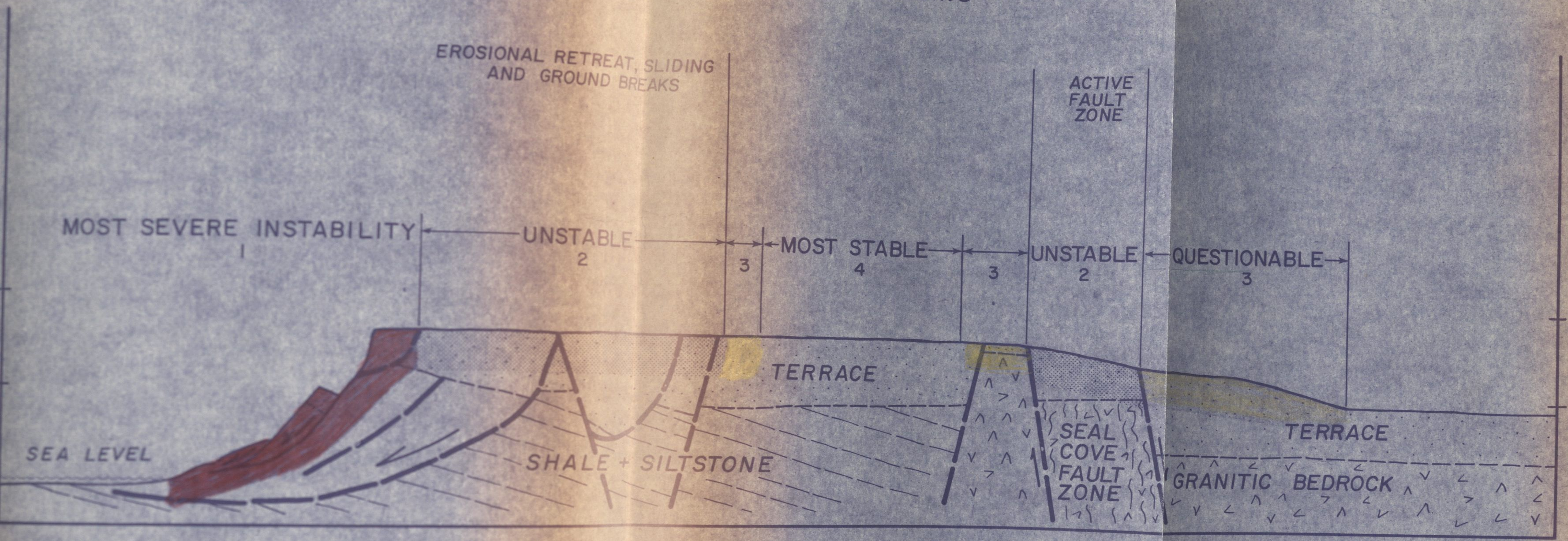
SCHEMATIC CROSS-SECTION ILLUSTRATING MAJOR GEOLOGIC PROBLEMS



Seal Cove-Moss Beach Area
San Mateo County
10-15-71
LEIGHTON

EXHIBIT D

INTRODUCTION
OF
TECHNICAL PORTION

Recognition of the Problem

Geologic hazards affect both man and man-made structures in the subject area and have been a source of concern to geologists for at least 3 years. Recent coastal landslide and erosion studies by the U.S. Geological Survey have identified and focused attention on some of these geologic problems.

Scope of the Investigation

The initial phase of the present investigation for the County of San Mateo began in August, 1971 with a study of vertical aerial photographs dating from 1930 (see separate list of referenced aerial photographs). Matching pairs of this time-lapse photography of the same area were stereoscopically studied in order to delineate pronounced lineaments and other features decipherable by photogeologic methods.

Geologic surface mapping began on September 16, 1971 and was progressively augmented by a subsurface program that was carried out in two stages: (1) a preliminary exploration, and (2) advanced exploration that sought answers to questions posed by both geologic mapping and the preliminary stage of subsurface exploration. A total of 41 subsurface probes were excavated. These include 15 backhoe trenches (test pits) 18± inches wide, 17 bucket-auger borings 24 inches in diameter and 9 flight auger borings 6 inches in diameter. The trenches range from 9 to 12.5 feet in depth and the borings range from 21 to 61 feet in depth. All were excavated and backfilled between September 17, 1971 and October 7, 1971. All have been checked for restoration to previous grade and for settlement.

Geologic data were compiled on 100-scale base maps and aerial photographs. A preliminary copy of the geologic map and Cross-Sections A-A' and C-C' were submitted to the County of San Mateo on October 1, 1971 in an interim geologic report that summarized the first phase of the preliminary geologic investigation.

Subsequently, the second (and final) phase of the preliminary investigation was undertaken. This included additional field mapping, 9 subsurface holes drilled with a 6-inch diameter flight auger, preparation of geologic illustrations including the Geologic Stability map and compilation of the report.

Acknowledgments

Time and space restrictions do not permit acknowledgment of all individuals and organizations who contributed to this study. However, within this firm Lawrence R. Cann, William R. Cotton and Edward A. Hay were responsible for most of the field mapping, and Lawrence R. Cann and Robert H. Dickey handled most of the geologic logging of borings and trenches. Katharine Friberg, our Information Specialist, researched outside sources of data. A number of private consultants reviewed the field program and field products, as well as contributing survey data, maps, logs and general information. The cooperation of these consultants, the County Engineer, County Manager, Planning, Legal and Building Departments and other County of San Mateo offices, the U.S. Geological Survey, the Division of Mines & Geology, and residents in the area is hereby gratefully acknowledged.

General Topographic and Geologic Setting

The setting is graphically shown by the geologic index map whose base is the Montara Mountain Quadrangle. A prominent northwest-trending topographic ridge crosses the study area. This ridge extends over 2 miles from Pillar Point northward to Moss Beach. It varies in width from a quarter mile to a half mile, and reaches its maximum elevation of approximately 190 feet immediately south of the study area. The west flank of the ridge is bounded by the sea cliff and the east flank is a gentle to moderately steep slope. A relatively flat terrace surface at about 100 feet elevation occupies much of the south study area.

Surf erosion along the western margin of the study area has produced a sea cliff which is 50 to 105 feet high except in the limited areas of slide and stream channels. Thus, most of the 125± feet of relief in the area is concentrated in the sea cliff zone.

The sea cliff generally exhibits natural slope angles ranging from 50 to 70° to near vertical in local areas. In places, landslides have altered the slopes to flatter angles that are between 1.5 (horizontal): 1 (vertical), and 3 (horizontal):1 (vertical).

Rainfall averages approximately 20-25 inches per year, about half the amount received by the mountains to the east. However, concentrations of fog, swept inland by the prevailing west and northwest winds, result in less loss of this precipitation by evapo-transpiration.

Nine major lithologic units have been mapped and appear on the map legend. These include six chief surficial units and three bedrock units. The mappable surficial units are TERRACE DEPOSITS, COLLUVIUM-SLOPEWASH, ALLUVIUM-COLLUVIUM, COLLUVIUM, ALLUVIUM, and ARTIFICIAL FILL. The mappable bedrock units are GRANODIORITE, SILTSTONE-SHALE and SANDSTONE-SILTSTONE.

Thus, the study area contains two distinct bedrock units: (1) a sedimentary unit consisting of the marine siltstone-shale and sandstone-siltstone sub-units of the Purisima Formation (Pliocene), and (2) an igneous unit of granitic plutonic rock (quartz diorite to granodiorite) in composition known as the Montara Formation (late Cretaceous).

The surficial units that overlie the bedrock stratigraphically range from late Pleistocene to late historical in age. All of these units except the alluvium have been affected by faulting and/or landsliding.

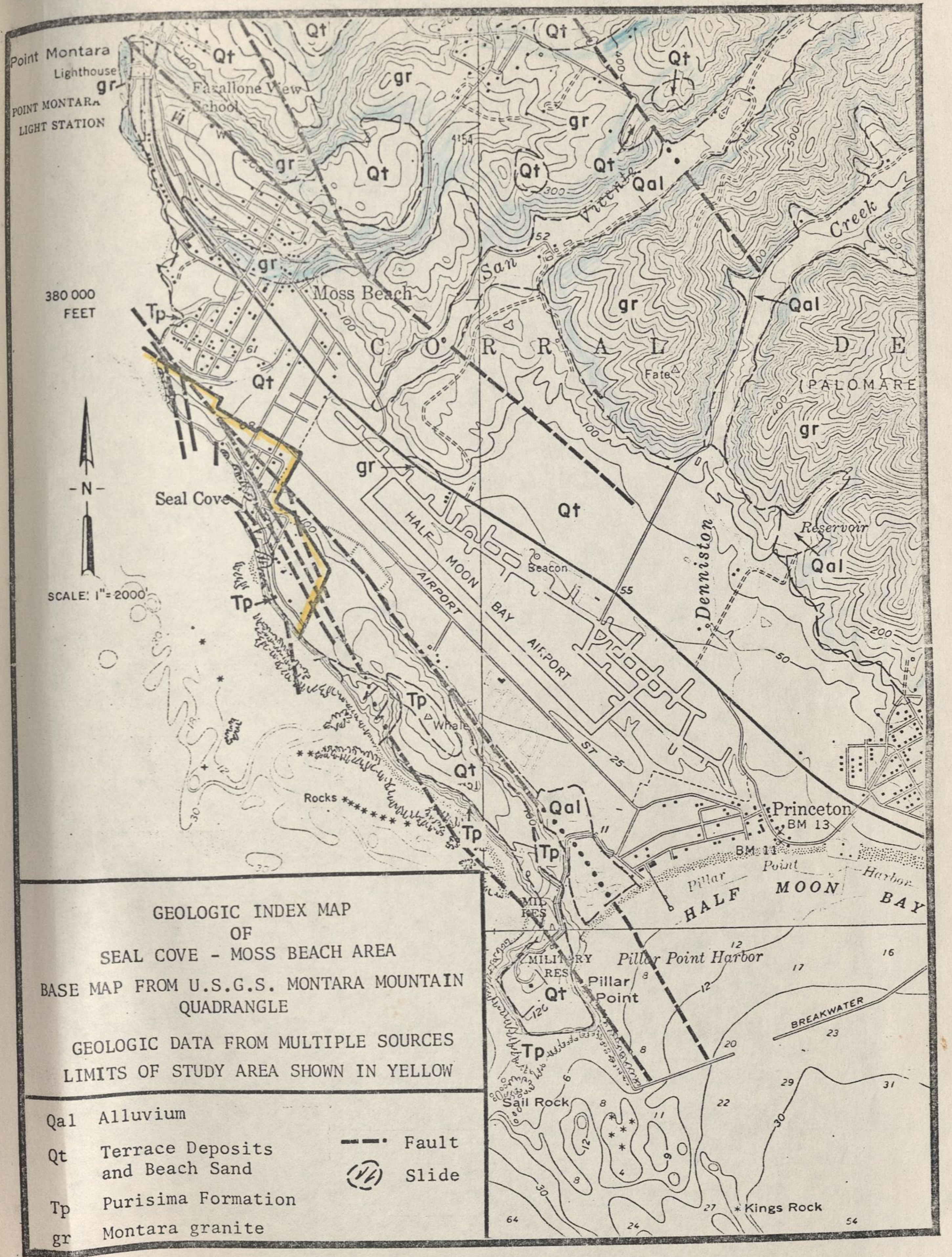

GEOLOGIC INDEX MAP
OF
SEAL COVE - MOSS BEACH AREA
BASE MAP FROM U.S.G.S. MONTARA MOUNTAIN QUADRANGLE
GEOLOGIC DATA FROM MULTIPLE SOURCES
LIMITS OF STUDY AREA SHOWN IN YELLOW
Qal Alluvium
Qt Terrace Deposits and Beach Sand
Tp Purisima Formation
gr Montara granite
Fault
Slide
Point Montara
Lighthouse
POINT MONTARA LIGHT STATION
Farallone View School
Moss Beach
Seal Cove
380 000 FEET
N
SCALE: 1" = 2000'
CORRAL DE
(PALOMARE
San Vicente
Creek
Denniston
Reservoir
HALF MOON BAY AIRPORT
Beacon
Whale
Rocks
Princeton
BM 13
BM 11
Pillar Point
Harbor
HALF MOON BAY
MILITARY RES
Pillar Point Harbor
BREAKWATER
Sail Rock
Kings Rock

EXHIBIT B

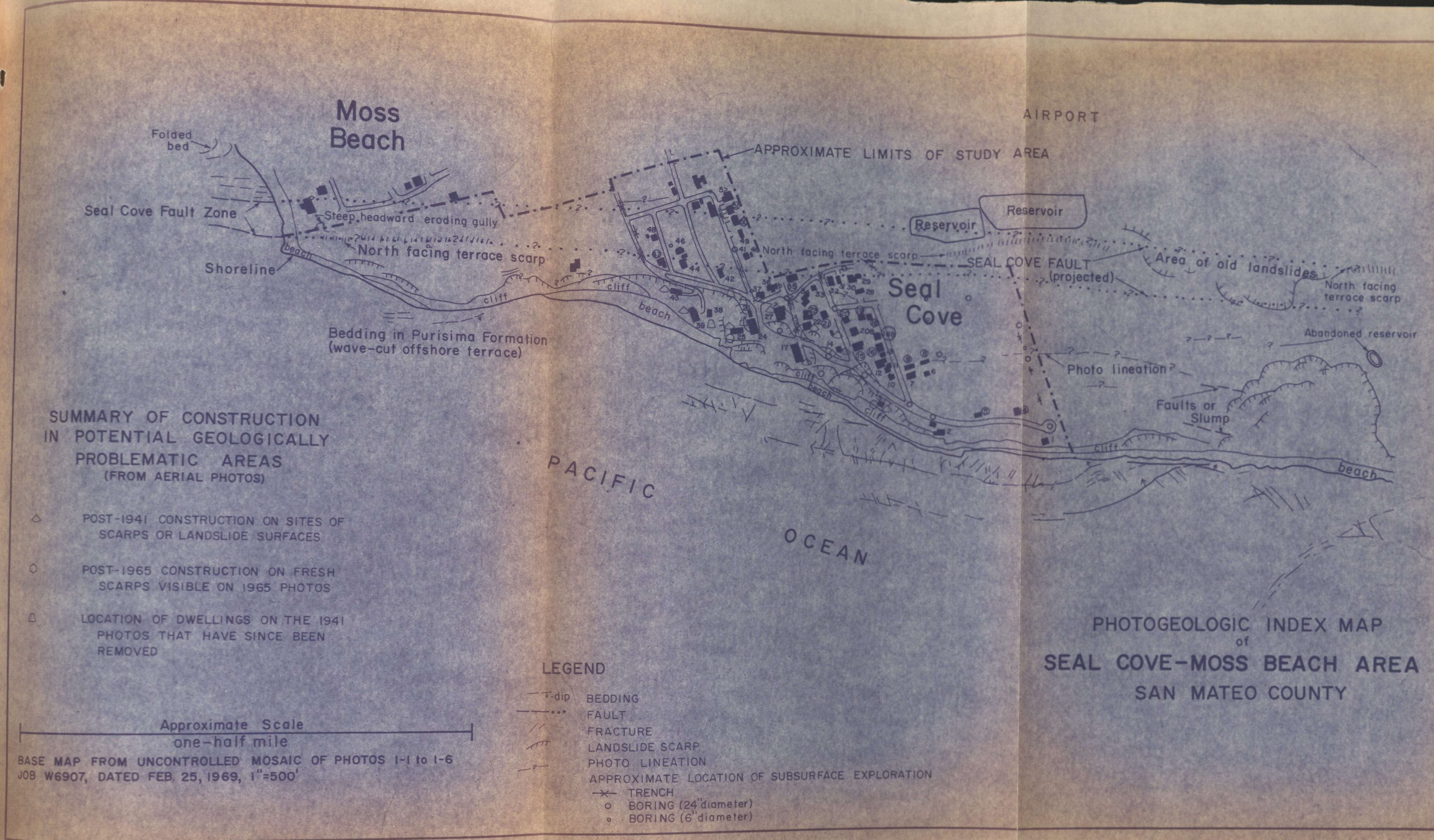

Moss Beach
Folded bed
Seal Cove Fault Zone
Steep headward eroding gully
North facing terrace scarp
Shoreline
beach
cliff
Bedding in Purisima Formation (wave-cut offshore terrace)
AIRPORT
APPROXIMATE LIMITS OF STUDY AREA
Reservoir
Reservoir
North facing terrace scarp
SEAL COVE FAULT (projected)
Area of old landslides
North facing terrace scarp
Seal Cove
Abandoned reservoir
Photo lineation
Faults or Slump
PACIFIC
OCEAN
SUMMARY OF CONSTRUCTION IN POTENTIAL GEOLOGICALLY PROBLEMATIC AREAS (FROM AERIAL PHOTOS)
POST-1941 CONSTRUCTION ON SITES OF SCARPS OR LANDSLIDE SURFACES
POST-1965 CONSTRUCTION ON FRESH SCARPS VISIBLE ON 1965 PHOTOS
LOCATION OF DWELLINGS ON THE 1941 PHOTOS THAT HAVE SINCE BEEN REMOVED
Approximate Scale
one-half mile
BASE MAP FROM UNCONTROLLED MOSAIC OF PHOTOS 1-1 to 1-6
JOB W6907, DATED FEB. 25, 1969, 1"=500'
LEGEND
dip BEDDING
FAULT
FRACTURE
LANDSLIDE SCARP
PHOTO LINEATION
APPROXIMATE LOCATION OF SUBSURFACE EXPLORATION
TRENCH
BORING (24" diameter)
BORING (6" diameter)
PHOTOGEOLOGIC INDEX MAP of SEAL COVE-MOSS BEACH AREA SAN MATEO COUNTY

EXHIBIT C

Surficial Units

The major surficial unit is a marine terrace deposit composed of unconsolidated gravel, sand and minor amounts of silt. This unit (Qt) caps the ridge area and the relatively flat terrace level that buries the bedrock throughout most of the area. The thickness of this cap ranges from 3-4 feet to 40+ feet. This variability in thickness is probably a reflection of the erosional topography upon which the marine sediments were deposited, but may, in part, be due to faulting. The sandy portion of the terrace materials consists of light tan to deep red-brown arkosic debris that is locally cross-bedded. In places the basal portion of the unit is a fine to medium-grained, micaceous sand that rests on a basal pebble to cobble conglomerate.

Other surficial units consist of alluvium, colluvium, mixtures of colluvium, alluvium and slope wash, and slide debris.

Alluvium (Al) is divided on the geologic map into beach sand (Al_b) and stream channel deposits (Al_s). The beach sand is confined presently to discontinuous patches at the base of the sea cliff, and the stream channel deposits are restricted to the stream channel at the north end of the study area.

Colluvium (Col) is mapped where the soil zone is known to be thicker than 4± feet. These thick colluvial soil zones commonly develop on and at the base of slopes by a combination of deep weathering, rain wash, soil creep and small-scale mass movements. Together with slope wash (Sw), colluvium poses local foundation problems largely because of its combined looseness, humus and swelling clay content and thickness.

The residual soil zone covers most of the area and has been mapped only where it is thicker than 4 feet. On the principal terrace surface in the south, it has developed a dark brown to black, potentially expansive mantle that is 1 to 4 feet thick. In reentrants and low gullies, the normal soil zone resting on terrace deposits merges downslope into a mixture of colluvium and slope wash.

Slide debris is divided into 10 mapped surficial slope failures and major slide areas, some of which are composite. The mapped slide areas are confined to the surf zone, sea cliff area, and a coastal belt that extends inland about 300 feet from the toe of the sea cliff.

Some of the surficial slope failures are extremely fresh and have occurred within the past year. At the other end of the time scale some slides are prehistoric. However, most of the slides are developing and enlarging now, both by growth headward and toeward. For example, analysis of aerial photographs taken in 1941 in the vicinity of the sea cliff between the foot of San Lucas and La Grande Avenues shows the existence of three slide scarps. By the time aerial photographs were taken in 1956, the terrain below these fresh scarps had deteriorated into a jumbled state.

Bedrock Units

The Purisima Formation is exposed along the entire length of the steep sea cliff, and where buried by terrace deposits it has been intercepted by most of the borings. Two sequences have been distinguished on the basis of the following dominant lithology: (1) sandstone-siltstone (5-10% of the mapped Purisima area), and (2) siltstone-shale (90-95% of mapped Purisima area). The sandstone-siltstone sequence forms the relative resistant promontory sections of the sea cliff. It consists of tan to light gray, fine to medium-grained sandstones interbedded with thin beds of siltstone. The sandstone beds of this unit are massive to thick-bedded, locally cross-bedded and contain lenses of well-rounded, gray pebbles of granitic composition.

The siltstone-shale portion of the Purisima constitute the dominant unit influencing bedrock stability. It is composed of dark gray to yellow-brown, thin-bedded bedrock materials. Within the sequence, are yellow-brown concretionary beds and lenses and pods of limonitic, calcareous siltstone that form useful marker horizons; they can in places be traced for several hundred yards.

The Montara Formation is not exposed at the surface but has been penetrated in the subsurface in the southeast portion of the study area. Here it is in fault contact with the younger Purisima Formation. Surface exposures of the Montara Formation lie outside the study area in the rugged sea cliff to the north, along the roadcut east of the Half Moon Bay County Airport, and in the high mountain terrain toward Montara Mountain (see Geologic Index Map).

Geologic Structure

The principal structural elements within the study area are: (1) the Seal Cove Fault Zone and its secondary branches, and (2) zones of intensely sheared and fractured bedrock.

The main trace of the Seal Cove Fault Zone is exposed at the north end of the study area along the sea cliff at Moss Beach. The zone measures approximately 100 to 150 feet in width. A well developed fault surface within this zone strikes N18-35°W and dips 65° to 80°E. Here, siltstones and shales of the Purisima Formation have been faulted against younger marine terrace deposits to the northeast. The apparent vertical separation in the sea cliff area is approximately 40 to 50 feet, with the north side down. Secondary fault and shear surfaces are abundant within the zone.

The main trace of the Seal Cove Fault Zone extends southward from the Moss Beach exposure and is marked by a prominent east-facing scarp. The scarp increases in height southward toward the Half Moon Bay area, suggesting greater vertical movement in this direction.

Three principal secondary faults have been mapped on the broad terrace surface west of the main Seal Cove Fault Zone. These faults have been delineated on the basis of subsurface geologic data and detailed mapping of subtle topographic features. They are subparallel faults that strike roughly N20-30°W.

In the subsurface they offset the terrace-bedrock contact, bringing granitic basement rock on the east side into contact with the Purisima Formation. The two westernmost secondary faults can be traced southward from the north end of Beach Boulevard, where they are detachment surfaces for ruptures associated with the heads of landslides. South of the study area the traces of the faults become more pronounced and can be identified on the surf-cut bench as a wide crushed zone. This zone can be traced to the southernmost exposure along the east side of Pillar Point where siltstone and shales are faulted against sandstones and siltstones of the Purisima Formation.

Three prominent fault and joint zones have been mapped within the Purisima bedrock exposed along the surf-cut bench and in the sea cliff. These zones have a general trend of north-south to northwest-southeast, and dip 41°E through vertical to 81°W. They range in width from a few tens of feet to nearly 300 feet. Within the zones are closely-spaced joint surfaces and myriads of small faults that in aggregate produce a highly-fractured condition in the bedrock. Clay-like gouge and brecciated seams occur along most of the faults, ranging in thickness from less than one inch to about a foot.

Ground Water

Shallow subsurface water is evidenced by running springs and seepages in the study area even during this dry season. Most subsurface borings intercepted moist to saturated surficial and bedrock materials at depths of 10 to 30 feet. Moreover, several of the shallow test pits encountered ground water which was not surprising in view of crop irrigation practices in the south area and localized heavy growth of water-seeking vegetation (phreatophytes). However, even where irrigation water has not been applied, a perched water table exists in some places.

Shallow perched water levels have been contoured from available subsurface data and are shown in Sections A-A', B-B', C-C', D-D', and E-E'. The common springs and seepages along faults and other rupture surfaces exposed in the sea cliff are illustrated in Sections A-A' and F-F'.

Much of the ground water encountered in the subsurface borings is located at or near the boundary between sandy terrace materials and the relatively impermeable shales and siltstones of the underlying Purisima Formation. Ground water contained in the relatively impermeable shales and siltstones and the granitic basement rocks is largely confined to fracture, bedding and slide surfaces.

The influence of faults and landslide rupture surfaces on the impounding, compartmentizing and controlling of the flow of ground water is graphically shown by Section C-C'. It is also noteworthy how the water table is much higher in the south portion than in the north portion of the area (compare Sections B-B' and F-F'). This condition is believed to reflect the thinner capping of terrace deposits, the more subdued topography, the greater number and complexity of fault and landslide blocks, and the heavier irrigation practices in the south than the north. Ground water probably travels northward into the study area from off-property to the south because of the bedrock high in that area.

Certainly, a major contribution to the recharge of the ground-water regime is the crop irrigation on slopes near the study area. Lawn and garden irrigation would probably become another major important source of ground water wherever residential development increases in density. The ponding of surface runoff in the poorly drained areas during the rainy season also contributes water to the ground-water system by percolation. Public sewers that presently serve all the residences except one greatly reduce potential man-induced infiltration.

Sea Cliff Retreat

An analysis of aerial photos taken over a 29-year period has been made to estimate the extent and rate of cliff retreat in the study area. Scales were determined by comparing map distance to photo distances between the center lines of Bernal Avenue and Los Banos Avenue parallel to San Ramon Avenue.

The results are presented in the table in the Appendix. They are compared with averages over a 60-year period determined by geologists of the U. S. Geological Survey who used a subdivision map produced between 1908-1912, and ground photos taken over a similar interval of time.

Two important conclusions can be drawn from the data shown in the table:

1. The average rate of cliff retreat over the last 29 years has been approximately 1 foot per year.

2. The rate of cliff retreat has been greater in recent years; since 1965 it has been 3 to 4 feet per year.

Fault Rupture and Active Faulting

Geologically active faults refer herein to faults which transect or disturb the Holocene overburden (younger than 10-11,000 years±). Clearly the main zone of the Seal Cove Fault has fractured the terrace deposits in backhoe trenches 1 and 9. Fault displacement of Holocene stream gravels and colluvium is displayed in the exposure at the nickpoint of the small stream within the northern tip of the mapped fault zone and within the Marine Reserve. Based on this evidence, the Seal Cove Fault Zone must be regarded as active, subject to more detailed probing and delineation during site investigations.

The Seal Cove Fault and its associated secondary faults in the study area have not had significant recorded earthquake epicenters. However, the "active" San Gregorio Fault located south of Half Moon Bay (approximately 12 miles south of Seal Cove) may be the southward continuation of the Seal Cove Fault. This apparent southern continuation appears to be seismically active on the basis of unpublished data from the U.S. Geological Survey.

Past seismic activity suggests that the subject area will be subjected periodically to ground motion from earthquakes that occur along faults in the general region such as the San Andreas Fault System. The San Andreas Fault System parallels the main trace of the Seal Cove Fault and lies approximately 7 miles east of the study area. Past performance of the San Andreas Fault has been analyzed by Dr. Robert W. Wallace of the U.S. Geological Survey. "Recurrence curves" constructed by him suggest that the average time interval between two successive quakes of Richter magnitude 6 along the San Andreas could be five years; the interval for magnitude 7 quakes, 15 years; and quakes of magnitude 8 might be expected at intervals of about 100 years.

Geologic Stability of Natural Slopes

Slope stability problems within the subject area are chiefly confined to the sea cliffs. Approximately 75± percent of the sea cliff area is involved in active mass movements at the present time. Three general types of slope movements have been identified: (1) small scale rock falls along portions of the sea cliff, (2) thin, surficial slumps on the sea cliff face, and (3) large, deep-seated slumps which may extend as far as several hundred feet back (east) of the top of the existing sea cliff. These movements generally involve the entire cliff face and portions of the surf-cut bench.

In several locations near the head of the major landslides, shallow linear depressions have been mapped. These depressions are transformed through time into linear troughs (grabens) bounded by parallel scarps. In addition, active displacement is substantiated by reoccurring breaks in water pipes, cracks in buildings, sidewalks, asphalt roadways and fences, and detached sewer pipes, drain pipes and sidewalk slabs exposed on the sea cliff. Slide surfaces exposed locally along and at the toe of the sea cliff are defined as zones of imbricate (overlapping) planes which often cross each other. In addition, the lowermost slide surfaces parallel the eastward-dipping bedding surfaces in the surf zone. Well-developed, linear fault zones are a persistent path of detachment.

Major factors which have contributed to unstable slope conditions in the Seal Cove - Moss Beach area belong to three distinct categories: (1) the physical character and chemical (mineral) make-up of the bedrock materials, (2) planar and curved structural features which have adverse orientations either singly or in combination, and (3) outside influential factors, either natural or man-induced, which place naturally stable slopes in jeopardy.

All of the major landslides have taken place in Purisima bedrock materials that are incompetent owing to the abundance of clay and the highly fractured, brittle condition. This inherent weakness has been aggravated by outside factors that in some cases have triggered the development of the large-scale slope movements along the western margin of the study area. An example of this is the infiltration of irrigation water and precipitation into the subsurface. This has resulted in seepages in the cliff face and a perched water condition in fault and landslide bounded areas.

A natural outside factor contributing to slope instability is the removal of beach sand, talus materials and the toe of the cliffs by both the sea waves and slope runoff. Reefs and protective rocks offshore act to reduce wave attack, but notches in the cliff and beach stripping testify to wave and current attack during storm seasons.

The erosional retreat that is occurring is influenced by the fault and joint control of the sedimentary units. The Purisima shales and siltstones appear to retreat at approximately the same rate as the terrace materials. This retreat as evaluated by aerial photographs is shown in a special table in the Appendix. A summary of the results is presented in the next section.