF LANDSLIDING

How do these landslides develop?

Periodically high soil water content and oversteepened slopes are the controlling parameters. Bedrock geology and structure, general climatic conditions and the influence of vegetation are important contributing factors. The stability of a shallow, coarse-grained, cohesionless soil overlying an impermeable bedrock surface can be expressed in a highly simplified way as the ratio between shear strength (S) or resistance of a soil to the downslope component of gravitational stress (T) and the gravitational stress itself. This ratio expresses the "factor of safety" (F) of the soil mass or its ability to resist slope failure.

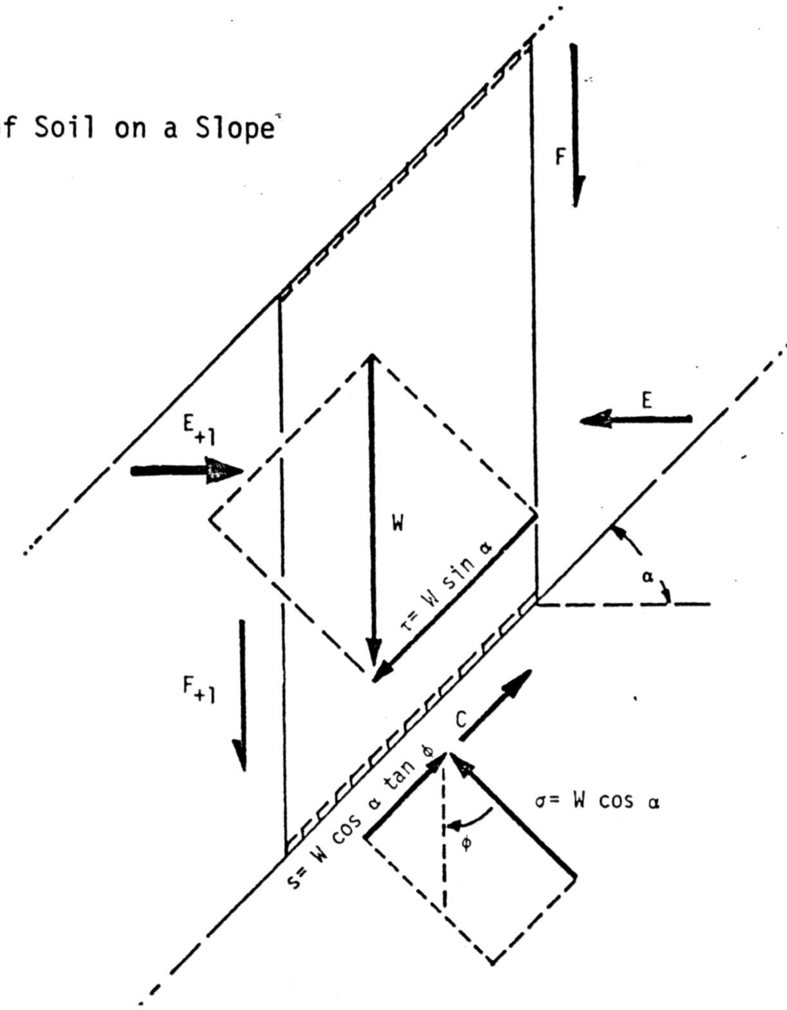
Thus: $$F = \frac{S}{T} = \frac{\text{Soil strength or resistance to sliding}}{\text{Downslope component of gravitational stress}}$$

Ideally, as long as the factor of safety remains greater than 1 (resistance to sliding is greater than the downslope pull of gravity), the slope will remain relatively stable. When the factor of safety equals one, the slope is on the verge of failure.

Landslides result from changes in the soil-shear strength--gravitational stress relationship at the point of failure. This may involve a mechanical readjustment between individual units or particles, as in rockfall, rockslide or talus creep; or a more complex interaction between intrinsic soil properties, ground water movement and external factors acting on the slope (roots, rockfall, artificial damming, etc.).

Figure 2 depicts the principal forces acting on a unit mass of soil on a slope in the Juneau area.

Figure 2
Forces Acting on a Mass of Soil on a Slope



E, E_{+1}	=	Equal and opposite normal forces acting on the soil mass
F, F_{+1}	=	Equal and opposite shear forces acting on the soil mass
W	=	Weight of the soil mass
α	=	Inclination of the sliding surface
τ	=	Sheer stress $= W \sin \alpha$
c	=	Cohesion, a soil property
σ	=	Normal stress on the sliding surface $= W \cos \alpha$
ϕ	=	Angle of internal friction, a soil property
s	=	Frictional resistance $= W \cos \alpha \tan \phi$

For simplicity, the lateral and shear forces acting on the mass are assumed equal and opposite and therefore cancel. The driving forces tending to cause downslope movement then consist of the weight of the soil mass (W) and its tangential component (τ) or sheer stress. Resisting forces consist of cohesion (c)[5] which is independent of the frictional forces and frictional resistance (s) which is proportionally related to the normal component of the soil weight (W cos α) through the angle of internal friction (ϕ).

Gravitational stress (τ) or the downslope component of gravity acting on the soil mass, is the resultant of the weight of the soil mass (W) acting along the sliding surface.

Thus: $\tau = W \sin \alpha$

For shallow soils of the type on the slopes above Juneau, the slope surface can be considered approximately parallel to the sliding surface. Thus, slope gradient becomes equivalent to the angle of the sliding surface (α) and a controlling factor in the downslope component of gravity. Any increase in soil weight or angle of slope will increase the gravitational stress acting on a soil.

For coarse grained soils of the Tolstoi-McGilvery type, cohesion can be considered negligible and soil shear strength (S) or resistance of a soil mass to sliding becomes a product of friction between the soil mass and the sliding surface and the friction between soil grains. Friction along the sliding surface is also controlled by slope gradient (α) and the weight of the soil mass (W) and is strongly influenced by pore water pressure development[6] (μ) which acts to reduce the weight of the soil mass. Friction between, and the mechanical interlocking of, soil grains is expressed as an angle of internal friction (ϕ).

Thus: $S = (W-\mu) \cos \alpha \tan \phi$

The stabilizing influence of external factors such as roots may add considerably to the overall resistance of a soil to failure but must be considered as an added influence independent of the above mathematical model.

Resistance to sliding is overcome by:

a) Saturation, which increases the weight of the soil mass and therefore the component of gravity acting to pull the soil downslope;

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[5]Cohesion is the ability of individual soil particles to stick or adhere together through the action of capillary tension, cementation or weak electrical bonding of clay minerals and organic colloids.

[6]Pore water pressure is pressure produced by the head of water (its vertical height above an impermeable base) in a saturated soil and transferred to the base of the soil through the pore water.

b) Active pore water pressure development in the soil, produced by rising free water levels, which decreases frictional resistance along the sliding surface, decreasing soil shear strength;

c) Hydrostatic pressure produced by seepage of water along cracks and joints in the rock which also decreases frictional resistance between overlying rock masses and joint surfaces;

d) Freeze and thaw action which pries out blocks and fragments of rock along joints and fractures, loosening the materials and mobilizing them in a downslope direction;

e) Destruction of stabilizing root systems by decay or breakage due to windthrow or timber harvesting activities;

f) The loosening effect of the prying action of root growth into joints and cracks and the working of roots by trees swaying in the wind, and;

g) Rapid surface loading from rockfall, rock avalanching or debris avalanching which increases the downslope component of gravity; produces temporarily high pore water pressures during periods of high soil water content due to rapid compression and release of water between soil grains and breaks and shears roots and other binders by force of inpact.

LANDSLIDE HAZARD IDENTIFICATION AND RATING

General Hazard Rating

Triaxial shear tests performed on soil samples taken from undisturbed portions of the unstable slopes behind the Juneau urban area[7] indicate that the soil is essentially cohesionless with an effective angle of internal friction of 36°. Slope angle and angle of internal friction play major roles in determining relative stability of a soil mass with these characteristics. In the absence of active pore water pressures, the ratio between resistance to sliding and gravitational stress, or more correctly, the "factor of safety" of the slope can be approximated by the ratio between the angle of internal friction and the angle of slope.

$$F = \frac{\phi}{\alpha}$$

Since the angle of internal friction is normally fixed at a specific value or within a certain range, slope angle becomes a prime indicator of the relative stability of these soils in place. Whenever the slope gradient equals or exceeds the angle of internal friction of the soil, the slope must be considered unstable and highly susceptible to occurrences or activities which tend to alter the factors contributing to soil shear strength.

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[7] Samples analyzed by J. R. Bell of the Civil Engineering Department, Oregon State University. A report of his findings is included in Appendix A.

While the angle of internal friction is ideally a single value for a specific soil type, under natural conditions engineering experience has indicated (Terzaghi and Peck, 1960) a considerable point to point variability. For soils of the type on the Juneau area slopes, these values range from a maximum of approximately 37° to a minimum of 28°.

The effective value of (ϕ) obtained from triaxial shear tests for these soils was 36°. However, since the angle of internal friction is so highly variable for natural, non-homogenous soils of this type, it is more realistic to consider zones of stability when rating slopes for purposes of hazard identification. Thus, slopes with gradients above 37° can be classified as highly unstable in terms of the susceptibility to events which might alter or reduce the delicate balance of forces operating on the slope. These are slopes which are subject to sliding whenever disturbed and may serve as major sources of landslide material during catastrophic events such as earthquakes or exceptional storms. Great care should be taken to prohibit urban development within or immediately below such areas. Road building and timber harvesting activities must be prohibited for the protection of the areas below the highly unstable zone and no dwellings should be allowed in the area.

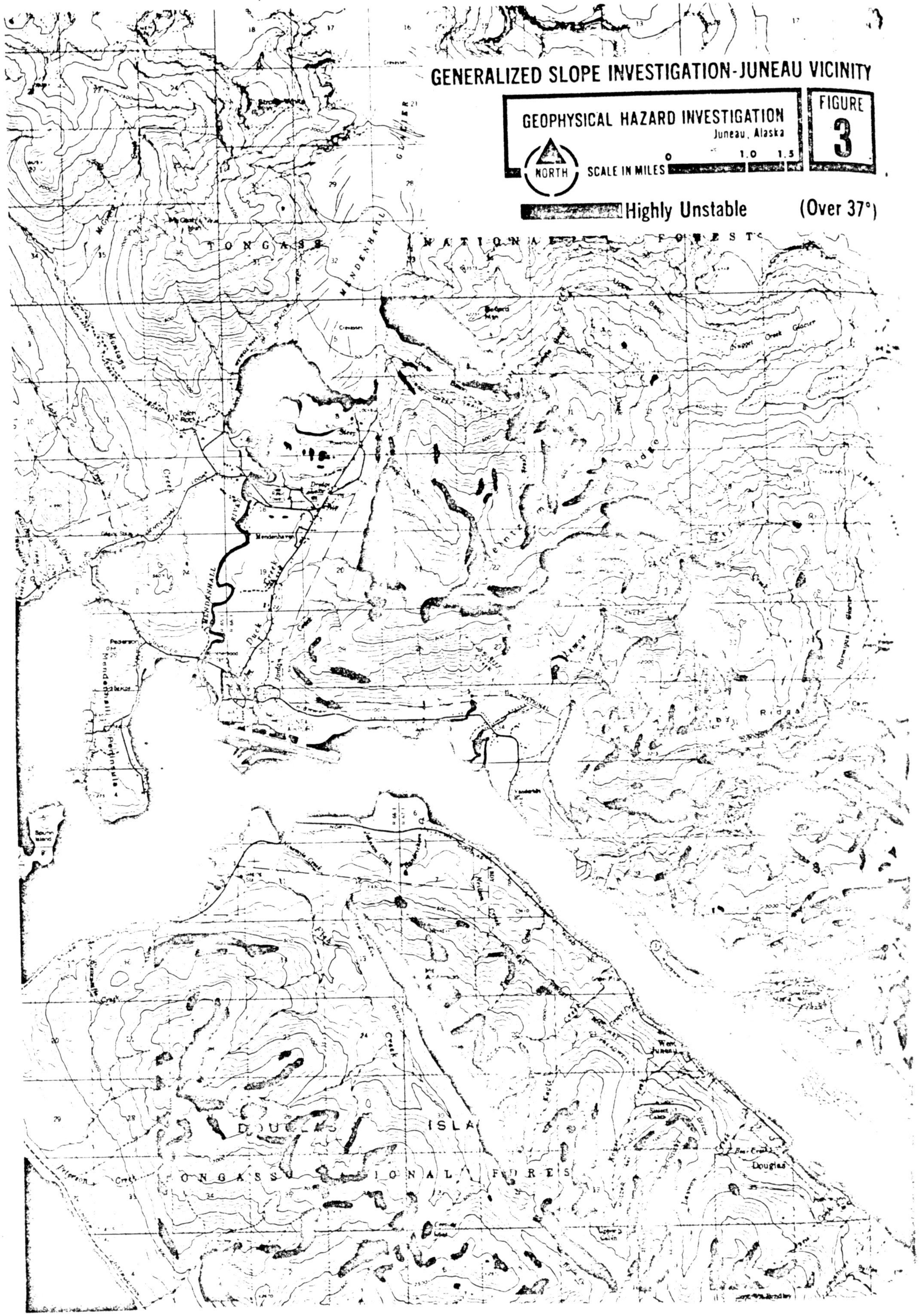
Slopes with gradients between 28° and 37° are classified as potentially unstable and should receive minimum development with full realization that local areas within this zone may be in a highly unstable state. It is essential that natural vegetation cover be maintained wherever possible. No timber harvesting or massive land clearing should be allowed in this zone. The potential danger of landsliding from the highly unstable slopes above this zone is always present and should be kept in mind at all times when development is being considered in this area.

Figs. 3 and 4 show the stratification of most of the slopes in the Juneau Borough into zones of highly unstable and potentially unstable ground on the basis of slope gradient.

Specific Hazard Identification

Landslide deposits occur at frequent intervals along the Mt. Juneau and Mt. Roberts slopes. The most massive of these are pre-Juneau settlement in age and support old growth stands of Sitka spruce and western hemlock indicating an occurrence 250 to 300 years ago. A substantial number of lesser but still destructive landslides have occured since the settlement of Juneau and can be traced as linear ridges and recently re-vegetated strips on the slopes behind the city. Most of these have been documented in the city newspapers, copies of which are included in Appendix X. A few have been dated approximately by dendrochronological methods.

All are indicators of active or dormant instability and of potential landslide recurrence. As a result, each of the landslide tracks have been carefully mapped, their probable points of origin indicated and the entire slope assessed in terms of immediate or potential hazard. The results of this investigation are shown in Figures 5, 6 and 7. Pre-settlement landslides and post-settlement landslides are shown in Figure 5.


GENERALIZED SLOPE INVESTIGATION-JUNEAU VICINITY
GEOPHYSICAL HAZARD INVESTIGATION
Juneau, Alaska
FIGURE
3
NORTH
SCALE IN MILES
0
1.0
1.5
Highly Unstable
(Over 37°)
TONGASS
NATIONAL
FOREST
MENDENHALL
DOUGLAS
ISLAND
Douglas

GENERALIZED SLOPE INVESTIGATION-JUNEAU DOUGLAS AREA

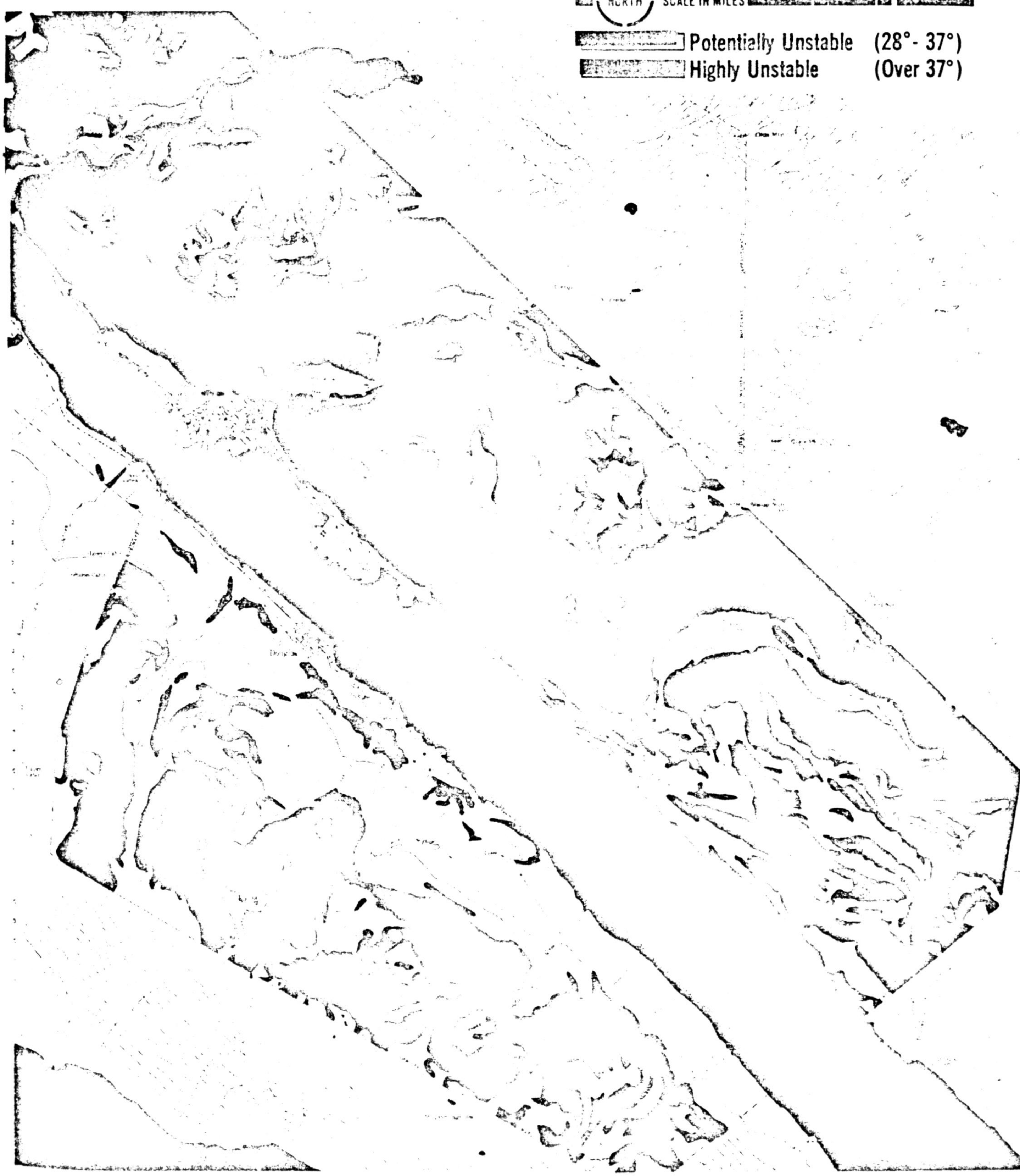
GEOPHYSICAL HAZARD INVESTIGATION
Juneau, Alaska

FIGURE 4

NORTH

SCALE IN MILES 0 0.5 1.0

Potentially Unstable (28°- 37°)
Highly Unstable (Over 37°)



HISTORIC LANDSLIDE DEPOSITS

GEOPHYSICAL HAZARD INVESTIGATION
Juneau, Alaska

FIGURE 5

NORTH — SCALE IN MILES 0 .25 .50

(P) Prehistoric (Before 1880)
(11) Historic (After 1880)

ESTIMATED AGE OF DEPOSIT

1-1912	7-1918	13-1932
2-1932	8-1935	14-1936
3-1892	9-1918	15-1952
4- --	10-1936	16-1952
5-1922	11-1949	17-1935
6- --	12-1920	

Broad areas of high and potential hazard from landslide damage are shown in Figure 6. Specific gullies and channels with a known or indicated history of past debris avalanche and debris flow activity are mapped in Figure 7.

Gullies with a high hazard rating exhibit substantial accumulations of organic debris, rocks and soil in their channels and have had a past history of debris avalanche-debris flow activity. These are mapped in Figure 7. Those with a potential rating do not exhibit substantial accumulations of debris, but extend to the upper slope and exhibit some evidence of past debris avalanche-debris flow activity. Table 1 summarizes the major historical landslides in the Juneau area with dates of occurrence, approximate location, associated 24-hour rainfall and damage.

URBAN AREA SOUTH OF GOLD CREEK TO THE CITY LIMITS (See Fig. 8)

Mt. Roberts Slope

By far the most hazardous area in terms of potential destruction of property and loss of life from landslides is that area at the base of the Mt. Roberts slope extending from the corner of 3rd and Harris Streets to the beginning of Thane Road. Eleven major debris avalanche-debris flow deposits have been identified and mapped on this slope. Three of these are massive in size and occured before Juneau settlement. The remaining eight were smaller but still destructive in size. All are identifiable on the ground and the eight post-settlement slides were well documented by local newspapers at the time of their occurrence (Appendix X).

Pre-settlement Landslides

The three pre-settlement landslides occur as major topographic features expressed as linear ridges extending approximately 700 feet through gullies in a cliff above the A.J. tram (approximately 400 feet elevation) and terminating at the beach. These deposits range from 20 to 50 feet thick and average about 200 feet wide. In every case, the debris deposit passes through or overlaps a lower cliff or bluff at the 400 foot level indicating an origin from a rock slide or soil failure on the upper slope. The gully through which the deposit passes must have served to channel the material onto the lower slope.

One of these massive landslide deposits crosses the southern terminus of Gastineau Avenue, one crosses Gastineau Avenue at the site of the A.J. bunkhouse foundation and one extends downslope from the southern end of the A.J. tramline. Many other pre-settlemt landslides have occured in the area and are indicated by deposits of mixed logs, rock and soil exposed in banks and foundation excavations between Gastineau Avenue and South Franklin Street, but are not recognizable as distinct units.

MASS WASTING HAZARD AREAS

GEOPHYSICAL HAZARD INVESTIGATION
Juneau, Alaska

FIGURE 6

NORTH

SCALE IN MILES 0 .25 .50

Potential Hazard

High Hazard

MASS WASTING CHANNELS AND ROCK SLIDE AREAS

GEOPHYSICAL HAZARD INVESTIGATION
Juneau, Alaska

FIGURE 7

NORTH

SCALE IN MILES 0 .25 .50

Rock Slide Hazard Areas

TABLE 1

LANDSLIDES LOCATED IN THE JUNEAU, ALASKA AREA

DATE	TIME	RAINFALL (inches/hrs)	TYPE	LOCATION	DAMAGE	COMMENTS	REFERENCE
10-18-1913	2100	3.5/24	rockfall, rockslide	Mt. Maria on Basin Road	homes damaged	5 landslides reported in Perserverence Basin, 1 landslide at Tredwell	Alaska Daily Dispatch, October 18, 1912
9-25-1918	--	6.32/24	debris avalanche	slope behind Gastineau Hotel	apt. building destroyed-Gastineau Hotel damaged $25,000	Swept apt. downhill and across Gastineau Ave., broke in back wall of Gastineau Hotel, small slide followed	Daily Alaska Empire September 28, 1918
9-25-1918	--	6.32/24	debris slide	7th and Goldbelt into Evergreen Bowl	cabin destroyed	Carried small cabin into Evergreen Bowl	Same as above
9-25-1918	--	6.32/24	debris avalanche	Gastineau Hts.	none	Other slides reported above Gastineau Hts., but not recorded	Same as above
1-2-1920	1130	warm weather, melting snows and heavy rain 1.79/24	debris avalanche	Gastineau Hts.	3 people killed, $50,000 damage	Destroyed boarding house, three homes, twelve cabins, broke into Goldstein's store, overflow of A.J. Flume	Daily Alaska Empire January 2 and 3, 1920
9-27-1935	--	2.89/24	debris avalanche	S. Franklin at A.J. oil tanks	road blocked	--	Daily Alaska Empire September 27, 1935
11-27-1935	1530	3.35/48	debris avalanche	Third Avenue above Harris	2 homes wrecked one damaged	Slide due to damming of gully by debris	Daily Alaska Empire November 29, 1935
11-27-1935	--	3.35/48	slump	5th Street above Kennedy	none	Slide possibly due to saturation of marine beach deposit in area	Same as above
11-27-1935	--	3.35/48	debris slide	Evergreen Bowl	none	A serious slide reported at Evergreen Bowl-no details	Same as above
10-16-1936	0800	1.43/3	debris avalanche	Gastineau Hts.	one woman injured, 2 houses damaged, Alaska Hotel damaged	Slide came down Mt. Roberts crossed Gastineau Ave. and broke in back of Alaska Hotel	Daily Alaska Empire October 16, 1936
11-22-1936	1930	3.89/24	debris avalanche	Gastineau Hts., above cold storage plant	14 died, 9 injured, apt. house, boarding house, 2 homes ruined	Slide resulted from slope failure below flume. Tension crack noticed	Daily Alaska Empire November 23, 24, 25, 27, 28, 30, 1936
11-30-1936	--	--	debris avalanche	Thane Road near Standard Oil	road closed	--	Daily Alaska Empire November 30, 1936
10-31-1949	--	2.36/24	debris avalanche	Gastineau Hts.	home destroyed	Moved 700 feet downslope, piled into home on Gastineau Avenue	Daily Alaska Empire October 31, 1949
10-1-1952	--	1.85/24	debris avalanche	S. Franklin by old Columbia Lumber Co. kiln	road closed	--	Daily Alaska Empire October 2, 1952
10-1-1952	--	1.85/24	debris avalanche	Gastineau Hts., piled behind 475 S. Franklin	home destroyed	--	Daily Alaska Empire October 2, 1952
10-1-1952	--	1.85/24	debris avalanche	Above Johnson Bldg., 261 Gastineau Avenue	home destroyed	--	Daily Alaska Empire October 2, 1952
12-16-1954	--	warm weather snow melt 2/24	debris avalanche	Irwin Street before Gold Creek.	1 home badly damaged	2 earthslides 1 hour apart near Gold Creek bridge	Daily Alaska Empire December 17, 1954

DATE TIME RAINFALL TYPE LOCATION DAMAGE COMMENTS REFERENCE

MASS WASTING HAZARD INVESTIGATION SUB-AREAS

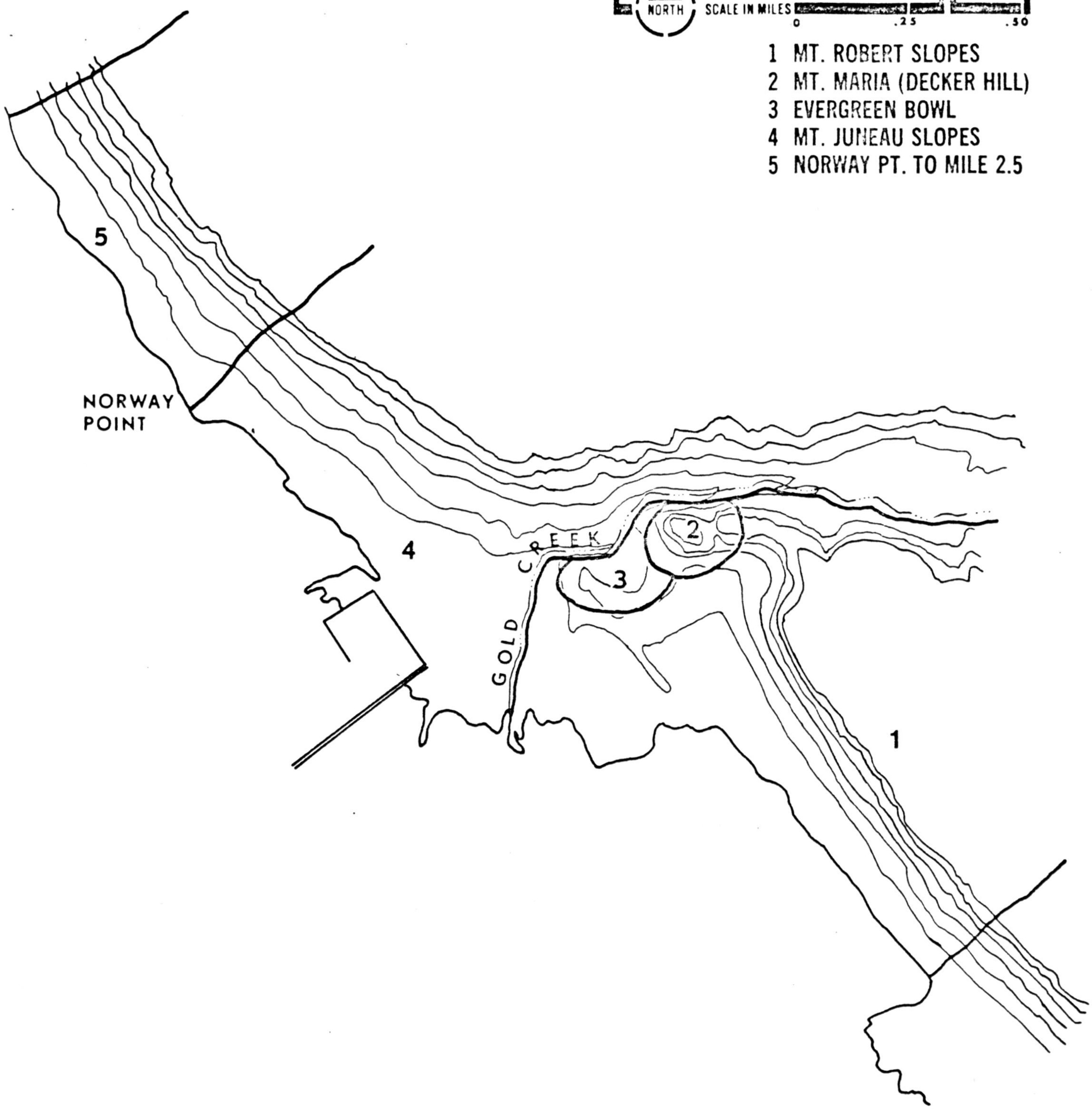
GEOPHYSICAL HAZARD INVESTIGATION
Juneau, Alaska

FIGURE 8

NORTH

SCALE IN MILES 0 .25 .50

1 MT. ROBERT SLOPES
2 MT. MARIA (DECKER HILL)
3 EVERGREEN BOWL
4 MT. JUNEAU SLOPES
5 NORWAY PT. TO MILE 2.5



Historical Landslides (Refer to Table 1)

The eight major landslides which have occured since Juneau was settled are expressed as linear ridges near the base of the slope or as bulked deposits above Gastineau Avenue and South Franklin Street. Five of these reached South Franklin Street but did little damage on the beach side of the street (side nearest the harbor) since most of their energy was dissipated by damage and destruction above South Franklin. Three terminated on Gastineau Avenue.

Six of the historic landslides or about 75% of the total occurring, originated in or were channeled by gullies and V-notch channels which extend from the upper slope. At least three of these probably originated from slope failure above the cliff where slopes exceed 70^{o} in gradient. The rest occured as a direct result of failure of accumulated debris in the gullies.

The two remaining historical landslides apparently resulted from open slope failure just below the A.J. tram. One was apparently triggered by rapid addition of water to an already saturated soil mass due to overflow of the A.J. water flume on January 1, 1920. The other occured as a result of failure, just below the tram and above the Cold Storage building on November 22, 1936. This later landslide was initiated during a period of exceptionally high rainfall (3.89 inches in 24 hours) and was probably triggered by active pore-water pressure development due to leakage of surface water into tension cracks developed at the outer edge of the tram. Unsubstantiated reports state that such tension cracks existed in the tram above the point of failure prior to the landslide.

Recent Landslide Activity

The last major landslide occured on the Mt. Roberts slope on October 1, 1952 but small debris avalanches and debris flows have continued to occur up to the present. For the most part these are small, flow only a short distance and have not reached into the urban zone. These are currently building up behind rocks, logs and other jammed debris in the gullies and constitute a continuing debris avalanche hazard to the area (Figure 4).

At least two small debris flows occured within gullies above Gastineau Avenue last fall. One in a gully above Ewing Way which terminated temporarily at the A.J. tram and remains as a future hazard to the slopes below. The other occured in a gully above the 1st Street stairs and flowed downslope until it was stopped behind the cable hand-rail along the old A.J. access trail to the Harris Street stairs.

In summary, 21 gullies have been mapped on the Mt. Roberts slope above the city; 15 identified as having a high debris avalanche-debris flow hazard. Considering the extremely steep slopes, unstable bedrock and soil conditions, numerous high hazard gullies extending directly into the urban area and its past history of landsliding, most of the Mt. Roberts slope above South Franklin Street and Gastineau Avenue must be considered as highly hazardous in terms of damage and potential loss of life from landslides.

Mt. Maria (Decker Hill)

Several landslides of major porportions have occured in this area during post-settlement times.

A combination rockfall-rock avalanche occured on October 18, 1913 from the open cliff face of Mt. Maria (Decker Hill) destroying several houses and creating a deposit of angular rock fragments exposed above Basin Road between 6th and 7th Streets. Similar small deposits of angular rock fragments and talus occur above 6th Street from Basin Road to Nelson Street. A talus cone at the base of a small cliff occurs behind a home at the corner of 6th and Nelson Streets.

The area directly below the open rock cliff above Basin Road lies in a high rockfall-rock avalanche hazard zone. While the bedrock exposed in this cliff dips into Last Chance Basin, it exhibits well developed fracturing and jointing along vertical planes and is highly susceptible to additional failures produced by freeze and thaw and the lubricating action of water in the cracks. The small cliff above the corner of 6th and Nelson Streets is fractured in a similar manner, and while the volume of materials would not be large, the area directly below it must be considered as a high rockfall hazard area. The cliffs of broken slate dipping downslope and at an angle to the road cut along the backside of Mt. Maria (the trestle portion of Basin Road) must also be considered a high hazard area for falling rock.

Evergreen Bowl

The slopes into Evergreen Bowl are greatly oversteepened and bedrock dips into the Bowl making the slopes potential areas for landslide damage, especially to buildings and property along the upper edge of the Bowl and adjacent to Basin Road, Gold Belt Avenue and 7th Street. A landslide occured on this slope in September 1918 beginning near the corner of 7th Street and Gold Belt and carried a cabin down into Evergreen Bowl. A serious landslide in Evergreen Bowl was also reported on November 27, 1935 but no details were provided.

A potential rockfall hazard exists above Calhoun Street between Dixon Street and 6th Street.

URBAN AREA NORTH OF GOLD CREEK TO MILE 2.5 (See Fig. 8)

Mt. Juneau Slope

The slopes of Mt. Juneau, from Gold Creek to Mile 2.5 Glacier Highway exhibit the same oversteepened slope gradients, cohesionless soils and bedrock jointing patterns found on the Mt. Roberts slope. A lower cliff or bluff at about 500' in elevation extends intermittently along the entire slope length and is broken only occassionally by gullies and V-notch channels. Each of these gullies serves to channel snow, rock and soil debris from the very steep slopes above the bluff to the slope below and there is much evidence of repeated snow and soil avalanching along these gullies and into the timber. Between these major gullies there is little evidence of large scale landsliding although numerous small slips and minor debris slides occur between the trees. Small debris and rock slides have occurred repeatedly on the bluff face and on the slope immediately below, but these have traveled relatively short distances into the trees before being stabilized by the timber cover. Large blocks of rock are scattered on the slopes below the bluff and within the timber indicating frequent local rockfalls but these do not penetrate far because of the stabilizing effect of the vegetation.

There are a number of shallow linear depressions and small gullies dissecting the slopes below the bluff and between major slide paths. These must have served at one time to channel snow and soil debris but are dormant or completely stabilized now; many having mature timber growing in them. For the most part, major landsliding activities have been confined to the principal gullies passing through the bluff.

Massive landsliding (rock and debris avalanches) have occured on this slope in the past and at least 11 landslides or landslide run-out zones can be recognized in the field as distinct linear ridges rising above the normally flat slope surface. The majority have terminated in the timber well above the urban and urbanizing areas, but in at least 5 cases these have reached the beach or extended into an urban zone.

Unfortunately, there is no record of the time of occurrence of most of these landslides, but an indirect age was obtained on many of them using an increment borer to determine the age of trees growing on the landslide deposit. Using this method, estimated ages of landslides ranged from 18 years for an alder growing in a landslide track above Evergreen Avenue to greater than 200 years for hemlocks growing in a stabilized, linear slope depression west of Norway Point.

As on the Mt. Roberts slope, the oldest and most extensive landslide deposits are pre-settlement in age and are covered by old growth Sitka spruce and western hemlock forests with an estimated age of greater than 250 years. All began by shallow rock and soil avalanching from the extremely steep slopes above the lower bluff and were funneled onto the lower slope through major gullies. Repeated sliding has taken place in most of these gullies and at several locales multiple deposition has created massive deposits of undifferentiated landslide debris. Where these deposits have been dissected locally by running water high banks of mixed rock, logs and soil material are exposed above the present stream channel. It is almost impossible to date these multiple landslides accurately because of the lack of established vegetation in the active zone of redeposition. This problem is compounded by the fact that most of these landslide tracks also function as active snow avalanche zones.

Norway Point to Mile 2.5

The largest landslide deposit in be urban area forms the ridge constituting Norway Point. This is a pre-settlement landslide which must have originally extended well out into Gastineau Channel. The lower part of this deposit is covered with old growth spruce-hemlock forest indicating a depositional age for the main slide mass in excess of 200 years.

A channel or series of channels leading from a break in the lower bluff and extending to the lower slope, is still very active and both snow and debris avalanching occur at frequent intervals from the slope above the bluff. This channel is classified as a high hazard debris avalanche track. The active state of these channels and the large potential source area for rock and debris above the lower bluff, make the major part of the Norway Point deposit and a zone extending a minimum of 100 feet into the timber for landslide run-out purposes, a high hazard area. Based on past history of massive sliding and the large source area for the origin of a potentially massive failure, the remainder of the area covered by the Norway Point deposit must be classified as potentially hazardous. It is vital that existing timber cover be maintained to serve as a protective screen for existing dwellings in the area, otherwise the high hazard zone would have to be extended to the beach.

Immediately west of and adjacent to the Norway Point landslide deposit is a second massive deposit or pre-settlement age forming a distinct linear ridge terminating in the trees above Glacier Highway. This deposit has an old growth spruce-hemlock forest growing at its lower end but is bare of major vegetation above about 200 feet in elevation due to frequent snow avalanching. The deposit passes upward through a main break in the lower bluff and has been dissected by the present stream forming a deep gully leading to the lower slope. This gully is currently active, primarily as a snow avalanche path but does carry soil and debris and must be considered a high debris avalanche hazard. Again, due to the large potential source area for landslide materials above the lower bluff and the active state of the V-notch channel, the open area of the deposit and a run-out zone of at least 100 feet into the timber below must be classified as a high hazard area. The intervening slope between the Norway Point deposit and the remainder of this deposit to the beach lies within a potential hazard zone.

A third massive deposit reached the beach in the vicinity of the Johnson Children's Home. This deposit also originates at an opening in the lower bluff and has also been dissected by stream cutting. It is pre-settlement in age with old growth timber at its lower end but shows much evidence of active snow and debris avalanche activity in its upper reaches. A recent debris flow has occurred within the active zone and extending 100 feet into the timber. The rest of the depositional area extending to the beach is classified as a potential hazard area. The channel dissecting the deposit in its upper reaches is classified as a high hazard debris avalanche track.

A fourth deposit terminates at the beach between Mile 2 and Mile 2.5 on the Glacier Highway. This landslide track also functions as a major snow avalanche track and the entire slide area is devoid of trees except for some alder growing near the highway. Unvegetated talus and landslide deposits occur at the lower end of the landslide track and there is evidence of repeated landsliding and active talus creep within the deposition zone. Because of the active nature of this landslide track and the absence of trees or protective vegetation to control landslide run-out, the entire landslide zone is classified as a high hazard area extending to the beach.

The intervening slope areas between these landslide tracks are classified as potential and high hazard areas using the method for general hazard rating.

Norway Point to Gold Creek

Two massive landslide deposits emanating from major breaks in the bluff and three smaller deposits beginning at small gullies occur above the urbanized area extending from Norway Point to Gold Creek. Both massive deposits show evidence of repeated sliding and at least one destructive debris flow has been channeled into the urban area along Gold Creek.

The slope between Norway Point and the Behrends Avenue snow avalanche tract is free from major landsliding. Unstable conditions exist on the slope, however, and there is much evidence of active creep and small scale sliding and slumping within the timber. Several shallow, partially stabilized gullies and a small V-notch channel leading through a small opening in the bluff dissect the slope in the area. These serve primarily to channel snow into the timber on the lower slope, but minor debris avalanching has also occurred in the V-notch channels. Because of the general unstable condition of the slope and the presence of channels which could function to carry landslide debris to the lower slope if massive failure occurred, the entire slope area above 28^{o} (maximum stable angle from the general hazard rating) and including a minimum strip of 100 feet of timber below the major break in slope is classified as a potential hazard area.

A landslide deposit occurs within the Behrends Avenue snow avalanche track, beginning at an elevation of about 500 feet, at the base of a small gully in the lower bluff and extending downslope along the west side of the snow avalanche zone. It terminates at an elevation of about 350 feet. An increment core taken from a lone spruce growing on the lower end of the deposit indicates an age of approximately 60 years. A channel extends along the western edge of this deposit beginning at the gully and may serve to carry additional landslide material downslope. This channel is classified as a high hazard debris avalanche track.

The Behrends Avenue avalanche track itself has functioned as a landslide path repeatedly and extensive deposits of talus and landslide debris are found at the lower end.

At least two major gullies or channels pass down the center of the track and function to channel landslide materials to the lower slope. These are rated as high hazard debris avalanche paths and the entire open zone of the Behrends Avenue track above the lower timber zone must be considered as a high hazard area in terms of landsliding. A potential hazard area extends to Behrends Avenue.

Immediately southeast of the Behrends Avenue snow avalanche track is a