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ENGINEERING-GEOLOGIC ASSESSMENT OF THE PROPOSED HATCHER PASS SKI RESORT AT GOVERNMENT PEAK, SOUTHCENTRAL ALASKA

By
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Alaska Division of
Geological and Geophysical Surveys

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INTRODUCTION

This report is a preliminary analysis of engineering-geologic factors that may affect development of a ski resort proposed by Mitsui (USA) and Company on land owned by the State of Alaska on and near Government Peak in the Hatcher Pass management area. Our analysis is based on a map entitled 'Preliminary zoning plan' (fig. 1) submitted by Mitsui and dated July 29, 1988. A report entitled 'Engineering geology of the Hatcher Pass management region,' prepared in 1985 by the Alaska Division of Geological & Geophysical Surveys, provides an overview of the engineering geology of the region.

For this report, a more detailed geologic map was prepared for the area of the Mitsui proposal (fig. 2). Engineering characteristics of the geologic units and terrain were qualitatively evaluated with regard to the proposed placement of resort facilities (table 1). This analysis consisted of a review of available literature and unpublished data, detailed examination of aerial photographs, and two days of field work. Because of the limited field work and lack of detailed quantitative analyses, conclusions and interpretations presented in this report are preliminary and do not offset the need for site-specific engineering studies to ensure safe design and construction. Site-specific studies should be the responsibility of the developer.

GEOLOGIC SETTING

Government Peak and Bald Mountain Ridge lie along the southwestern margin of the Talkeetna Mountains in southcentral Alaska. Within the area proposed for development, major bedrock units comprising these topographic highs include mica schist of Paleozoic age; a basement complex of amphibolite, mafic gneiss, and quartz diorite, also of Paleozoic age; and dense conglomerates of the Paleocene (lower Tertiary) Arkose Ridge Formation (fig. 2 and table 1). The schist contains small local intrusions of rhyolite (sills; rs in fig. 2) and serpentine (ma), and the basement contains intrusions of gabbro (ga).

This area was intensely glaciated during the late Pleistocene. Glacial processes during late-Wisconsin time (about 35,000 to 10,000 yr before present), followed by stream processes and mass wasting during the Holocene, are responsible for the present topography and surficial deposits. During late-Wisconsin time, ice flowing southward through Little Susitna River valley joined ice flowing westward from Matanuska River valley. These glaciers deposited silt-rich basal till at least several tens of feet thick on hillslopes and valley bottoms below about 2,700 ft elevation. Small glaciers flowing from northeast-facing cirques on Government Peak and east of Bald Mountain Ridge coalesced with the south-flowing ice in Little Susitna River valley. Similarly, small glaciers flowed from northwest-facing cirques along Bald Mountain Ridge, coalescing with glaciers from the north to form a glacier that flowed west through Willow Creek valley. These smaller glaciers scoured steep

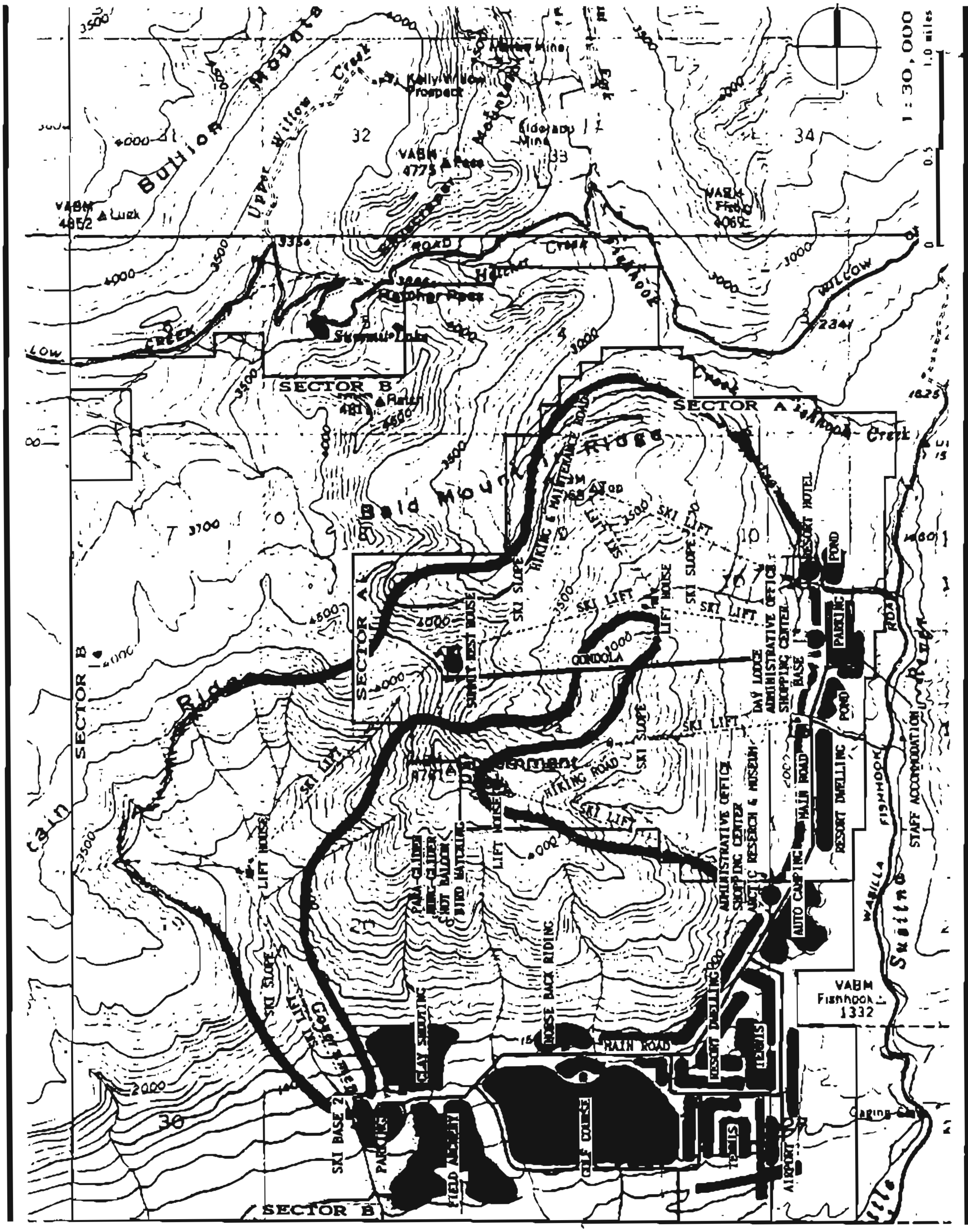


Figure 1.— Proposed Hatcher Pass ski resort (Mitsui (USA) and Company).

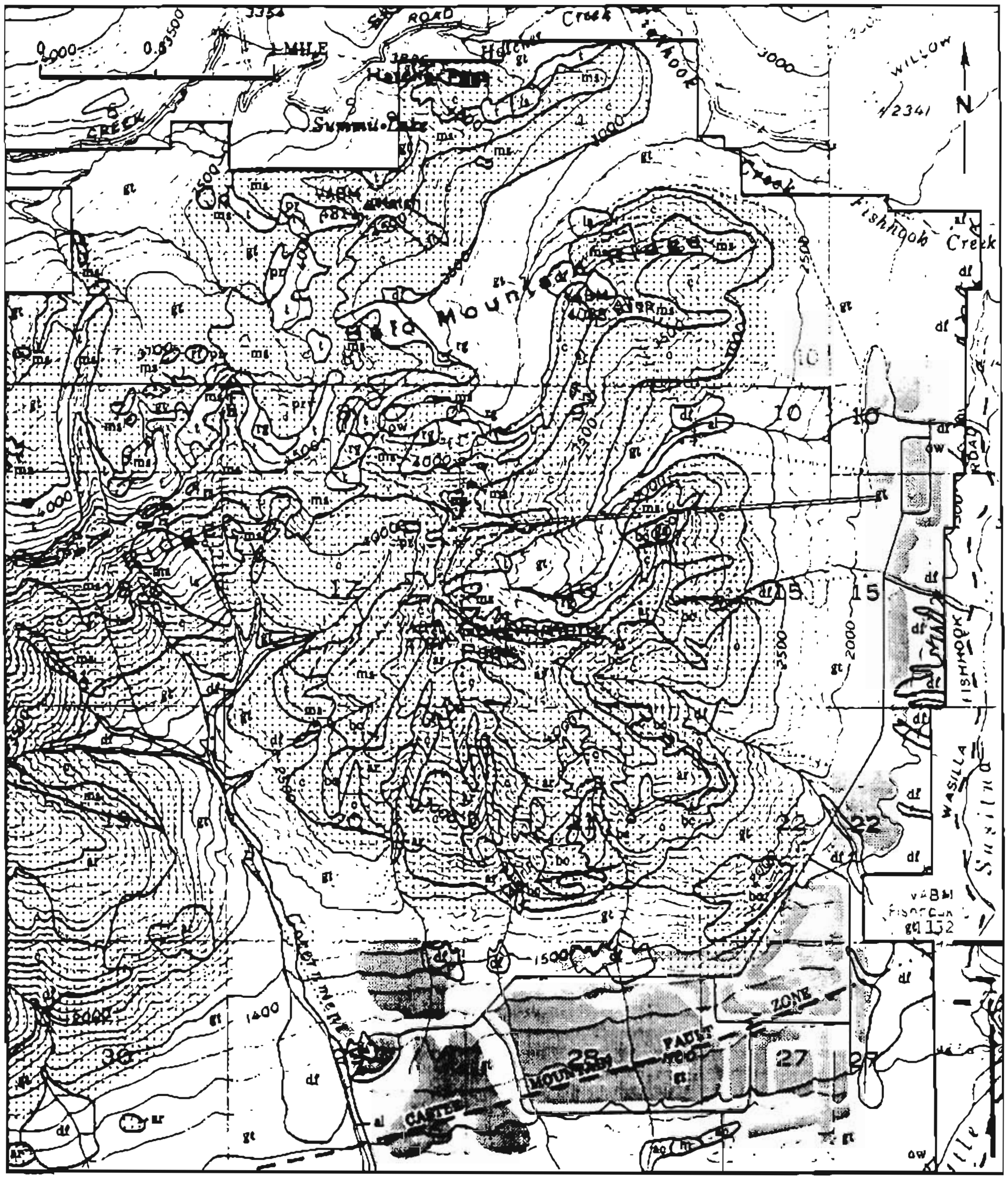


Figure 2.— Geologic map of the proposed Hatcher Pass ski resort. Geologic units are described in Table 1. Coarse stippled pattern indicates where bedrock is shallow (less than about 10 ft). Areas proposed for development are also indicated (see fig. 1).

Table 1.- Descriptions and engineering characteristics of geologic units (fig. 2).

GEOLOGIC UNIT	COMPOSITION AND ESTIMATED THICKNESS	GROUND-WATER TABLE	SURFACE DRAINAGE AND PERMEABILITY	SUSCEPTIBILITY TO EROSION	SLOPE STABILITY
Till (gt)	Poorly to well-graded gravel, sand, and silt overlain by thin (1-2 ft) peat and organic-rich silt. Silt content generally increases downward to very high (>20%) below 3-6 ft, except in morainal ridges where silt content is low. Up to 80 ft thick.	Moderate to deep.	Poor to good surface drainage. Low to moderate permeability.	Moderate to high. Very high where vegetation is removed. Susceptible to gullying.	Low to moderate. Susceptible to shallow debris flows after very heavy rains where vegetation is removed.
Debris-flow deposit (df)	Thin peat overlying poorly- to well-graded silt, sand, and gravel with scattered to numerous large boulders and some plant debris. Thickness up to 12 ft.	Shallow to moderate.	Poor to moderate surface drainage. Low to moderate permeability.	Moderate to high. Susceptible to gullying.	Moderate. Susceptible to renewed debris flows after very heavy rains where vegetation is removed.
Colluvium (c)	Moderately- to well-graded silt, sand, and angular gravel. Less than 10 ft thick.	Below base of deposit.	Good surface drainage. Moderate to high permeability.	Moderate to high. Susceptible to gullying.	Moderate to high. Susceptible to shallow debris flows after very heavy rains.
Alluvium (al)	Moderately- to well-graded sand and pebble-cobble gravel. Locally contains minor debris-flow deposits and concentrations of large boulders, especially near moraines and high bedrock outcrops. Up to about 30 ft thick.	Very shallow in low-level floodplains. Intermittently shallow along ephemeral streams at high elevations.	Poor surface drainage. High permeability.	Low to moderate.	High.
Glacial-outwash alluvium (ow)	Moderately- to well-graded pebble-cobble gravel with some sand. Locally contains concentrations of large boulders. Up to about 80 ft thick.	Moderate to deep.	Good surface drainage. High permeability.	Low to moderate.	High.
Abandoned-channel deposit (ac)	Elongate accumulations of thin peat and silt overlying pebble-cobble gravel with sand and local concentrations of of boulders. About 10 ft thick.	Shallow.	Poor to good surface drainage. Moderate to high permeability.	Low.	High.
Alluvial-fan deposit (af)	Moderately- to well-graded subangular to subrounded cobbles and boulders in a matrix of sand and silty sand. Locally contains debris-flow deposits, especially in upper part of fan. Thickness up to about 20 ft.	Shallow to moderate.	Good surface drainage. Low to high permeability.	Low to moderate.	Moderate to high.
Talus (t)	Steep cones and aprons of angular fragments of local bedrock with minor silt and sand. Thickness up to 50 ft.	Below base of deposit.	Excellent surface drainage. Moderate to high permeability.	Low to moderate.	Low to moderate.

FROST SUSCEPTIBILITY	STABILITY OF SPOILS	EASE OF EXCAVATION*	SUITABILITY FOR FOUNDATIONS**	SUITABILITY FOR SEPTIC DISPOSAL	SUITABILITY FOR CONSTRUCTION MATERIALS
Generally low to moderate, except high where sandy, gravelly surface layer is removed and silty basal till is at or near surface.	Low to moderate (susceptible to gullying and liquefaction). Moderate to high frost susceptibility.	Moderate, except difficult where very dense (basal till) or where numerous large boulders are present.	Good except near steep slopes and where disturbed.	Generally poor to fair except locally good where silt free.	Adequate source of coarse- and fine-grained material, but highly variable and may require extensive processing. May lack intermediate sizes.
Moderate to high.	Low (susceptible to gullying and liquefaction). Moderate to high frost susceptibility.	Easy to moderate.	Poor to good depending on amount of buried vegetation. Poor in vicinity of gullies and on steep slopes. Subject to seasonal floods and occasional debris-flow activity.	Poor to fair.	Probable source of mixed coarse and fine material. Local excessive amounts of organic material.
Low.	Moderate to high.	Easy except where steep.	Good, except generally steep.	Generally too shallow and steep.	Limited source of mixed coarse and fine material.
Very low.	High.	Easy.	Excellent. May be subject to seasonal flooding.	Generally poor because of shallow water table.	Excellent source of well-graded aggregate and crushed stone.
Very low.	High.	Easy, except difficult where large blocks are present (may require blasting).	Excellent.	Excellent.	Good source of aggregate and crushed stone. Some oversized material.
Low. High in silt or peat that may cover deposit.	High.	Moderate.	Excellent.	Poor because of shallow water table and underlying low-permeability till.	Probable source of aggregate and crushed stone.
Low to moderate.	Moderate to high.	Easy to moderate.	Good, except subject to seasonal flooding and occasional debris flows.	Poor near active channel because of shallow water table. Good elsewhere depending on silt content (poor where silty).	Adequate source of aggregate and crushed stone. Locally abundant fines and oversized material. May require extensive processing.
Low.	Moderate.	Moderate to difficult.	Moderate to good, except generally steep.	Poor because of steep slopes.	Probable source of angular cobbles and boulders for riprap.

Table 1.- (continued)

GEOLOGIC UNIT	COMPOSITION AND ESTIMATED THICKNESS	GROUND-WATER TABLE	SURFACE DRAINAGE AND PERMEABILITY	SUSCEPTIBILITY TO EROSION	SLOPE STABILITY
Landslide deposit (ls)	Poorly graded mixture of large angular blocks of local bedrock with minor silt and sand. Thickness up to 20 ft.	Deep or below base of deposit.	Good surface drainage. Moderate to high permeability.	Low.	Low to high.
Rockfall deposit (rf)	Large angular blocks of local bedrock. Thickness about 10 ft.	Below base of deposit.	Excellent surface drainage. High permeability.	Low.	High.
Rock glacier (rg)	Angular to subangular blocks of local bedrock with considerable silt and sand at depth. Locally frozen and ice rich. Up to about 50 ft thick.	Deep.	Excellent surface drainage. Moderate to high permeability except very low where ice or silt rich.	Low, except moderate where ice rich.	Moderate, except low on steep scarps and on active fronts.
Protalus-rampart deposit (pr)	Subangular blocks of local bedrock with minor sand and silt. Up to 10 ft thick.	Below base of deposit.	Good surface drainage. Moderate to high permeability.	Low.	High.
Marsh deposit (m)	Interlayered peat, organic-rich silt, and sand. Locally frozen. Up to 10 ft thick.	Very shallow or at surface.	Poor surface drainage. Low permeability.	Low.	No exposed slopes.
Arkose Ridge Formation (ar)	Very hard cobble-boulder conglomerate with subordinate dense sandstone. Intensely sheared, especially near base of unit.	Very deep.	Excellent surface drainage. Low to moderate fracture permeability.	Very low.	Susceptible to large-scale block creep because of closely spaced shear planes and steep slopes.
Mica schist (ms)	Medium-grained quartz-muscovite-chlorite schist in fault contact with undifferentiated basement complex (bc). Nonconformable contact with Arkose Ridge Formation is locally faulted.	Very deep.	Excellent surface drainage. Very low to moderate fracture permeability.	Very low, except low to moderate where frost shattered.	Moderate. Subject to local rock slides and block creep.
Undifferentiated basement complex (bc)	Amphibolite, mafic gneiss, and quartz diorite.	Very deep.	Excellent surface drainage. Very low permeability.	Very low.	High.
Altered rhyolite sill (rs)	Very hard fine-grained tabular rhyolite up to 3 ft thick interlayered and folded with mica schist.	Deep below base of deposit.	Excellent surface drainage. Very low permeability.	Very low.	Moderate.
Gabbro (ga)	Very coarse-grained hornblende-feldspar intrusive igneous rock.	Very deep.	Excellent surface drainage. Very low permeability.	Very low.	High.
Massive antigorite (ma)	Faulted and deformed irregular bodies of microcrystalline serpentine, talc, and chlorite within mica schist (ms).	Very deep.	Excellent surface drainage. Very low permeability.	Very low.	High.

* Ease of excavation with large power equipment.
** Foundation suitability for large permanent structures.

FROST SUSCEPTIBILITY	STABILITY OF SPOILS	EASE OF EXCAVATION*	SUITABILITY FOR FOUNDATIONS**	SUITABILITY FOR SEPTIC DISPOSAL	SUITABILITY FOR CONSTRUCTION MATERIALS
Low.	Moderate to high.	Moderate to difficult. May require blasting.	Poor.	Generally poor because of steep slopes and thin deposits.	Possible source of angular cobbles and boulders for riprap.
Very low.	High.	Moderate to difficult. May require blasting.	Good.	Poor because deposit is thin.	Possible source of angular cobbles and boulders for riprap.
Very low.	Moderate, except low where ice rich.	Moderate to difficult. May require blasting of large blocks.	Moderate, except poor where ice rich (large thaw consolidation) or actively flowing.	Poor where silty or frozen, otherwise good.	Probable source of angular pebbles, cobbles, and boulders. Possible source of mixed coarse and fine material.
Very low.	High.	Moderate.	Good.	Excellent.	Possible source of angular cobbles and boulders for riprap.
Moderate to high.	Very low.	Easy, except moderately difficult where frozen and tightly bonded.	Very poor (shallow water table, low bearing capacity, and large thaw consolidation.)	Very poor.	Good source of peat.
Very low.	High.	Blasting required.	Excellent. Permanent structures on block-creep failures may become misaligned over long periods or may be subject to major displacement during large-magnitude earthquakes.	Poor.	Adequate for riprap and crushed rock.
Very low.	Moderate. Frost splitting readily breaks rocks into small fragments.	Moderate. Rips easily.	High where unweathered, except poor where part of a creep block (see Arkose Ridge Formation).	Poor.	Adequate for shot rock (mixed coarse and fine angular fragments). Poor for large, competent blocks (such as for riprap).
Very low.	High.	Blasting required.	Excellent.	Poor.	Adequate for riprap and crushed rock.
Very low.	Moderate to high.	Moderate. May require ripping.	Moderate to excellent, except poor where part of a creep block (see Arkose Ridge Formation).	Poor.	Adequate for riprap and crushed rock.
Very low.	High.	Blasting required.	Excellent.	Poor.	Adequate for riprap and crushed rock.
Very low.	High.	Blasting required.	Excellent.	Poor.	Adequate source of decorative stone.

slopes in the bedrock and left moraines and basal till in tributary valleys above 2,700 ft that are less dense and less silty than deposits left by the main valley glaciers. The bowl at the head of Government Creek apparently was not a cirque during the Wisconsin glaciations; however, ice from the large Matanuska valley glacier pushed northward into the bowl and deposited a thick layer of till up to about 2,500 ft.

By about 10,000 yr ago, the main valley glaciers had retreated up the Matanuska and Little Susitna valleys. A small moraine about ¼ mile east of the proposed resort hotel indicates that a minor readvance occurred, probably during the early Holocene, but this is the last time ice occupied lower Little Susitna valley. Cirque glaciers subsequently disappeared from Government Peak and Bald Mountain Ridge.

During the last several thousand years, the relatively smooth, U-shaped valley profile left by the main valley glaciers has been intensely modified by slope processes. Extensive gullying and debris-flow activity have dissected most of the hillside below 2,500 ft east and south of Government Peak and along Government Creek to form ridges and troughs with up to about 60 ft of relief. Although these processes probably were most intense before larger vegetation became established on deglaciated hillsopes, there is much evidence that they continue on a smaller scale. Small, scattered active debris flows observed in the field suggest that gullying and debris-flow activity could be rejuvenated at a larger scale if vegetation is removed or slope drainage is disturbed. There is also a strong possibility that the process is episodic, becoming more intense during periods of very heavy rain.

GEOLOGIC CONSTRAINTS AND MITIGATING MEASURES

Geologic constraints to construction and use of the Government Peak area as a ski area vary with the types of geologic deposits present at the surface and the topography. Figure 2 is a geologic map that shows the distribution of geologic units in relation to the topography and proposed ski-area facilities. Descriptions of the geologic units and their engineering characteristics are summarized in Table 1. The areal distribution of major geologic constraints is shown in Figure 3.

Topography

Description

Because of the steep topography needed in ski areas, certain geologic processes like slope failures and snow avalanches are more pronounced than in other areas with gentler slopes. These processes are described for the proposed Hatcher Pass ski area in the following sections. Aside from geologic effects, some observations can be made about the possible impacts of steep slopes as a practical consideration on the placement some of the facilities proposed in the Mitsui plan:

1. The proposed locations for ponds near the main base are on slopes of 11° (20%) or more, which would require either excavation of deep basins or major cut-and-fill for impoundment.

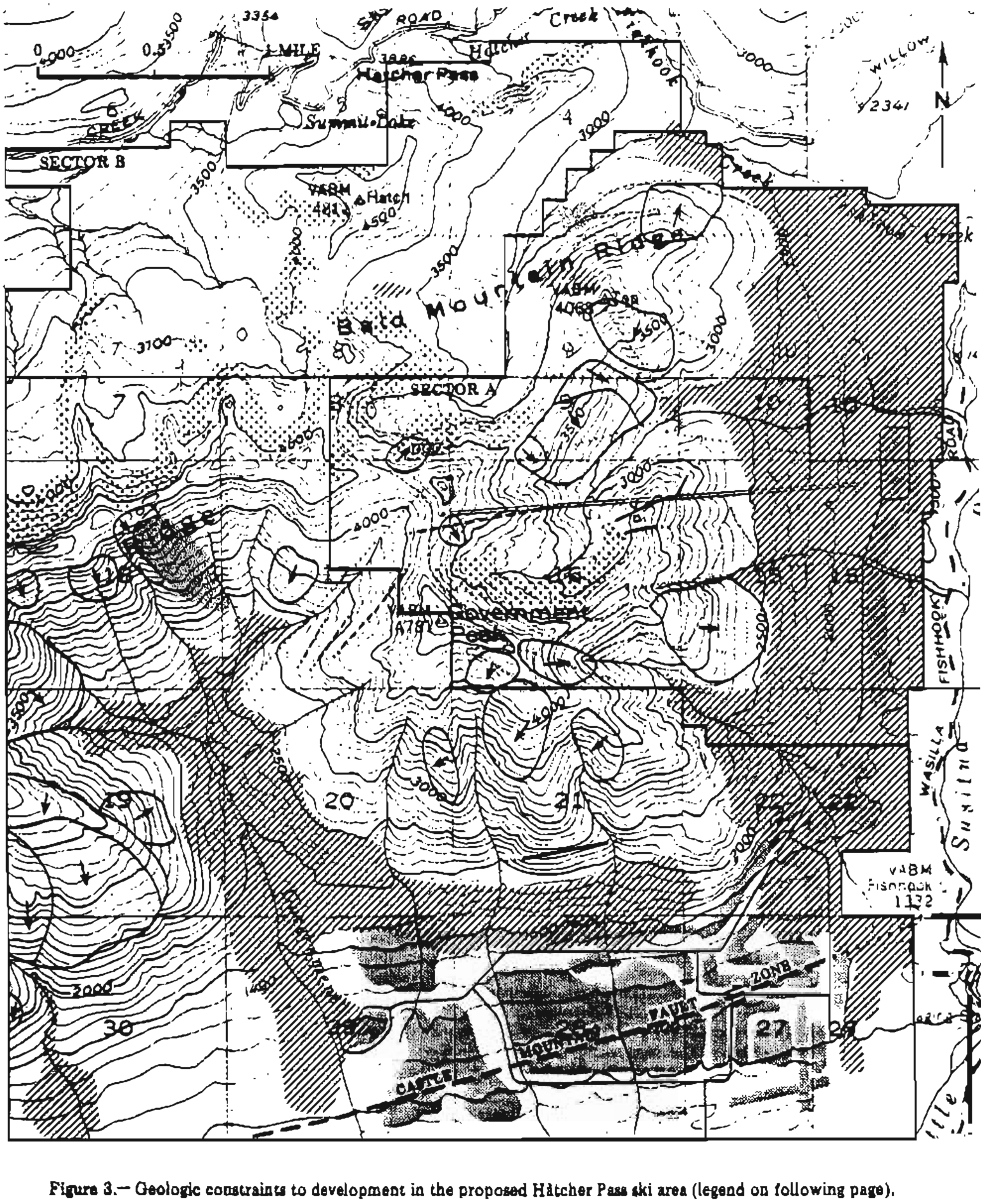
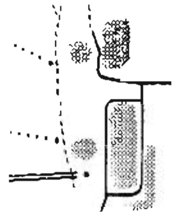


Figure 3.— Geologic constraints to development in the proposed Hatcher Pass ski area (legend on following page).

Figure 3 (cont'd) - Legend



Areas proposed for permanent structures and other developments. Ski lifts are shown by straight dotted lines, gondola by parallel straight lines, main roads by solid lines, and hiking/maintenance roads by fine broken lines (see fig. 1).

Areas subject to erosion and debris-flow activity.

Talus and other areas of loose rock, generally on steep, avalanche-swept slopes. Subject to rock falls where steep. Includes local concentrations of boulders on gentle slopes, but does not include locations of individual glacial erratics.

Landslide deposits. May or may not be active, but are potentially unstable.

Marsh.

Block creep (sackung). Arrow shows approximate direction of movement.

Approximate location of active fault zone. Dotted where inferred. Arrows indicate relative motion.

Other faults; activity unknown. Relative motion indicated by U (up) and D (down). Dotted where inferred.

Photolineaments, possibly faults; activity unknown. Dotted where inferred.

2. Terrain along the north-south runway at the proposed airport has a difference in elevation of almost 250 ft from one end to the other, a slope of about 5° (8%). The maximum runway grade used by the Alaska Department of Transportation and Public Facilities is 2% (1.2°).

3. The proposed location for resort dwellings northwest of the main road in Sector B has bedrock slopes approaching 40° (84%).

4. The proposed main road and resort dwellings south of the main ski base cross numerous steep ridges and troughs that have up to about 60 ft of relief. Construction of a road along the proposed route will require major cut-and-fill, which may have considerable impact on the drainage, vegetation cover, and stability of the deposits (see Erosion and Debris Flows).

There is almost always a means of building any facility on a steep slope. Because of the probable need for extensive cut-and-fill to accommodate these facilities, there may be an indirect or induced effect on the intensity of some geologic processes. Considering the probable induced effects of substantially disturbing the drainage, vegetation, and underlying soils (discussed under Erosion and Debris Flows), alternative locations on terrain that is not as steep should be considered for some facilities.

<u>Alternatives</u>

1. Permanent structures requiring extensive cut-and-fill on steep slopes could be moved to gentler slopes in the southeast corner of Sector B.

2. The golf course and field-archery areas could be moved west of Government Creek to provide room on gentler terrain for some of the permanent structures that would require extensive cut-and-fill on steep slopes. Because the Castle Mountain fault zone crosses the proposed golf course and field-archery areas, however, parts of these areas may not be suitable for permanent structures (see Earthquakes and Active Faulting).

Soil Suitability for Construction

<u>Bearing Capacity of Soils</u>

The proposed locations for most facilities in the base areas of the ski resort are on glacial till (fig. 2). This deposit contains varying proportions of gravel, sand, and silt, including local concentrations of large boulders. In its natural state, the till is generally very dense and firm below a looser surface layer of peat, silt, and sandy till that ranges from about 1 to 6 ft thick. Its bearing capacity is therefore high and well suited as foundation material for large structures. If the till on or near steep slopes becomes saturated, however, it can be subject to flow failure (see Erosion and Debris Flows).

Some of the proposed facilities are located partially on debris-flow deposits. Because these deposits are made primarily of disturbed till and organic debris that has flowed downslope, the bearing capacity can be expected to be much lower than in undisturbed till.

Water Table

Although no wells or pits were dug to determine water-table depth, some generalizations can be made (Table 1). In general, the water table can be expected to be shallow at low elevations and deep at high elevations. A shallow water table can be expected in the immediate vicinity of perennial streams and intermittently along high-elevation ephemeral streams. Because permeability in till is low, a shallow perched water table is locally possible in depressions or level areas. The till surface is typically sloping, however, so perched water is probably rare.

Suitability for Waste-water Disposal

The high silt content and generally low permeability of the till and debris-flow deposits make them relatively poor candidates for waste-water disposal. Leaching fields would have to be very large. On-site treatment may be necessary, but this should be determined only after field percolation tests have been performed.

Marsh Deposits

The only marsh deposits encountered in the study area are in a small meadow near the southern edge of Sector B. This is the only area observed in which there is standing water on surface deposits consisting of several feet of peat and organic-rich silt. Elsewhere, a moist vegetation mat was encountered locally on till and debris-flow deposits, but the surface organic layer was not observed to be more than 1 ft thick and the water table was not encountered while digging shallow test pits.

Erosion and Debris Flows

Description

Although debris flows are a type of landslide, they are treated here with erosion because the two processes operate together to modify the till-covered lower hill slopes in the area. There is considerable topographic and geologic evidence that gully erosion and debris flows have occurred extensively in till on the lower east- and south-facing slopes below Government Peak and along Government Creek. Numerous deep troughs trending down slope dissect the till. The heads of these troughs are bowl-shaped with serrate scars where the gullying advances upslope, and the down slope terminus opens onto a fan- or tongue-shape debris-flow deposit. Till and the soils above them are most susceptible to failures of this type where the till has high silt content and, therefore, low permeability. High silt content is characteristic of basal till, which comprises most of the lower slopes in the area. Morainal till, which is commonly silt free, was observed in only one locality near the east edge of Sector A, northeast of the proposed resort hotel.

Most of the till surface on which this gullying and debris-flow activity has occurred is below 2,500 ft elevation and is now vegetated with alder, willow, cottonwood, birch, and shrub birch. The surfaces of debris-flow deposits are similarly vegetated, indicating that most have not been recently active. On aerial photographs, however, the trees on some debris-flow deposits appear younger overall than those on the surrounding till, suggesting that some of the debris-flow activity may have taken place within the last few decades.

Numerous small slope failures are present in the till, mostly in gully heads. These slope failures are generally small debris flows or slumps where firm till is exposed in a headwall scarp and saturated till, surficial soils, and organic debris have recently flowed down slope. They indicate a potential for renewed slope failure and debris-flow activity on steep slopes (probably greater than 35°) where the till becomes saturated. Because the soil in debris-flow deposits is already disturbed, saturation or further disturbance could cause renewed failure on relatively gentle slopes.

Elsewhere in southern and southeastern Alaska, debris-flow activity in till on steep mountain slopes has been shown to correlate directly with rainfall and vegetation removal. Debris-flow activity accelerates dramatically 3 to 5 yr after vegetation removal because that is the length of time it takes for the root systems to decay, thereby reducing the stabilizing effect of the vegetation on the soil. Removing vegetation also allows more rain water and runoff to enter and saturate the soil mass.

Areas that are susceptible to gullying and debris-flows, based on evidence of where these processes have occurred in the past, are shown in Figure 3. Development activities in these areas that could increase the likelihood that gullying and debris flows become a hazard to facilities and public safety include:

1. Removal of vegetation.

2. Disruption of natural drainage.

3. Overloading slopes.

4. Moving of till soils on steep slopes (till spoils are less stable).

5. Excavating and leaving exposed steep cuts.

Some gullying and debris-flow activity also occur in thin till and colluvium over bedrock on slopes above 2,500. Because these deposits are very thin (on the order of several feet or less), the gully channels are typically shallow and the debris-flow deposits are small. Although these smaller debris flows on higher slopes are not likely to be a hazard for permanent structures with foundations in bedrock, they may be a minor maintenance problem on ski slopes and along maintenance roads. Removal of vegetation is likely to accelerate debris-flow activity on higher slopes as on lower slopes.

<u>Mitigating Measures</u>

1. Perform a slope-stability analysis wherever permanent structures will be located on till slopes to ensure that the slope after construction will have a safety factor of at least 1.5.

2. Remove as little vegetation as possible within areas prone to erosion and debris flows (fig. 3) and revegetate excavated slopes where possible. On ski slopes, maintain as much ground vegetation as is consistent with the primary use of the slopes. Small debris flows may be a persistent minor maintenance problem on the ski slopes.

3. Install carefully engineered diversion ditches and interceptor drains to divert drainage around structures and away from disturbed surfaces and unstable slopes into existing channels.

4. Refrain from placing permanent till spoil piles on slopes. Where used for fill or levelling, till spoils should be compacted and revegetated.

5. Use pilings driven to bedrock or into firm till to support permanent structures wherever possible to allow natural drainage to continue underneath structures and to alleviate some of the need for cut-and-fill.

6. Excavate and maintain cut slopes in till consistent with sound engineering practice.

Landslides

Description

In addition to debris flows, there are two other types of landslides in the area. Debris slides (ls) were identified in three places (figs. 2 and 3). The two small slides in the northern part of the area are probably inactive, although they would not be good sites for permanent structures because of possible renewed activity. A large debris slide in the headwater area of Government Creek is probably still active. Present movement is probably by creep, although a major rapid failure is possible. No permanent structures should be built on or below this slide.

The second type of landslide is block creep, sometimes referred to as 'sackung' in the technical literature. This type of slope failure is more widespread in the area than debris slides (fig. 3). Sackung are not well understood, although they are common in glaciated alpine areas worldwide. This type of failure is characterized by an uphill-facing scarp or ridge-top depression at the top and a bulging out of the mountainside below, sometimes with multiple uphill-facing scarps continuing down the bulge. Sackung are believed to result from unloading of the rock mass after deglaciation and 'sagging' of the mountainside under the force of gravity. Major earthquakes may activate slow movement or trigger rapid failure if ground acceleration is very high. Although the uphill-facing scarp at the head is usually easy to identify, there is no identifiable basal shear plane, so the toe is difficult to locate. Movement is by very slow creep along multiple planes of weakness, like bedding planes or fractures, or by slow plastic deformation of the rock.

Sackung can progress into complete failure, like the debris slide at the head of Government Creek, or cause smaller slides by oversteepening the slopes. Whether sackung in the Hatcher Pass area are active is not known. They may have been active for a brief time following deglaciation and then stopped, or may still be active. Some areas may be active and others not. In the proposed ski area, sackung are most common in the Arkose Ridge Formation, which is locally intensely sheared.

Block creep may have no effect on structures or may result in gradual misalignment or displacement. Because it affects primarily upper slopes, it is most likely to affect ski-lift support structures and lift houses.

Mitigating Measures

1. Refrain from building permanent occupied structures on debris slides or block-creep (sackung) failures.

2. Install survey stakes and/or slope-indicator tubes on one or two block-creep failures near proposed facilities to determine whether they are active and, if so, their rates of movement.

3. If ski-lift supports are installed in block-creep areas, they may be subject to gradual misalignment. Careful monitoring of their alignment and spacing would provide a good indication of any block movement.

Earthquakes and Active Faulting

Description

Development in the Hatcher Pass area may be affected by large deep earthquakes along the Alaska-Aleutian Subduction Zone 50 to 100 miles southeast of the area, by moderate to large shallow earthquakes along nearby active faults, and by random shallow earthquakes in the area. The great Alaska earthquake of 1964 (magnitude 9.2) caused virtually no damage in the Wasilla area, although possible effects such as landslides in the mountains may have gone unnoticed. Although future major earthquakes along this portion of the subduction zone are possible, an earthquake as large as the one in 1964 is unlikely in the near future because some time will be required before an equivalent amount of strain is again accumulated on this portion of the subduction zone.

Local earthquakes of magnitude 5.5 or greater are considered potentially damaging. A regional seismicity study performed for the proposed new state capital site at Willow, 20 miles west of Government Peak, provides an estimate of the seismicity that can be expected in the area (Table 2).

Table 2.-Estimated return intervals for earthquakes within 75 miles of Anchorage and the proposed capital site at Willow (from R&M Consultants, 1978).

Magnitude->	5	6	7	8	8.5
Capital Site	2 yr	11 yr	85 yr	631 yr	1700 yr
Anchorage	1 yr	7 yr	36 yr	199 yr	467 yr

The Castle Mountain fault zone, which passes through the southern part of the area (figs. 2 and 3) is probably more likely to cause damage to structures in the proposed ski area than earthquakes along the subduction zone. The term 'fault zone' is used because the Castle Mountain fault has no single well-defined plane of displacement in this area. Rather, it is a zone of fault planes that may be several hundred feet wide. Geologic and seismologic evidence shows that this fault is active. A scarp more than 6 ft high along the fault between Houston and the Susitna River marks an area where the fault has displaced recent alluvium, and a magnitude 5.2 earthquake near Sutton in 1984 was directly attributed to slip on the fault.

The time of most recent rupture of the segment through the proposed ski area is not known, and the exact location is obscured by surficial deposits and vegetation. Some earthquakes will not result in displacement at the surface, as was the case with the Sutton earthquake, so lack of geologic evidence of breakage at the surface does not necessarily mean that recent earthquakes have not occurred along a particular zone. This also means that it is impossible to determine whether an earthquake centered in the ski area will result in direct damage from fault offset to structures built on or across the fault zone.

The largest earthquake possible along the Castle Mountain fault system has been estimated at magnitude 7.5, but the system is not understood well enough to state that larger magnitudes are not possible. A magnitude 7.5 earthquake resulting in ground breakage in the proposed ski area would cause severe damage or destruction of facilities built on or across the fault zone and severe damage to nearby facilities from ground shaking. Ground failures resulting in debris flows would probably be extensive in saturated, disturbed till or debris-flow deposits on the lower slopes, and small to large displacements could be triggered on the sackung failures (see sections on Erosion and Debris Flows, and Block Creep). The likelihood of such an earthquake occurring in this area within the design life of the ski-area facilities is not known, but is probably low. However, the probability of surface fault rupture within the ski area associated with a moderate earthquake is high enough that reasonable precautions should be taken to reduce the risk of damage to permanent structures, particularly residential dwellings.

Several other small fault zones and lineaments are visible on aerial photographs and in the field (figs. 2 and 3). There is no evidence that these faults are active, but they should be considered potentially active. As presently proposed, no permanent structures will be located on or near these faults.

Mitigating Measures

1. Design and construction of all facilities in the area should conform to the earthquake provisions of the Uniform Building Code for seismic zone 4 as appropriate for the type of facility.

2. Dynamic loading using design ground-motion parameters appropriate for the area should be incorporated into slope-stability analyses where permanent structures for human occupancy are proposed.

3. Although all structures are vulnerable to damage if built on an active fault, residential buildings specifically should not be constructed on or adjacent to the Castle Mountain fault zone. The State of Alaska has no requirement for minimum setback from active faults, but California requires that structures for human occupancy be no closer than 50 ft from an active fault. This should be considered a minimum guideline. To locate fault planes, a geologist with experience in fault studies should conduct detailed surficial mapping and trenching surveys across the fault zone. If structures are located at least ¼ mile from the mapped fault zone (figs. 2 and 3), there should be no need for detailed fault studies.

4. In the event permanent structures are proposed on or near the smaller fault zones around Government Peak (figs. 2 and 3), field studies should be conducted to accurately map their locations and to determine the probable age of most recent activity.

Boulder Fields and Talus Slopes

Description

The only deposit known to consist almost entirely of large boulders is a small rock-fall deposit (rf) on gently sloping terrain north of Bald Mountain Ridge (fig. 2). This deposit probably originated as a rock slide that was deposited on glacial ice, then was transported a short distance before melting out onto the ground.

Several other deposits in the area contain scattered boulders exposed at the surface. Scattered large glacial-erratic boulders are common on the surface of till (gt) and on colluvium (c) and bedrock slopes at high elevations. These boulder locations have not been mapped. They are a serious hazard to skiers because they are isolated and protrude up to several feet above the surrounding surface. Talus (t) commonly contains boulders, which are generally more numerous near the base of the deposit than at the top. Talus slopes are generally very steep, subject to rock falls, and swept by snow slides and avalanches. The glacial-outwash deposit (ow) on the east edge of the map area (fig. 2) contains numerous very large rounded boulders. Many boulders have been excavated from this outwash deposit and are strewn across the ground along Wasilla-Fishhook Road downvalley from the deposit.

Mitigating Measures

1. All areas within and adjacent to ski runs should be examined carefully for large boulders, which should be removed.

2. If ski runs are extended north of Bald Mountain Ridge, the rock-fall deposit (rf, fig. 2) should be barricaded to prevent skiers from crossing it. Slopes in this area should also be examined for scattered erratic boulders, which should be removed.

3. Facilities and roads should not be placed on talus slopes or near their bases (fig. 3).

Snow Avalanches

(by G.D. March)

Description

Most of the terrain within the Mitsui development plan is above timberline and is relatively steep. The snow load in the area is consistently heavy, and the potential for snow avalanches is high. Although avalanches are a common problem in ski areas, usually controlled by artificial release, the proximity of proposed buildings to the potential avalanche areas must be carefully evaluated before development.

Interpretation of aerial photographs and prior knowledge of the area indicates that snow-avalanche potential is moderate to high in nearly all areas above about 1,100 ft (fig. 4). The proposed ski area places structures at the bottoms of slopes with high avalanche potential, especially on the eastern side of the area.

Mitigating Measures

1. Building sites should be examined in detail by trained personnel to ensure that they will be safe from 100-year snow avalanches, as one of these could happen in any year. Examination should occur both winter and summer before construction begins.

2. 'Designation of Special Use Lands, Hatcher Pass Management Unit, Addendum A to Document of Intent, date November 21, 1986' states that a snow-safety plan will be required for winter commercial operations. Backcountry skiing operations are specifically listed, but downhill ski areas are not. This document should be updated to include the proposed downhill ski area, and a snow-safety plan should then be required.

SOURCES OF CONSTRUCTION MATERIALS

Sources of clean, well-graded sand and gravel for construction are scarce within the area proposed for development. Alluvium (al) and glacial outwash (ow) are the best available sources of clean aggregate (fig. 2; table 1), but these sources are very limited. Outwash is also likely to contain much oversize material (large rounded boulders) that could make excavation and processing difficult.

Till is the most widespread deposit in the areas proposed for major facilities. Debris-flow deposits containing primarily material derived from till are also common. The grain-size content of these deposits is highly variable; all sizes except clay are present in varying proportions. Silt content is commonly higher than acceptable for most construction purposes (greater than 10%). Large boulders are also locally abundant and would make excavation and processing difficult. Intermediate sizes in the coarse-sand to pebble-gravel range desirable for construction use may be lacking. However, the till may contain locally washed deposits of sand and gravel, such as in moraines, that would be adequate but limited sources of aggregate. One such moraine was identified about ¼ mile east of the proposed resort hotel.

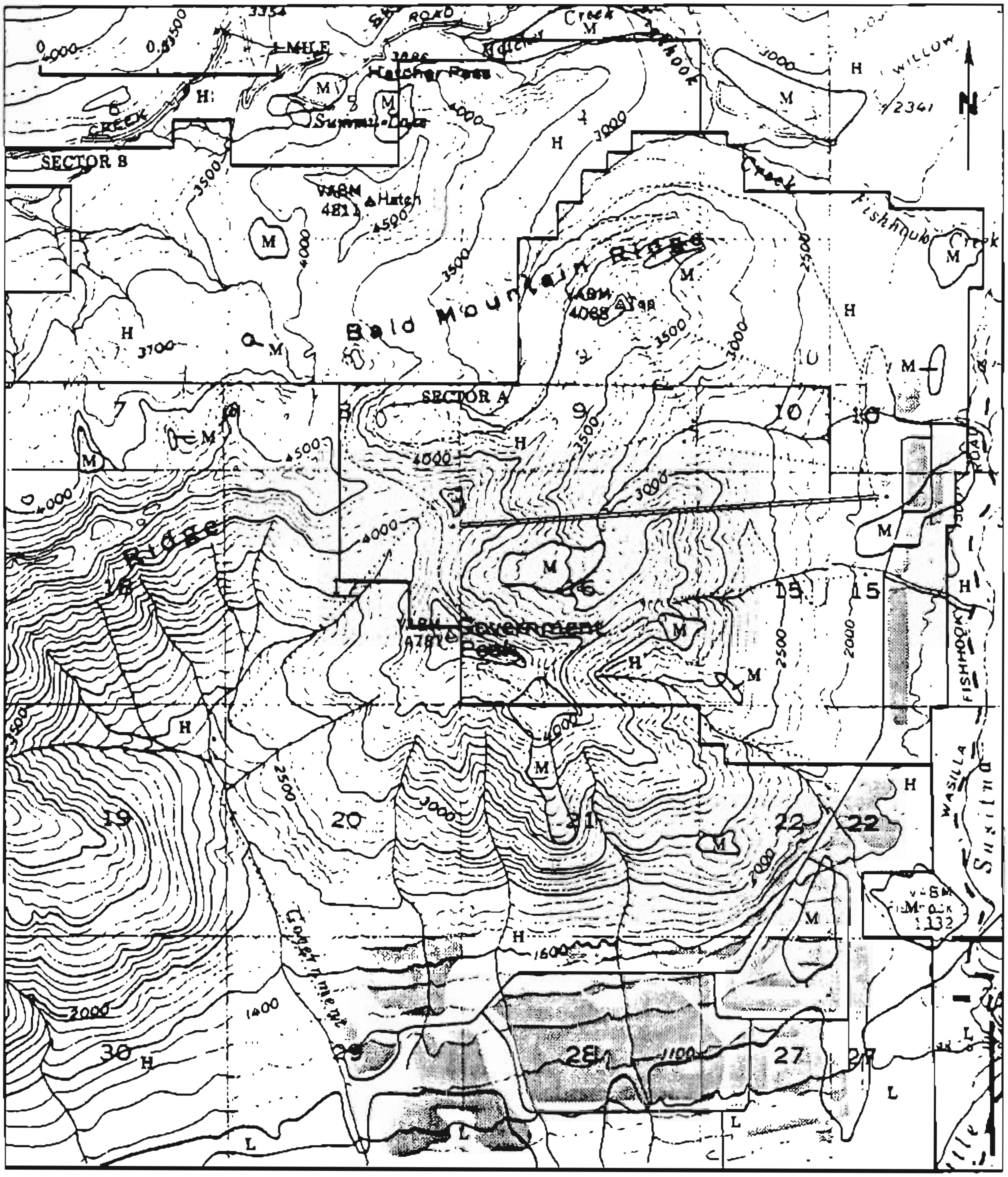


Figure 4.— Snow-avalanche potential in the proposed Hatcher Pass ski area. H—high potential, M—moderate potential, L—low potential. Areas proposed for development are also shown (see fig. 1). (Figure by G.D. March)

Other possible limited sources of aggregate include the alluvial fan (af) near the mouth of Fishhook Creek and the abandoned-channel deposits (ac) in the southern part of the area.

The most widespread source of natural angular rock for riprap is talus (t). Other limited sources include rock glaciers (rg), rockfall deposits (rf), and protalus ramparts (pr). The Arkose Ridge formation (ar) and mica schist (ms) could be mined for rock, but these highly sheared and fractured bedrock units are likely to produce primarily small rock. The basement complex (bc) is the most likely source for large angular armor rock.

The Palmer-Wasilla area has some of the most extensive and accessible deposits of construction-grade aggregate in the state, so aggregate sources outside the proposed ski area are not far away. Although land-ownership and access questions would need to be resolved, possible closer off-site sources include an outwash fan along the Little Susitna River near the southeast corner of the area, and a large pitted-outwash plain that extends southward from its contact with the till just south of the area.

SUMMARY

The terrain and geologic features in the proposed ski area at Government Peak are dominantly a product of late-Wisconsin alpine glaciation, followed by erosion and mass wasting after deglaciation. Primary engineering-geologic constraints are, therefore, related to glacial deposits and steep slopes. Significant constraints include (not necessarily in order of importance):

1. Erosion and debris-flow activity in till in areas proposed for primary base facilities. Vegetation removal, disruption of drainage, and major cut-and-fill will increase the potential for this activity.

2. Low permeability and poor internal drainage of till, making it a poor material for septic disposal and increasing susceptibility of surficial soils to slope failure.

3. Earthquakes and fault displacement along the Castle Mountain fault system.

4. Snow avalanches.

5. Block creep (sackung) may cause long-term misalignment of facilities if active. In the worst case, complete failure of blocks may be triggered by a major earthquake. Not enough is known about this phenomenon to define its significance for development in the ski area.

These constraints can be minimized by selecting alternative sites in the area for some facilities and by designing and building according to sound engineering practice. For example, undisturbed till is excellent material for foundations if it is kept well drained and facilities are kept away from steep, nonvegetated or sparsely vegetated slopes. Slope-stability analysis can be used to determine whether the slopes will be stable after construction.

Suggested mitigating measures are presented in the sections on geologic constraints. Site-specific engineering studies will be necessary to determine the severity of constraints for individual facilities and to design and build for acceptable factor of safety. If engineering analysis shows that abatement of geologic constraints within the proposed area is too costly, some consideration should be given to acquiring or leasing private land or Borough land outside the state lease area for the resort housing.

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