FINAL REPORT

Research Unit - 59

Task D-4

OIL SPILL VULNERABILITY, COASTAL MORPHOLOGY, AND SEDIMENTATION OF THE KODIAK ARCHIPELAGO

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I. Abstract - This report contains our Oil Spill Vulnerability Index, as it applies to the Kodiak Archipelago. Included under separate cover with this text is a set of 47 standard U.S.G.S. Quadrangle Maps with the color coded OSVI. Each of the maps also shows the position of the 127 sample and profile sites established in the study area, as well as longshore sediment transport direction arrows. A complete set of Appendices follows the body of the report. Data from these Appendices is available in total from the NODC. This is our Final Report for Kodiak.

II. Task Objectives - The major emphasis of this project falls under Task D-4 which is to: evaluate present rates of change in coastal morphology, with particular emphasis on rates and patterns of man-induced changes, and locate areas where coastal morphology is likely to be changed by man's activities, if any. The relative susceptibility of different coastal areas will be evaluated, especially with regard to potential oil spill impacts.

III. Field and Laboratory Activities - Included in the body of this report.

IV. Results - The results have been summarized in the text and appendices of this report as well as on the set of basemaps being sent under separate cover.

V. Preliminary Interpretations - Does not apply.

VI, Auxiliary Material - Set of 47 U.S.G.S. Quadrangle Maps with the color coded Oil Spill Vulnerability Index and station locations.

VII. Problems Encountered - None.

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GEOMORPHIC SETTING

Kodiak Island is a mountaneous island in the western Gulf of Alaska covering an area of approximately 25000 sq km (Fig. 1). Composed of igneous and metasedimentary rocks derived from uplifted subduction zone complexes, the mountains are very rugged in character. Trending in a northeast-southwest direction, the Kodiak mountains have maximum elevations of 600-1200 m. During the Pleistocene, the mountains were very heavily glaciated. The area differs from one side of the island to the other, these differences are a function of differing geologic controls.

The northwest side shows dramatically the effects of glaciation. Long narrow fjords and U-shaped valleys predominate. Trending in a northwest-southeast direction, the valleys lie perpendicular to the axial trend of the mountains. Shorelines are straight, having narrow gravel beaches butted against steep valley walls. On the sides of the valley walls are elevated kame terraces formed during the last period of glaciation. At present there is no active glaciation occurring on the islands.

The southwest corner of Kodiak Island and all of Tugidak Island have a morphology somewhat different. Although still controlled by glaciation, the flatter topography reflects a continental form of glaciation rather than the valley glaciation of the NW. Deposits of glacial till blanket the entire area with thick deposits in the valleys and thin deposits on the ridges. The shorelines are generally long and continuous with a few crenulate bays eroding back into the glacial till. The till outcrops in a 15 m scarp along much of the coast and contributes large erratics as well as sand and gravel to the beach sediments.

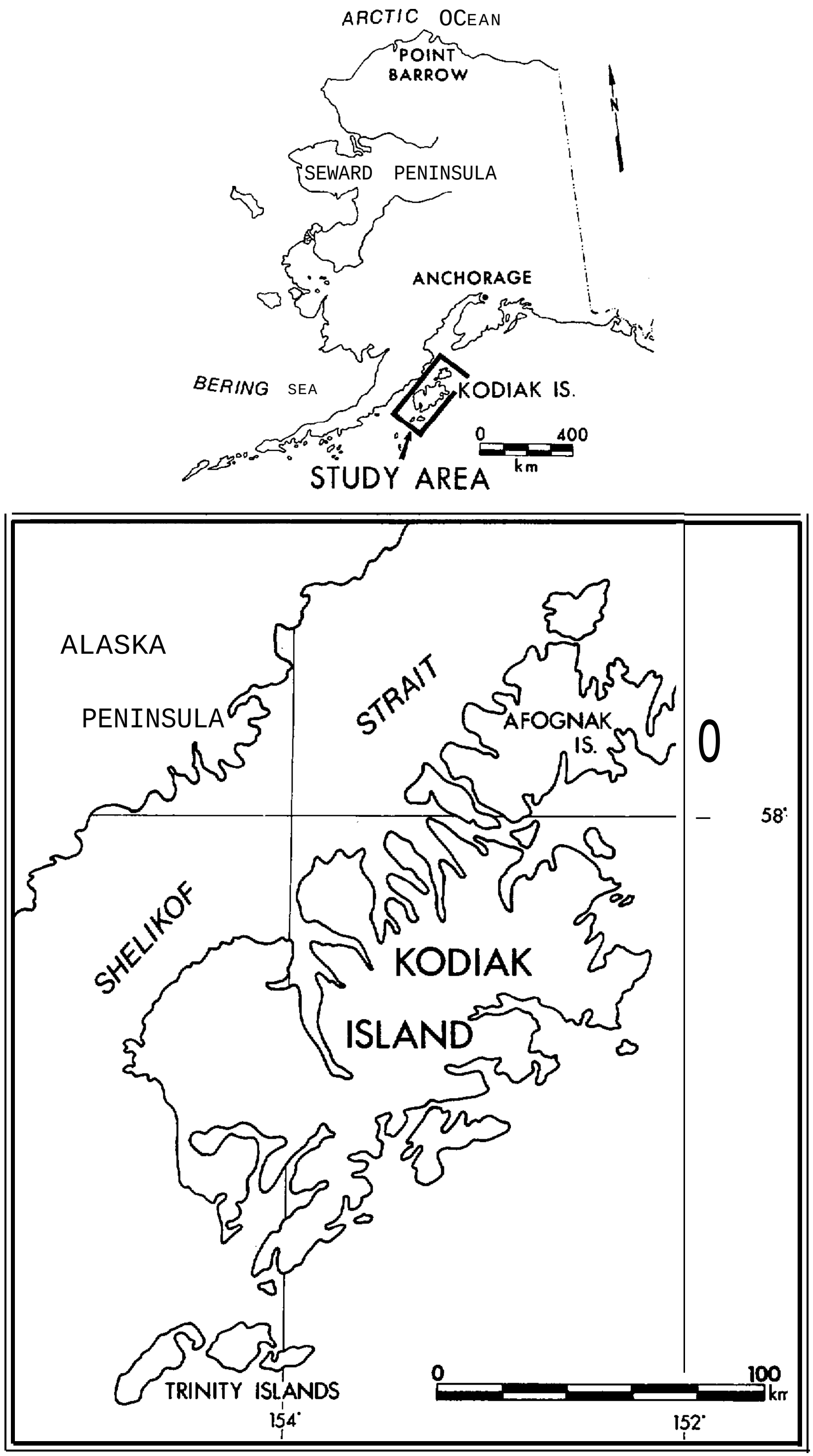

Figure 1. The study area includes all of the marine shoreline of Kodiak. Afognak and the Trinity Islands. It encompasses about 4300 shoreline kilometers (see Appendix 3 for breakdown).

The southeast side of the island is characterized by short wide estuary type embayments. The trend of most of these embayments is northeast-southwest running parallel with the major thrust faults on the island. They appear to be rift valleys or down dropped blocks formed when subduction complexes are thrust up over the existing rocks, (Fig. 2).

Afognak Island is somewhat similar to the southeast side of Kodiak. Smaller pocket beaches predominate where wave energy has eroded back into less resistant units of a wacke-shale interbedded subduction complex. The topography is less rugged than Kodiak and consists of hilly lowlands.

Drainage patterns on the islands tend to be short straight streams running northwest or southeast from a divide that trends northeast-southwest along the Kodiak Batholith. All the streams debouch into the heads of the fjords or small embayments. A few lakes occupy alpine valleys on the southwest side of the island. In addition, a few small ponds associated with drainage streams are found in the glacially scoured topography.

Island Arc System

The theory of plate tectonics has been able to explain a wide variety of large scale geographic forms on our planet. Southwestern Alaska is a dynamic area where plate tectonics plays a major role in the general formation of the physiography.

Using the geophysical classification of coasts in terms of plate tectonics (Inman & Nordstrom, 1971; Davies, 1973), Kodiak Alaska would be classified an island arc collision coast where relatively thin dense oceanic crust is being thrust under a less dense continental plate. A long linear subduction zone results and parallels an island arc system with andesitic island volcanoes. Major thrust fault systems trend parallel with the island arc system and exert a strong control on local morphology.

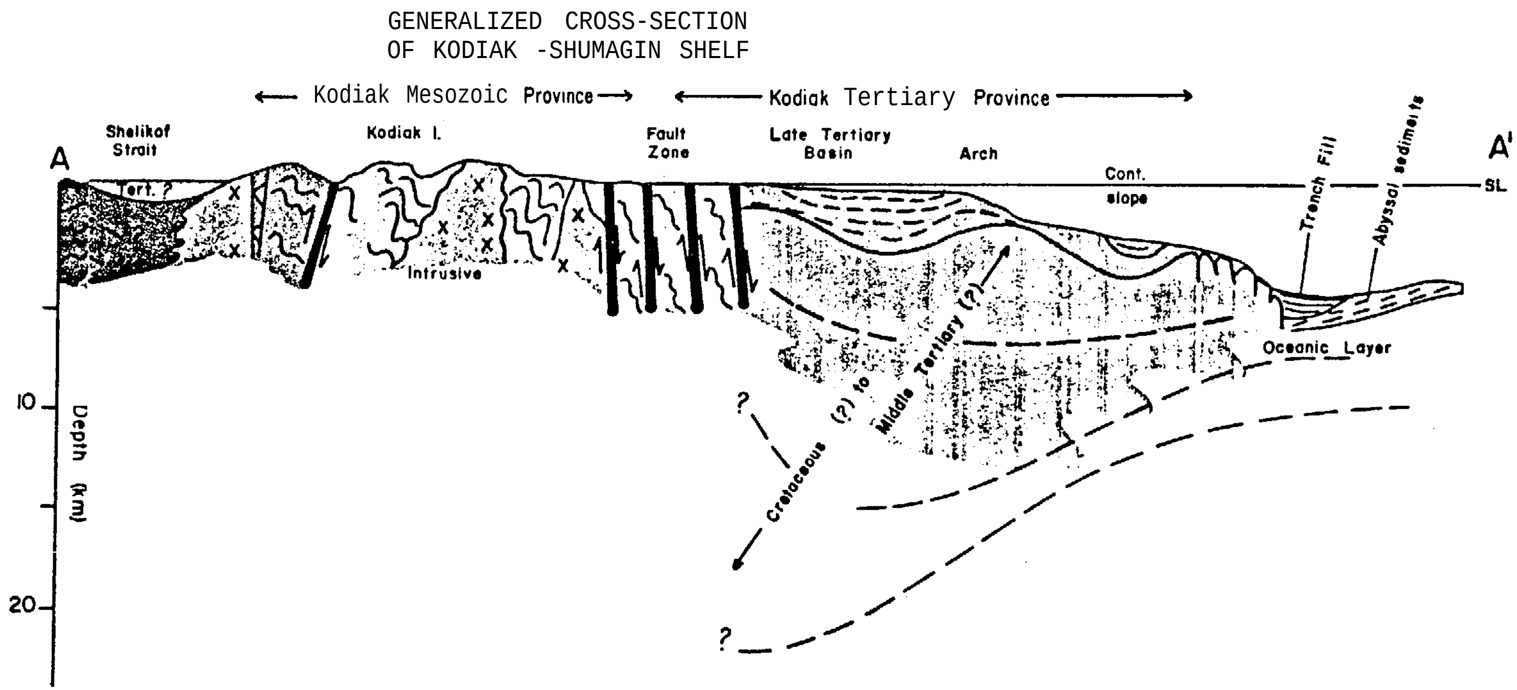

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Figure 2. Generalized Cross-Section of Kodiak Island taken from Alaska Regional Profiles: South Central Region (1974). See Figure 3 for Cross-Section A-A′.

Island arc systems are highly active tectonically and are by far the major loci of world seismic activity. Coastlines along island arcs are typically straight with high rugged cliffs and narrow continental shelves. Deep earthquakes centered around the trench are instrumental in causing catostrophic changes to coastal shorelines. Stanley (1968) described those changes created by the 1964 Good Friday Earthquake and illustrated the effects of submergence and uplife on coastal morphology. On the island of Kodiak, an axial line running south from Narrow Cape of Sitkalidak Island to the west of Sitkidak Island separates a zone of submergence from a zone of uplift. Submergence occurred to the northwest of the axial line. Increasing in a northerly direction, a maximum of 2 m of submergence occurred on the northeast corner of Kodiak. Uplift occurred to the southwest of the axial line with maximum uplift of 1 m occurring at Narrow Cape. Plafker and Kachadoorian (1966) described in detail other geologic effects created by the Good Friday Earthquake. In addition to vertical displacements, landslides and tidal waves created noticeable changes on the coastal shorelines on Kodiak.

Thus, today, 15 years after the earthquake, there are very numerous geomorphic indicators still present on the shorelines. Some of the indicators of downwarp are 1) wave cut notches into bedrock scarps backing narrow intertidal beaches of gravels and cobbles on a bedrock platform, 2) dead tree lines on narrow spits and along low scarps into bedrock or unconsolidated material, 3) washover fans of unconsolidated sediments backing highly vegetated spits and beach ridge pocket beaches, 4) bedrock platforms which are never exposed at low tide. Indicators of uplift are 1) highly vegetated storm berms, now above the "reach" of storms, 2) infilled lagoons, 3) cut off inlets, sometimes with lakes occupying abandoned lagoon channels, 4) elevated bedrock platforms, often with barnacle or mussel covered boulders above the normal tidal range, 5) dead and vegetated scarps sometimes found with beach ridges fronting them, 6) multiple swash lines of storm debris, 7) deeply incised river channels at delta mouths at the heads of fjords. These and many more indicators of the Good Friday Earthquake are found in the Kodiak Archipelago.

Kodiak has undergone tectonic change (primarily uplift) for millions of years. Thus we find on the island broad areas of wave-cut platforms sometimes over 300 m above the present sea level. Often times these areas will have a terraced or stair-stepped appearance, with each terrace indicating a relict stillstand of the island with respect to sea level. It is clear that tectonics plays a major role in the formation and modification of the island shorelines both in the long term geologic sense and on a much shorter historical time scale.

Today we find an island dominated by the tectonic uplift which pushed it out of the sea, and modified by periods of glaciation which are responsible for the second order features on the islands. The valley glaciers formed the fjords and sculped the mountains into their present form. They also left behind vast amounts of semiconsolidated and unconsolidated materials which play a major role in the formation of the beaches. Where glacial outwash or till is present backing the coast, these deposits act as a sediment supplier to the shoreline. The beaches tend to be wide and generally flatter than in sediment starved areas. Beach sediments range from sand to gravel and boulders generally, dependent on the original make-up of the glacial deposit and the wave energy at the beachface. The only other broad depositional beaches on the island are associated with the fjord head rivers and rivers draining glacial deposits. At the fjord heads, deltas dominated by tides are common. These areas are characterized by fan deltas of sand and fine gravel with highly developed bifurcating river channels and bars. Where rivers drain glacial deposits and empty onto the open coast, sand and gravel beaches occur downdrift. Sometimes, cuspate deltas and spits are developed. Thus, glaciation plays a very major role as a general modifier of regional topography and a sediment supplier to the rivers and shorelines.

The third order features of the island are those associated with marine modification. These features are the subject of this report.

GEOLOGIC SETTING

Kodiak and surrounding islands in the southwestern Gulf of Alaska constitute a Cretaceus subduction complex within a tectonically active plate margin. Located at the southern most margin of the continuous Kodiak-Kenai-Chugach mountain belt, Kodiak Island is composed of highly deformed and uplifted marine sediments and ultramafic rocks. The Uganik thrust marks the boundary between a younger belt of deep sea rocks seaward and an older belt landward showing the accretion that continues today within the Aleutian trench (Burk, 1965; Plafker, 1972; Connelly, 1978; Moore, 1978). Seven major lithologic units occur on Kodiak Island, (Fig. 3).

Lithologies

Shuyak Formation

The oldest rocks are found on the northwest side of Afognak and Shuyak Islands. Composed of pillowed greenstones and volcaniclastic turbidites, they form the upper Triassic Shuyak Formation (Connelly, 1978). The pillowed

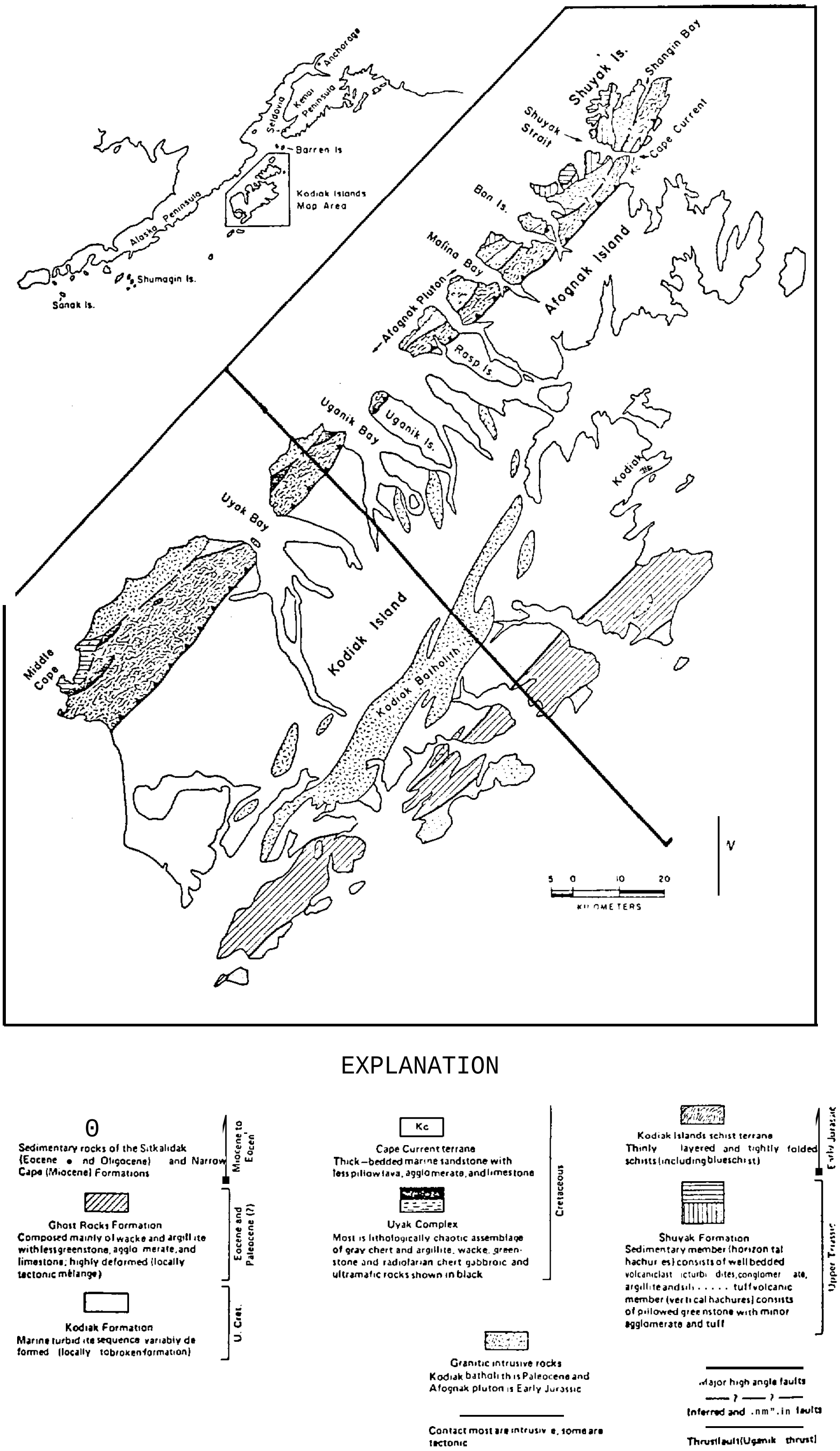


Figure 3. Generalized geologic map of Kodiak Islands; after Connelly and Moore (1977), Moore (1967), and Capps (1937).

greenstones have been interpreted by Jakes and Gill (1970) and by Connelly (1978) to be an island arc basalt formed at the early stages of volcanism. The upper sedimentary member consists of bedded turbidites with complete Bouma sequences indicating deposition by density currents at the seaward margin of the early arc basin (Connelly, 1978).

Kodiak Island Schist Terrane

To the southeast of and structurely beneath the Shuyak Formation lies the early Jurassic, Kodiak Island Schist Terrane. Consisting of quartz mica schists, greenschists, epidote schists and epidote amphibolites, the rocks are thinly layered and highly folded (Carden, et.al., 1977). Carden (1977) believes the schists were formed under extremely high pressures and temperatures as part of a subduction complex altered slightly to intensely by the intrusion of the Afognak pluton. The long narrow pluton is early Jurassic in age and is composed of foliated diorites and quartz diorites with abundant hornblende and little or no biotite (Connelly, 1978).

Uyak Complex

To the southeast of and structurally beneath the Kodiak Island Schist Terrance, the Uyak complex comes in contact along the Rasberry Fault (Moore, G.W., 1969). Connelly (1978) has modified the formerly Uyak formation to be called the Uyak Complex because of the complicated and disorderly assemblage of rocks within the unit. The complex is Cretaceus in age and consists mainly of gray and radiolarian cherts, wackes, greenstones and ultramafic rocks. A sedimentation model of this unit has been proposed by Connelly (1978) and described as being oceanic crust, subducted then uplifted.

The ultramafic rocks consist of gabbros, clinoproxinite, dunites and plagioclase peridotite. They constitute 6% of the unit. Hill (1975) has interpreted these rocks as being fragmented oceanic crusts, fractures at the subduction zone then uplifted with the overlying rocks.

Radiolarian cherts are found in small bedded tectonic blocks scattered throughout the unit. They are red in color, very homogeneous, and thinly bedded. The cherts amount to 2% of the unit, They have been interpreted as being a redeposition of radiolaria on the flanks of the mid-ocean rise by turbidity currents (Matthews, 1971; Nisbet & Pierce, 1974).

The gray cherts, thinly interbedded with deep sea sediments, account for 45% of the Uyak complex. Deposited above the radiolarian chert, they are believed to be the opalene skelital remains of microplankton deposited as deep sea sediments (Wise & Weaver, 1974). The gray chert along with the radiolarian cherts are fractured and have been uplifted with the oceanic crust at the subduction zone.

Massive units of wacke are found within the Uyak complex. Connelly theorized that the wackes were derived from an arc-derived adesitic source, mixed with recycled cherts and then deposited as a normal trench turbidite sequence. The entire Uyak sequence was then underthrusted and uplifted along the Uganik thrust fault by the Kodiak formation (Copps, 1937; Moore, G.W., 1969).

Kodiak Formation

The Kodiak Formation is the principle unit on Kodiak, underlying approximately 60% of the islands. It consists of arkosic wackes interbedded with shales and scattered pebbly conglomerates (Moore, G.W. , 1969). The rocks comprise a widespread turbidite sequence accreted at the continental margin (Clark, 1972; Moore, 1973; Budnick, 1974; Nelson & Bouma, 1977). The formation has been interpreted as a typical trench and deep sea sequence deposited during the late Cretaceus subduction (Plafker, 1972; Moore, 1973a; Moore, 1973b; Jones & Clark, 1973; Budnik, 1974).

Ghost Formation, Sitkalidak Formation & Narrow Cape Formation

Minor outcrops underlie the southeastern margin of Kodiak and make up the youngest rocks on the island, Predominately wackes and argillites they make up another subduction complex (Moore, G.W., 1969) that grades into younger sediments seaward of Kodiak. This gradation change indicates a continued accretion up to Holocene time (von Huene, 1972).

The rock type backing a section of shoreline can play a major role with regard to the shape of the beachface and the shape and quantity of sediments available to form beaches.

Highly bedded rock types like slates and shales can form a variety of scarp configurations, dependent on the dip of the bedding planes. Where bedding planes are nearly horizontal, the scarps will be very irregular and wave cut platforms will be quite flat and uniform. If the bedding planes are near vertical, the scarps will be uniform and wall-like, broken and displaced by fracture and fault patterns, while associated wave-cut platforms will be very irregular containing numerous tidal pools. Bedding planes dipping from near vertical to about 50 or 60° will often result in a dip-slope scarp. There scarps are flat and slope downward at the angle to dip of the bedding. Dips from 50° to about 20° will usually result in an irregular scarp and an irregular wave cut platform.

Bedded rock types yield platy fragments to the beachface. Thus gravels, cobbles and boulders will generally be flat regardless of their degree of rounding. Very well rounded gravels will look like discs and are referred to as discoidal gravels.

Unbedded rock species like quartz diorite have a more uniform strength and thus the shape of scarps and wave cut platforms becomes a function of fracture and fault patterns in the rock rather than their own internal structure. The scarps usually appear rather massive and rather steep. The wave cut platforms at their base are moderately uniform with undulatory surfaces and scattered tidal pools.

Gravels and boulders of this rock type will usually be equant in shape regardless of the degree of rounding. Well rounded gravels will be spherical.

The slate and quartz diorite are two end members of rock species control of scarp and platform shapes as well as gravel shapes. Most other rock types will fall, behaviorally, somewhere between them. Thus, scarps, platforms and beach sediment can take an extremely wide variety of shapes.

OCEANOGRAPHIC AND METEOROLOGIC SETTING

Tides

Mean tidal range, recorded in the Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska, Volume 1 (1977), is variable along the Kodiak and Afognak coastline. Diurnal range, or the average difference in height between mean higher high water and mean lower low water in feet on a single day ranges from 7.5 at Sitkinak Lagoon on the southwestern coastline of Kodiak Island to 13.7 at Redfox Bay located on northeast Afognak Island. The harbor at Kodiak has a diurnal range of 8.5 feet; while Larson Bay, a small fjord adjacent to Uyak Bay on the north side of Kodiak Island shows a tidal range of 13.7 feet. It is apparent from this data and field observation that tidal range increases from southwestern Kodiak Island to northeastern Afognak Island. Tidal range further increases in a northeasterly direction into Cook Inlet where funneling of the tidal wave contributes to an amplification of the tidal range. Seldovia on the Kenai Peninsula exhibits a tidal range of 17.8 feet while Anchorage in upper Cook Inlet has 29.0 foot diurnal range (Fig. 1).

Kodiak Island has a large number of fjords, especially along the northern shoreline. There fjords formed during the Pleistocene by valley glaciers over-deepening and widening pre-existing river valleys. Usually, fjords have well developed terminal moraines which lie submerged at the fjord mouth (Dyer, 1973). However, the fjords on Kodiak are generally unrestricted, the moraine deposits are either absent or lie submerged deep enough to permit easy passage of the tidal waves. In general, there is a free exchange of water with the seas. The funnel shape of the fjords along with their lack of restriction to flow provides an amplification of the tidal range. Thus, Larson Bay shows the 13.7 foot tidal range which is unusually large for that section of Kodiak Island. Many of the fjord heads contain well developed delta-marsh systems which appear to be tide dominated.

Meteorology

Weather conditions in the Kodiak Archipelago are regulated by the maritime environment of the southwestern Gulf of Alaska. Winter temperatures range between 26° and 45°F. Precipitation is heavy with 47″ of rain and 71″ of snow annually, buy varies locally. Considerably more precipitation occurs on the eastern side of the island.

Wind and wave data taken from the Survey of Synoptic Meteorological Observations (1970) and the Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska, Volume 1 (1977) indicate a prevailing and predominant northwesterly and westerly wind frequency, wind velocity, and associated wave energy flux (Fig. 4). The average wind direction is from the northwest at five knots. A counterclockwise flow associated with low pressure cells in the Gulf of Alaska during winter storms causes this prevailing and predominant wind and wave setup for Kodiak Island. During the summer months the major storm track is to the west of Kodiak Island, hence strong and frequent easterly winds are common. During January, 53% of the winds arrive from the west and northwest. During July, 38% of the wind is from the east and northeast, while only 25% is from the northwest and west. Thus wind velocities and directions and associated wave height and approach directions vary on a seasonal basis.

Kodiak Island weather observations show wind speeds greater than 22 knots 32% of the time in January as compared to 10% during July. 15% of the measured waves approaching Kodiak and Afognak Island during January are greater than 4 meters; while only 2% of the July waves are greater than 4 meters. Wave period is longer during January with 23% of the waves 7 seconds or longer. July waves are much shorter with only 6% greater than 7 seconds. These figures demonstrate a definite winter storm condition.

Oceanography

Ocean bathymetry rapidly deepens off the coastline within both the Gulf of Alaska the Shelikof Strait and the Island's numerous fjords and estuaries. Depths of 120 to 300 m are common within one kilometer of the shoreline. There is tremendous variability in relative wave energy from one area in the Kodiak Archipelago

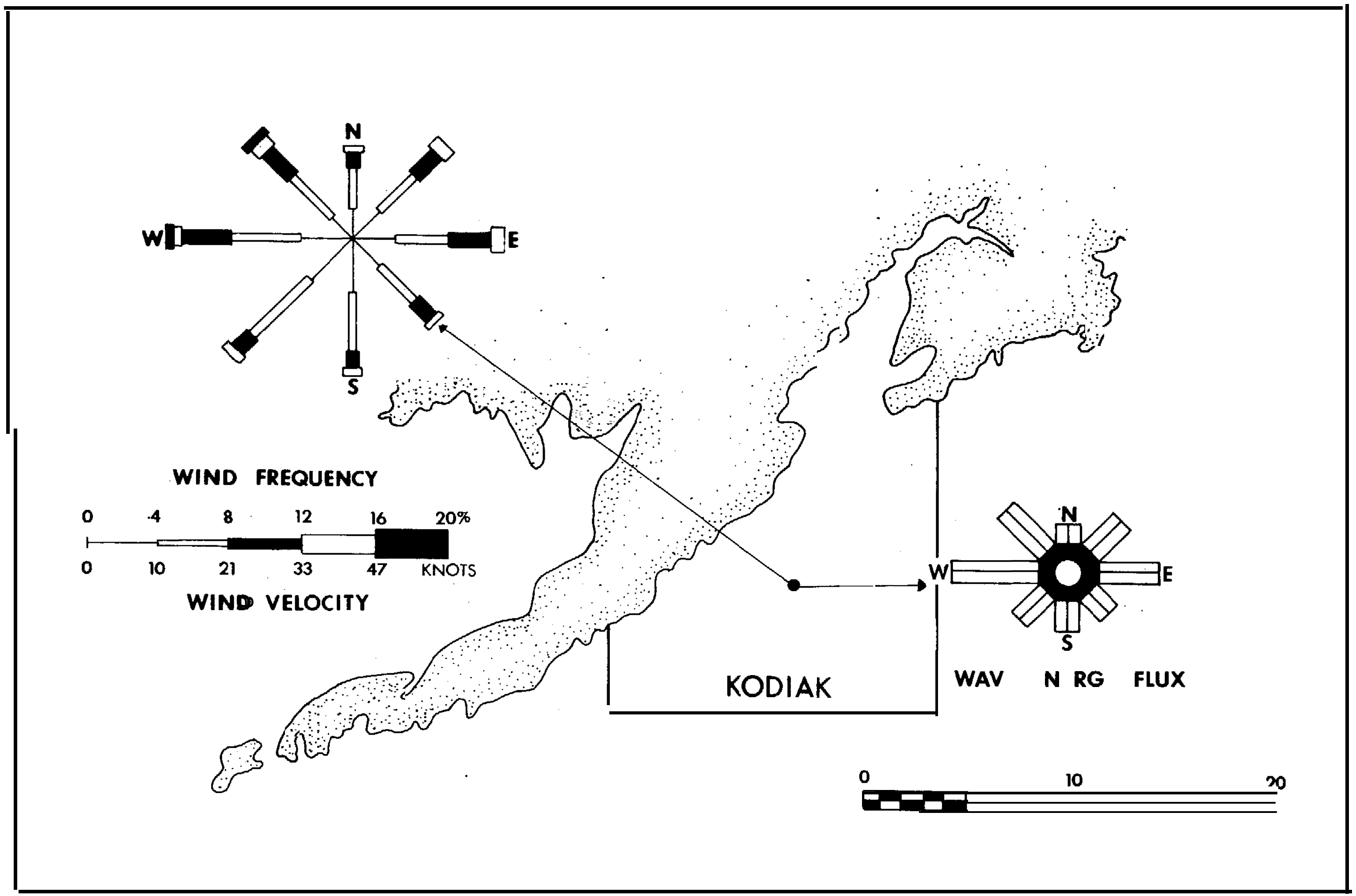


Figure 4. Wind and wave data taken from the Survey of Synoptic Meteorological Observations (1970). Note the predominance of the westerly and northwesterly wind and resultant wave energy flux.

to another. This is due to the variable fetch distance as well as the orientation of the shoreline with respect to incoming waves. As seen in Figure 4, predominant wind and resultant wave energy flux is from the northwest. However, the Shelikof Strait, which abuts the western side of Kodiak, is only 60 km wide. The narrowness of the Strait limits the maximum wave size which can be generated by a given wind velocity. For example, a 40 kt. wind blowing for two days across the Strait, will generate a maximum wave of 7 second period and 10 ft. height. If the same wind blows for two days across a 1000 mile wide section of the Gulf of Alaska, it will generate a wave of 12 second period and 30 ft. wave height, (Coastal Engineering Research Center, Shore Protection Manual, Vol. I). Thus, it is apparent that even though higher overall wind velocities are greater from the west, larger waves can be generated from the east due to the much greater fetch distance. By far the largest waves occur along the shorelines on the eastern side of the islands.

Many of the fjords tend to generate local wind systems, especially near their heads. They are usually backed by relatively high mountains which can generate catabatic winds which blow down slope toward the mouth of the fjord. In some of the inner parts of fjords, midbay spits and cuspate spits indicate transport out of the bays as a result of there wind systems. In general, there is a uniform decrease in wave energy as the fjord heads are approached. The fjords have wave energies only a fraction as large as the wave energies on either the exposed east or western shorelines. The exposed shorelines usually have well developed high storm berms indicative of frequent large storms where as the more protected fjords have much lower generally vegetated storm berms, indicative of milder very infrequent storms. The heads of the fjords as well as the very numerous protected areas on Afognak Island have exceptionally low wave energy.

SEDIMENTOLOGY

Tectonic activity has had a profound effect on the sedimentology and coastal geomorphology of Kodiak and Afognak Islands. Most of both islands show evidence of downwarping such as erosional scarps, washovers and drowned forests. Although the shoreline of the study area is predominantly erosional, depositional features such as tombolos, spits, beach ridge plains, mid bay bars and crenulate bays do occur. Salt marshes and tidal flats are found rarely, usually at the fjord heads. The absence of these features is related to the generally steep nearshore topographic slope and a lack of fine grained sediments (silts and clays). There is also considerable evidence of uplift in the form of raised beaches, vegetated storm berms, wave cut platforms well above sea level and incised river channels. Uplift features are especially evident along the southern and southeastern shoreline of the islands.

The last glaciation during the Pleistocene has played a major role in shaping both the coastal geomorphology and the sedimentology of Kodiak beaches. Beaches within much of the western half of Kodiak Island, northern coast of Afognak Island, and the Trinity Islands are backed by scarps into glacial till. A coarse-grained beach material with a complex composition is supplied by the glacial deposits. The eastern beaches of Kodiak Island and most of Afognak Island are backed by more homogeneous bedrock outcrops. Composition of beach sediment within these areas is highly homogeneous and very coarse grained due to the supply by local bedrock. The shape of the western beach cobbles and pebbles is mostly bladed to equant with very good rounding. Their well rounded character is the result of both the glacial abrasion and later reworking by marine processes. They are more mature than gravels and cobbles fronting bedrock scarps. Gravel composition of schist and slate on the central and eastern shorelines results in a bladed to disc shape with fair to good rounding.

Most of the beaches along the coastline of both islands are very coarse grained ranging from cobbles and gravel to granules and coarse sand. A predominance of sandy beaches appear on the western coast of Kodiak Island and within the Trinity Islands due to an abundance of unconsolidated glacial material with a high percentage of sand. Thus on Tugidak Island, a till and outwash sediment source and a shallow shelf has resulted in the development of a very long recurved spit complex.

Overall mean grain size (see Appendix 1 for Kodiak and Afognak Island beach samples) generally ranges between 0.0ø (very coarse sand) and -3.5ø (pebbles). With a mix of large grain sizes and sand, sorting is relatively poor. Standard deviations of 2ø or greater are common. The very coarse material is supplied by glacial deposits as well as bedrock scarps and this results in the poor sorting of the sediments.

Beach material in southwest Kodiak Island and the nearby Trinity Islands is relatively fine. Tugidak Island, the wester.nmost Trinity Island is composed of 2.2ø fine sand to -0.2ø very coarse sand. Again, this grain size is a function of the size of the material supplied by the glacial deposits. The more distal glacial deposits (outwashes) are finer grained and more uniform than the proximal deposits (moraines and tills) and thus yield a finer grained beach material.

The beaches within the fjords are quite variable, but tend to be quite coarse due to their local bedrock sediment sources. However, at the fiord heads. rivers often introduce a fine sediment suite ranging from clays to granules. Sand size at the head of Terror Bay is 1.37ø.

Long term transport directions can sometimes be determined by a close analysis of grain size. In general, there is an expected fining trend away from sediment source in the direction of dominant transport. However, Kodiak Island shorelines are so complex and the sediment sources are so variable that no clear trends have been noted in this study. Grain size and sorting is primarily a function of the local geology and wave energy. Transport directions were determined by analysis of local coastal morphologic features such as spits, crenulate beaches, cuspate forelands, tombolos, ridge and runnel systems and natural grain development. As a very general rule, there is a dominance of southerly transport along the southwestern side of Kodiak Island. Other than that area, transport direction is a function of shoreline orientation into prevailing wave approach direction and thus is highly variable over most of the island.

In general, the extreme complexity of the Kodiak Archipelogo results in very complex and variable sedimentological characteristics which change rapidly from one shoreline section to another. Grain size, sorting and composition cannot be used as process indicators as on straight more homogeneous shorelines. Only local conditions determine the sediment character and behavior.

COASTAL MORPHOLOGY

The Kodiak Archipelago is an extremely diverse area. Almost any type of coastal environment can be found somewhere on the islands. High winds and waves have interacted with the rugged tectonically active geography to produce an incredibly beautiful and complex coastal morphology.

In general, the islands are erosional. High and low rock scarps and scarps into glacial material occur over much of the shoreline. Of the 4270 km of shoreline classified in this study, 1084.2 km or 25.3% falls into the categories of shear exposed rock scarps or exposed rock scarps with wave cut platforms (see Appendix; Coastal Classification and Oil Spill Vulnerability). In addition to the exposed rock scarps, there are 1462 km of protected rocky headlands representing 34.2% of the total study area. Further, many of the beaches which fall into the sand and gravel class (942 km or 22.1%) and the pure gravel class (634 km or 14.9%) are, in reality, erosional beaches cut into bedrock or semiconsolidated tills and covered by thin sediment accumulations. Thus, the upper limit on actively eroding shorelines is 4122 km or 96.5% of the total shoreline. This is an upper limit only. Some of the gravel and sand and pure gravel beaches are depositional in nature; perhaps as much as 20 or 30%, This reduces the total erosional beaches by 10% (down to approximately 86%).

Of the depositional shorelines, there are 60 km of sheltered tidal flats and 50 km of marshes. Together these two classes represent only 2.6% of the total shoreline. They are found most commonly at the fjord heads and major river mouths. An additional 40 km of shoreline falls into the classes of fine sand beaches, medium to coarse sand beaches and exposed tidal flats. These areas, representing only 0.9% of the total study area are also depositional in nature. Thus, given that 30% of the gravel and sand and pure gravel beaches are depositional, the study area has only 14% depositional shoreline. For details pertaining to the actual shoreline kilometers and percents of each coastal type see Table 1 and the Appendix.

Figures 5 through 12 show some of the typical coastal types in the Kodiak area. They range from highly erosional to highly depositional. Following this section, is a more detailed analysis of specific study sites visited during the summer of 1978.

TABLE 1
COASTAL CLASSIFICATION
KODIAK ARCHIPELAGO

Class Description	Shoreline Kilometers	% Total Study Area
1. Straight Rocky Headlands	376.6	8.8
2. Eroding Wave-cut Platforms	706.6	16.5
3. Flat, Fine-grained Sandy Beaches	30.0	0.7
4. Steeper, Medium-to-Coarse Grained Sandy Beaches	5.4	0.1
5. Impermeable Exposed Tidal Flats	3.2	0.1
6. Mixed Sand and Gravel Beaches	942.4	22.1
7. Pure Gravel Beaches	634.2	14.9
8. Sheltered Rocky Headlands	1462.0	34.2
9. Protected Estuarine Tidal Flats	60.1	1.4
10. Protected Estuarine Salt Marshes	49.7	1.2
	4270.2	100.0

NOTE : In general, classes 1 and 2 are highly erosional in nature. Classes 5, 9 and 10 are depositional. Classes 3, 4, 6, 7 and 8 can be either erosional or depositional but in this area they tend to be more erosional.

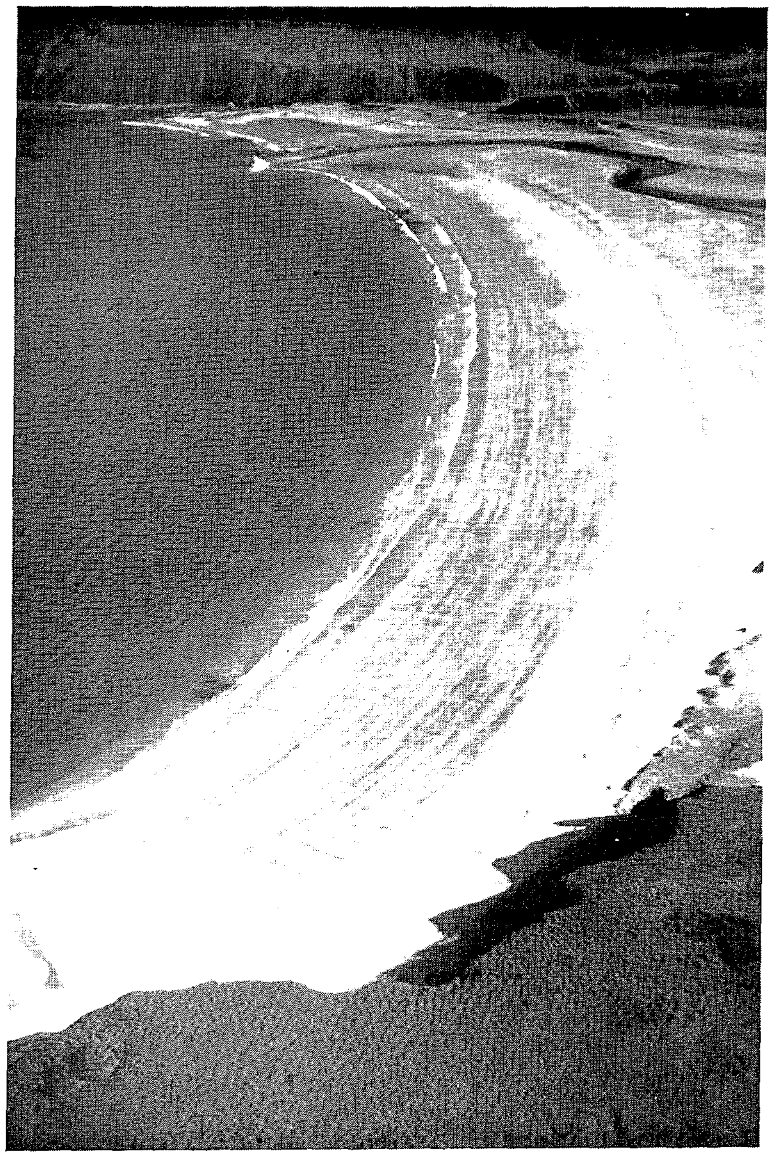


Figure 5. Typical sandy pocket beach. This coastal class is very rare in the Kodiak area due to a very low sand supply. This particular beach has a ready sand supply from the river backing the shoreline. The protected nature of this pocket beach is ideal for the deposition of sand. In general, these sandy beaches do not permit deep penetration of oil and will clean by natural processes rather rapidly. They are a very low #3 on the Oil Spill Vulnerability Index.

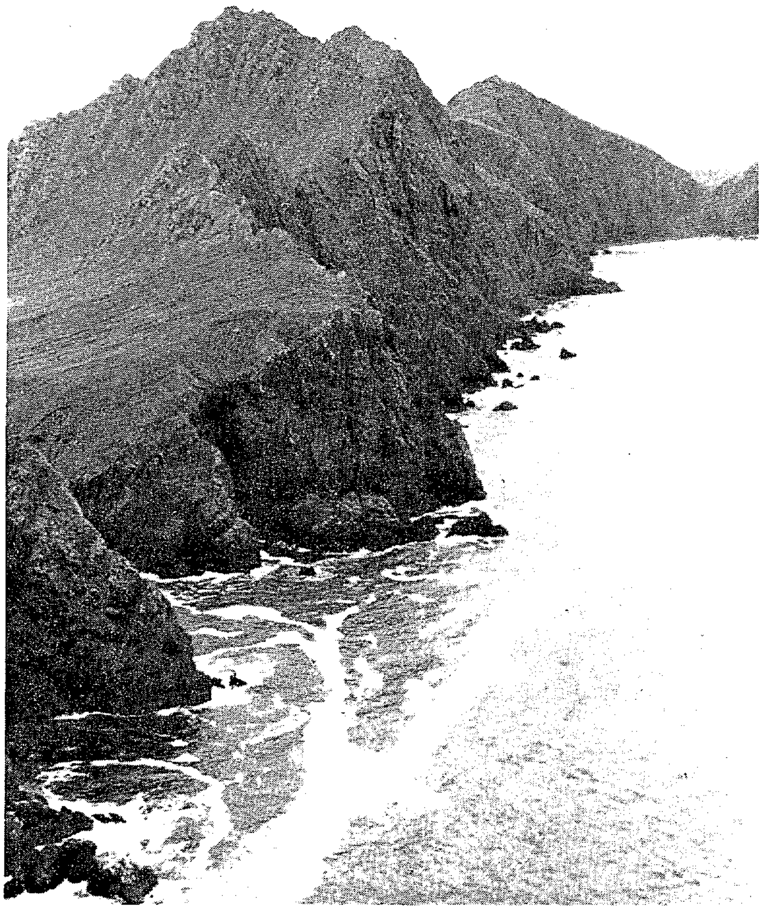


Figure 6. A typical high bedrock headland exposed to direct wave attach even at low tide. These areas, in this case on the western side of Kodiak Island, are exposed to very high wave energy and will clean themselves, in the event of an oil spill, within a few weeks. Further, the waves reflect off of the scarps and generate a return flow of water which tends to keep floating oil away from the rocks (note white foam line). These areas will fall into the #1 class of the Oil Spill Vulnerability Index, the lowest class.

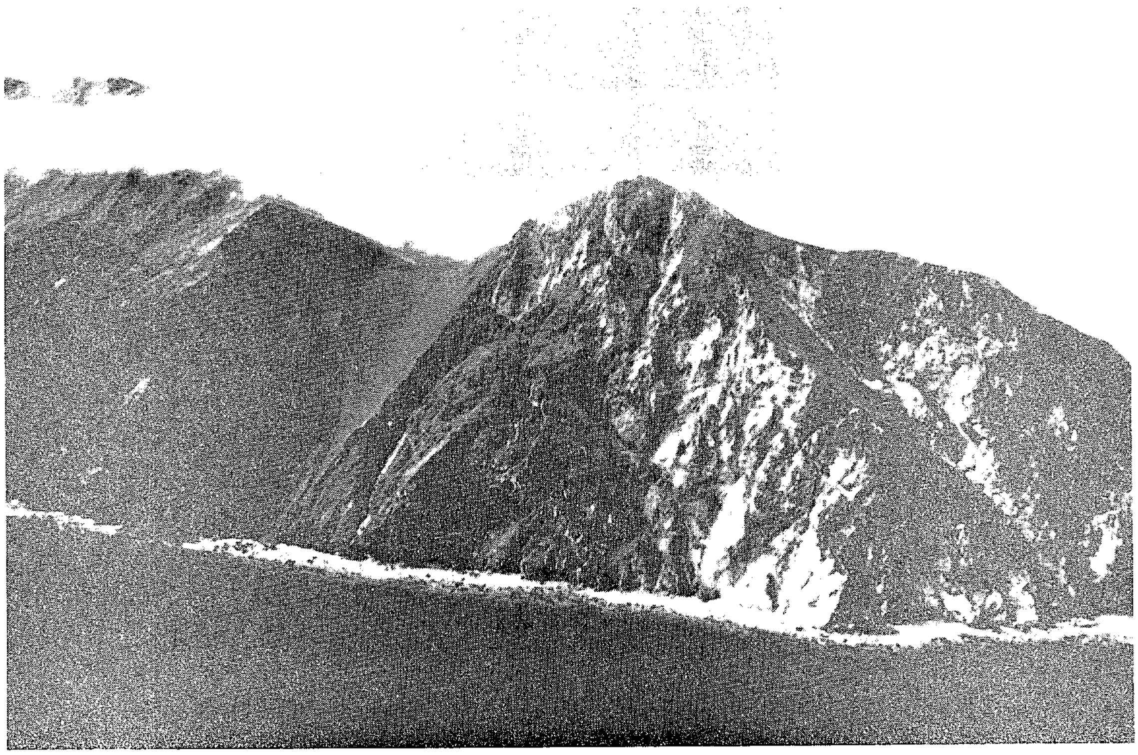


Figure 7. This shows another type of bedrock headland. In this case a very poorly sorted boulder and gravel beach is developed at the base of the scarp. At high tide, waves break directly out the face of the scarp, but at low tide, the beach is exposed. Thus , the area becomes more vulnerable to oil spills at low tide. Usually these areas have very high wave energy and are thus generally classed #1, however, if the beach is broad enough to remain exposed at high tide, they are classified as #7 on the Oil Spill Vulnerability Index (pure gravel beaches).

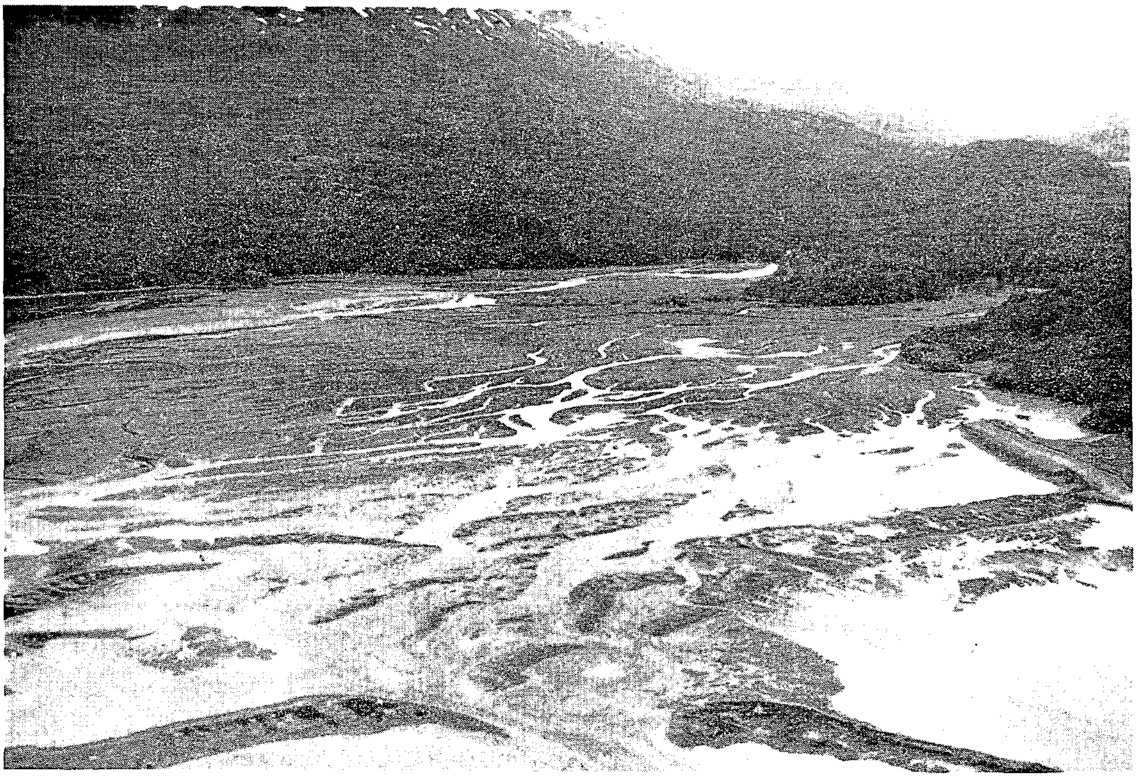


Figure 8. A typical fjord head system. Most of the fjords have rivers which drain into their heads. Usually this results in a delta-tidal flat complex. The fjords tend to amplify the normal tides, thus the fjord heads display many macrotidal characteristics. In this figure we see a typical braided stream river delta of sands and gravels fronted by large swash and tidal bars of coarse sand and granules, covered with mussels. These areas are generally backed by a narrow marsh system and fall into the two most vulnerable classes on OSVI, #9 (protected estuarine tidal flat) and #10 (protected estuarine marsh).

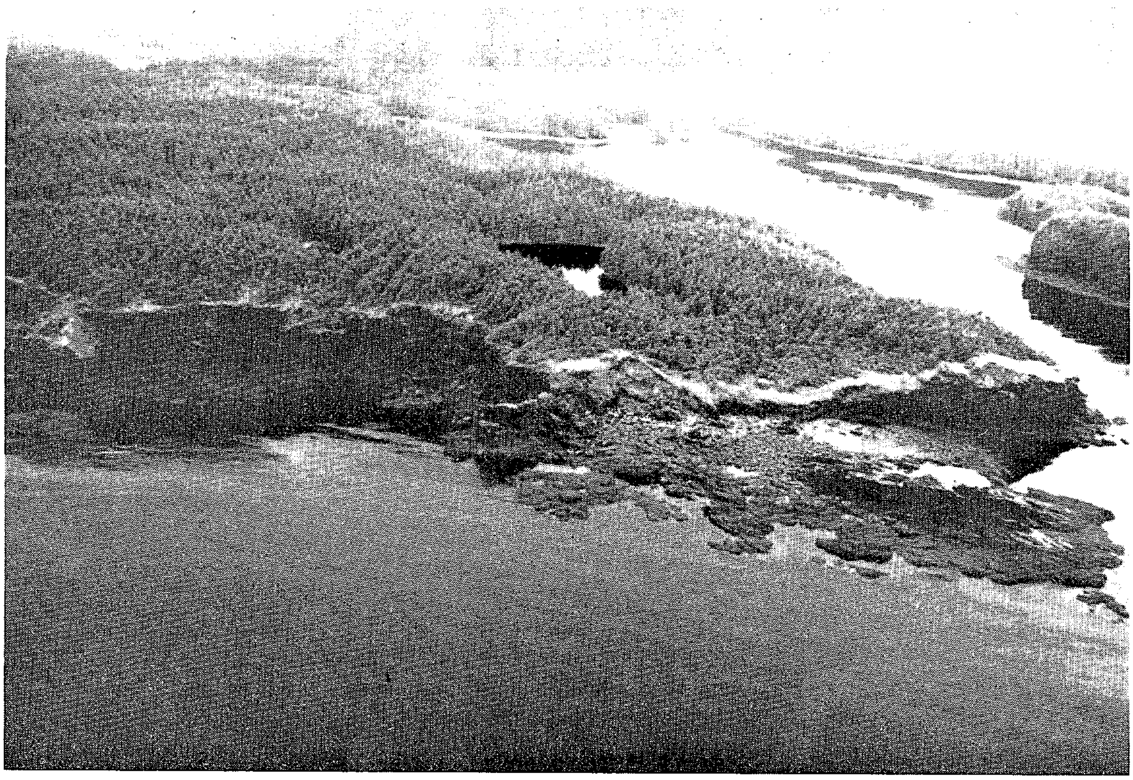


Figure 9. This area, located on the northern Afognak shoreline, shows a typical low energy low irregular rock scarp. These areas are usually classified as #8 on the OSVI. Very abundant intertidal life covers the intertidal and subtidal rocks. The low wave energy results in heavy oil coating in the event of an oil spill. It also results in very slow natural cleaning. More than 40% of Afognak Island is of this highly vulnerable class.

Figure 10. This is a ground level photograph of an area classed #8 (protected rock headlands). The headlands are associated with very numerous poorly sorted gravel accumulations perched on bedrock. Intertidal life is extremely abundant and wave energy is very low. Oil introduced into these areas will do great damage and remain for long periods. These systems will tend to hold floating oil, once is has been introduced.

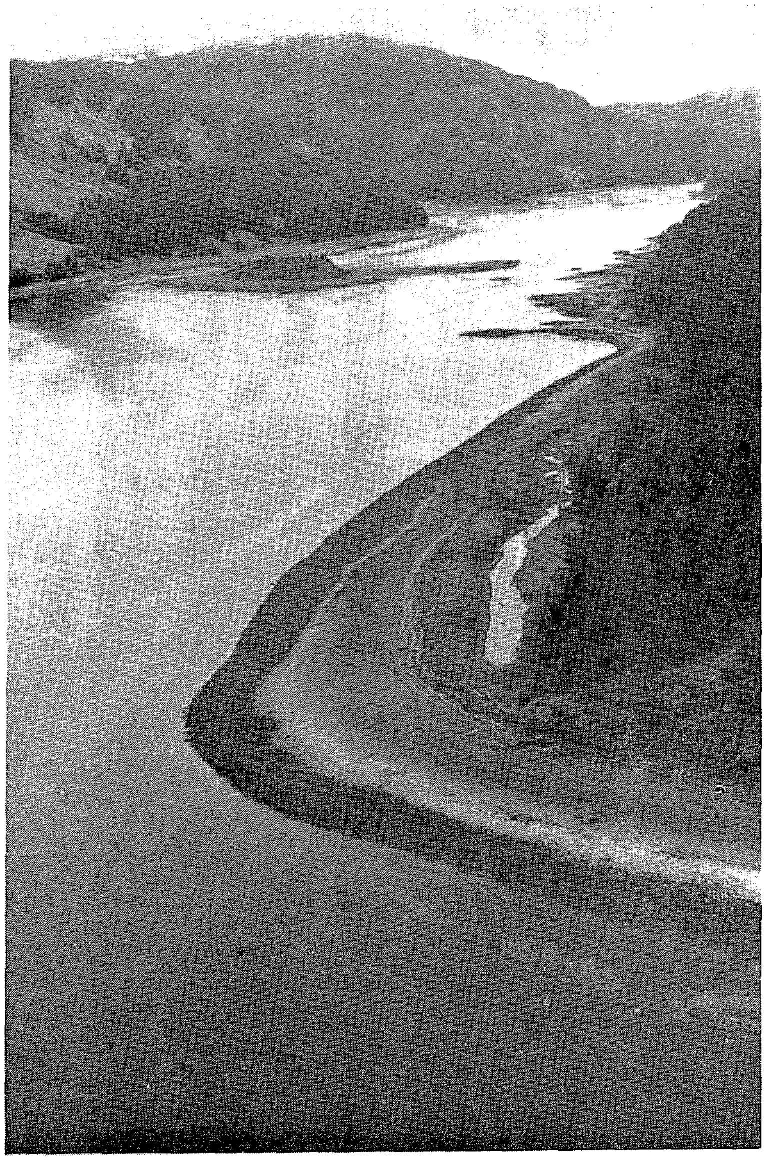


Figure 11. This shows a characteristic moderate energy pure gravel beach. In the background there are two gravel spits indicating transport into the fjord. The beach in the foreground shows a number of features. At the base of the beach face there is a dark boulder-cobble low tide terrace which appears darker due to heavy algal coating on the rocks (this indicates that the wave energy is not high enough to move the coarse sediment on the L.T.T. The middle beach face is mostly coarse gravel (clean). Above that, there are storm swash lines of logs and debris, backed by a storm berm and scarp. This is a very typical pure gravel beach. OSVI = 7. These areas permit deep penetration of spilled oil.

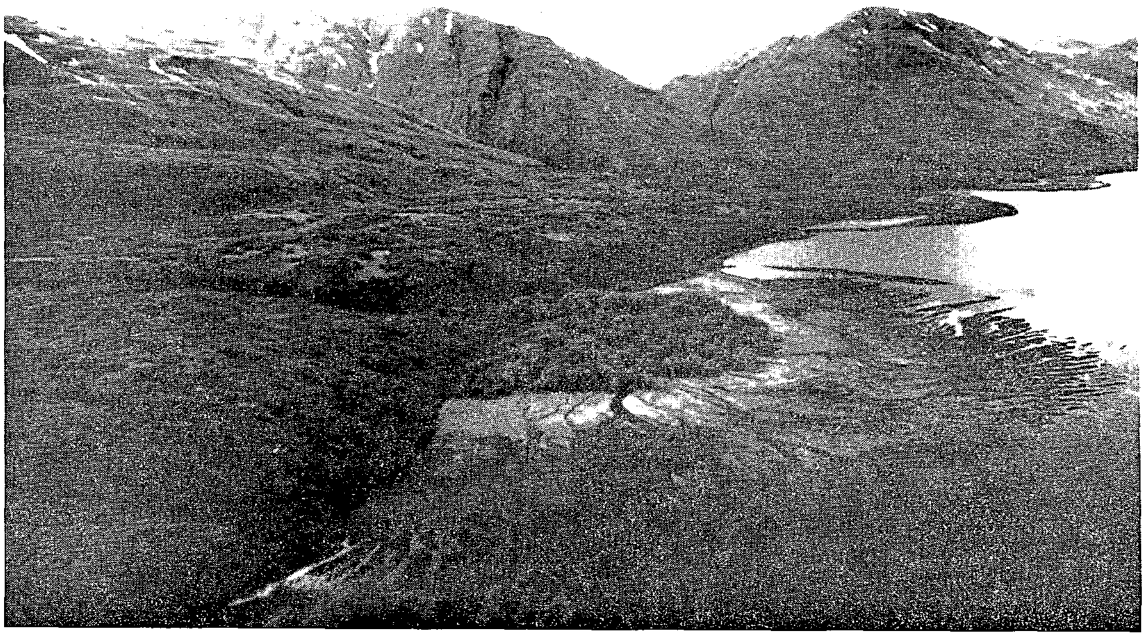


Figure 12. Well developed fan delta in the inner portion of Uyak Bay. Note two fan deltas in background. This delta displays a prominant zonation. At the outer funge of the delta are wave and tidal bars of fine gravel and sand with a heavy coating of mussels. Landward of that zone is a sandy flat usually with considerable infauna. At the top of the intertidal zone is a marsh which is backed by a low fresh water brushy vegetation. These areas, because of their sensitive marsh zones, are very vulnerable to oil spills, however they represent less than 1/10% of the shoreline.

Profile Site Analysis

This section describes, in a more detailed format, a variety of the shoreline types studied on Kodiak and Afognak Islands. During the summer of 1978, 127 stations were established. The even numbered stations consisted of the following:

1. Detailed taped description of beach morphology, back beach morphology, oil spill vulnerability, sediment characteristics, wave and tidal energy, and general biotic abundance.
2. Aerial photographs.
3. Ground photographs.
4. Description of rock type in scarps, and sediment composition on beach face.

The odd numbered stations consisted of all of the above plus:

1. A detailed line transit (profile) of the active beach face and any relevant back beach morphology.
2. Sediment samples taken from the upper, mid and lower beach face as well as any dunes or other interesting depositional features.
3. A sketch of the entire profile and surrounding area.
4. Measures of wave height and approach direction.
5. Temperature, wind speed and direction, general weather.

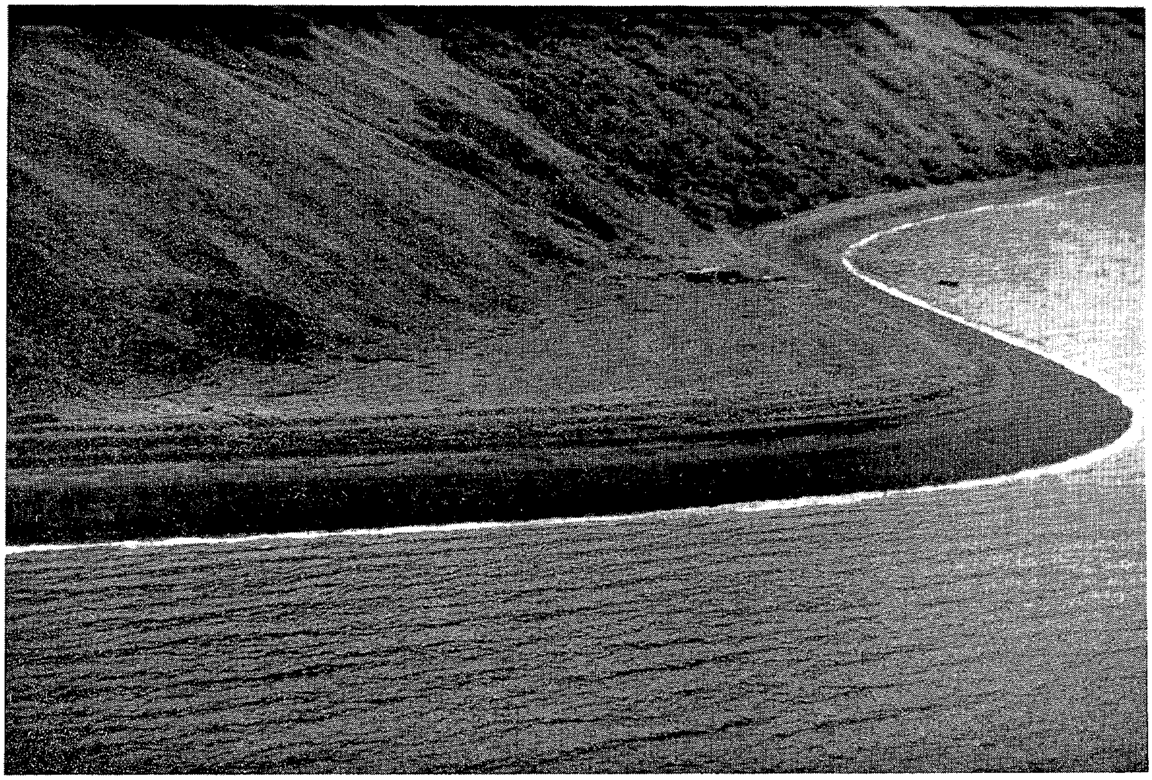
Later, coastal flights were made to fill in the shoreline between stations and to get a good overall picture of the study area. The Oil Spill Vulnerability Index is applied at that time.

Finally, laboratory analysis is conducted as follows:

1. All profiles are reduced to digital form and run on to computer tape. The tape is then used to plot the profiles (at a 1:5 vertical exaggeration) and then sent to the National Ocean Data Center.
2. All sediment samples are split, washed and either analyzed using seives and a ro–tap machine, or sent down a settling tube. In either case, the data is reduced to digital form and run and plotted by computer. Magnetic tapes are then sent to the NODC.
3. All taped descriptions are transcribed.

The Appendix of this report contains a section labeled "Profile Sites". This section gives the details of each of the odd numbered stations. Each station is located both by longitude and latitude and by geographic position. The station is then described as to wave energy, sediment type, beach morphology, storm activity etc. Below that the general wave and tidal energy is characterized as well as the rock type of scarps and beach sediments. Finally the sediment samples which were taken are described. For further information regarding sediment samples, see the Appendix (Grain Size Analysis).

Figures 13 through 23 follow. Each figure describes a particular profile site, with photos, a beach sketch and a caption. These 11 figures will demonstrate some of the variability of coastal morphology found in the Kodiak Archipelago. They are not in any particular order and should not be viewed as representative of any percentage of shoreline in the study area.



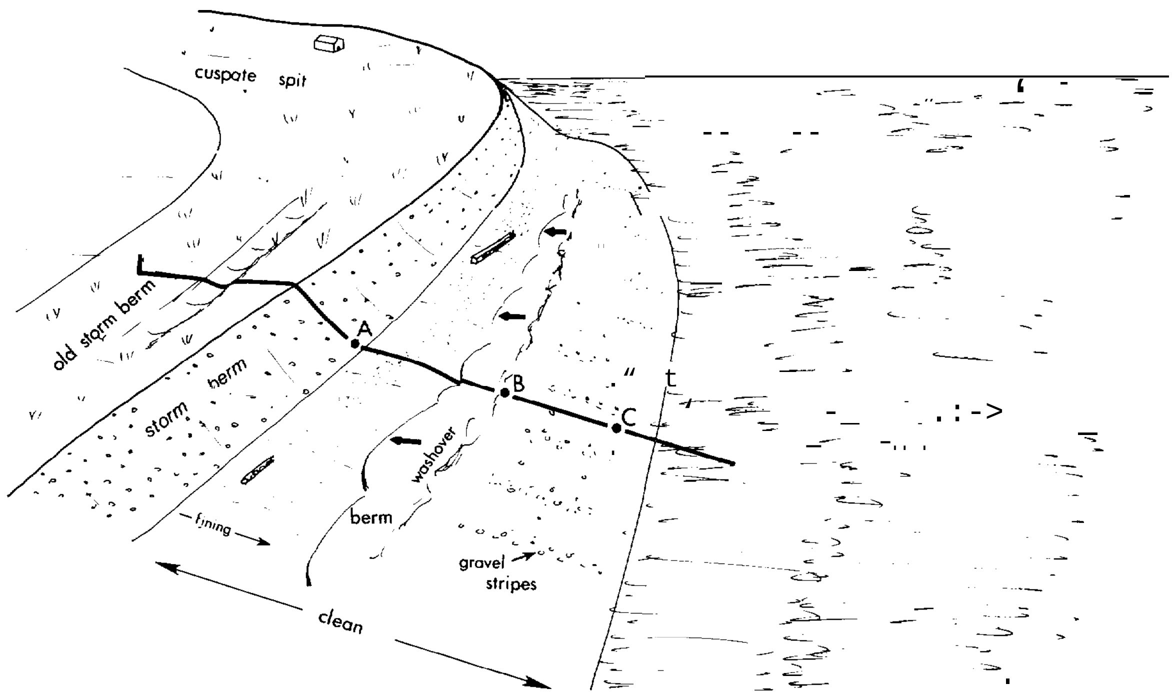
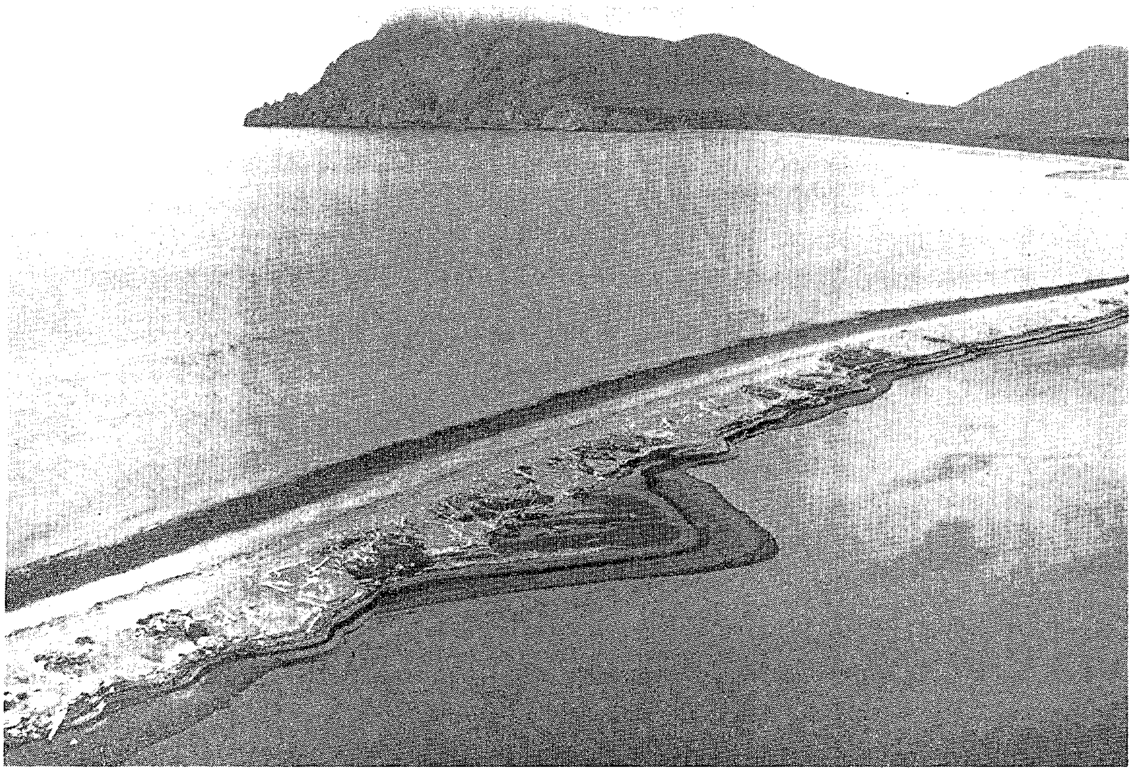


Figure 13. Profile site KDP-73 located in Dead Man Bay. The profile is set on the more exposed southern side of a very well developed cuspate spit composed mostly of gravel and granules. The aerial photo shows the multiple vegetated storm berms at the top of the beach face. These either indicate uplift or very infrequent storms, or both. The beach face has a uniform convex upward shape and a strong fining trend toward the water line. Thus the top of the beach face is composed of coarse discoidal gravel while the base of the beach face has finer, more equant gravel. There are prominant gravel stripes on the lower 1/3 of the beach face, evident in the ground photo as well as the sketch. Wave energy is moderate with occasional high storm waves. The letters A, B and C on the sketch refer to sediment sample locations.



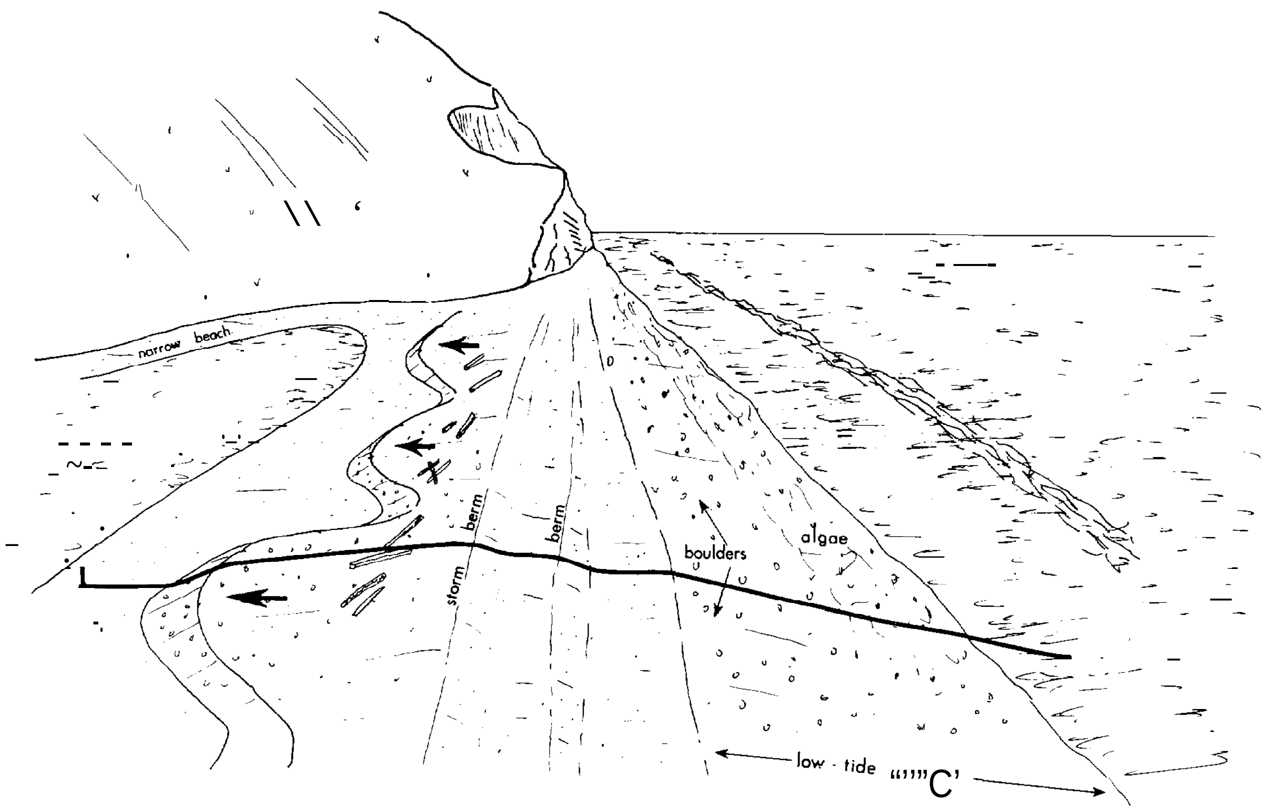
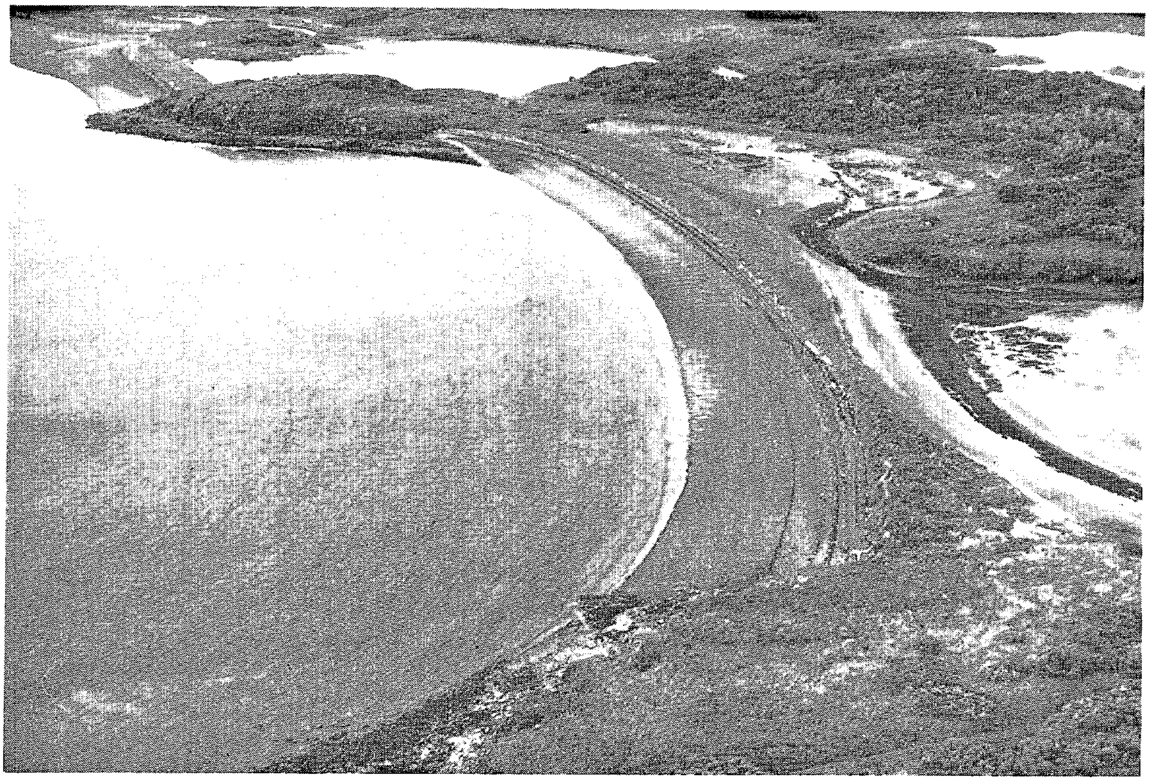
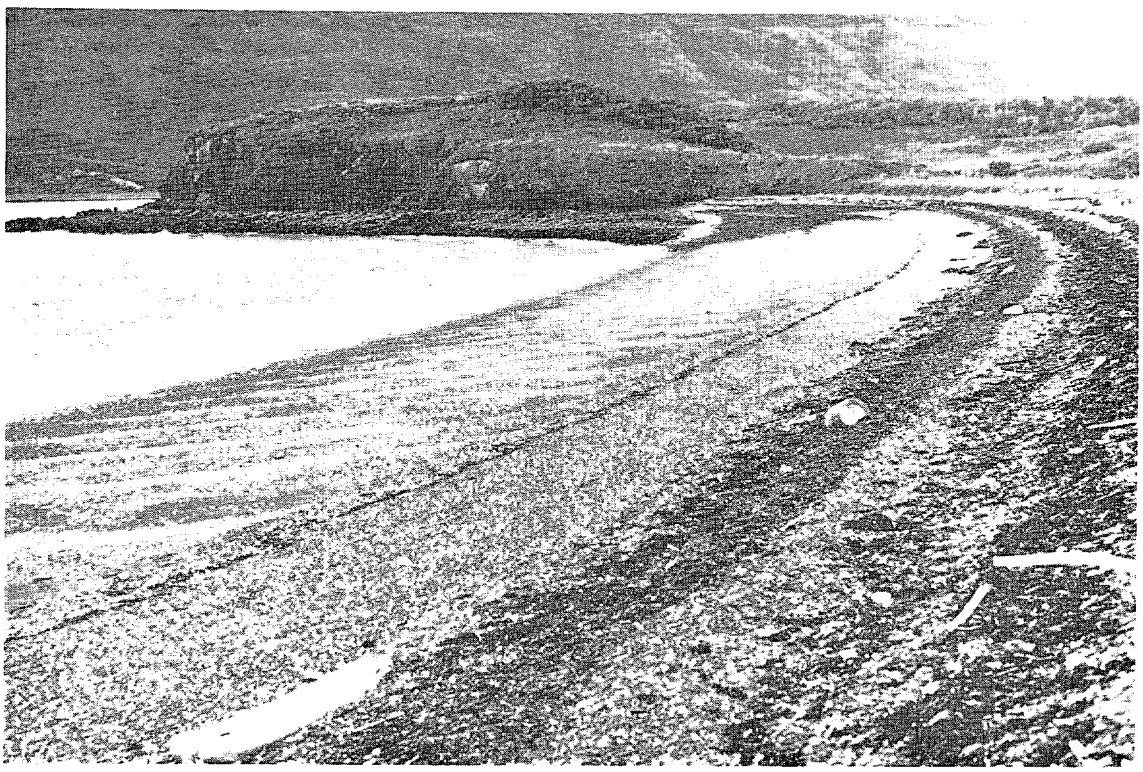


Figure 14. Profile site KDP-63 located on the spit fronting the Sturgeon River. This is one of the best examples of a very coarse grained transgressive washover profile in the study area. This narrow spit is composed of almost pure coarse gravel and cobbles and boulders. The aerial photograph shows a dark band across the base of the beach face. That band is an algal coating covering the boulder-cobble low tide terrace, illustrated in the ground photo. The beach face is narrow, clean, and composed of gravel. There are two berms up high and then a well developed washover terrace, active only during violent storms. The scalloped nature of the washover terrace is especially evident in the aerial photo and sketch. The coarse gravel is transported over the top of the spit and then deposited on the accreting face of the washover (lagoon side) by high velocity sheet flow caused by large breaking waves. Thus the spit migrates landward. The lagoon side beach has a narrow flat low tide terrace at the base of the washover slip face. This type of beach will hold oil for long periods due to its great porosity.





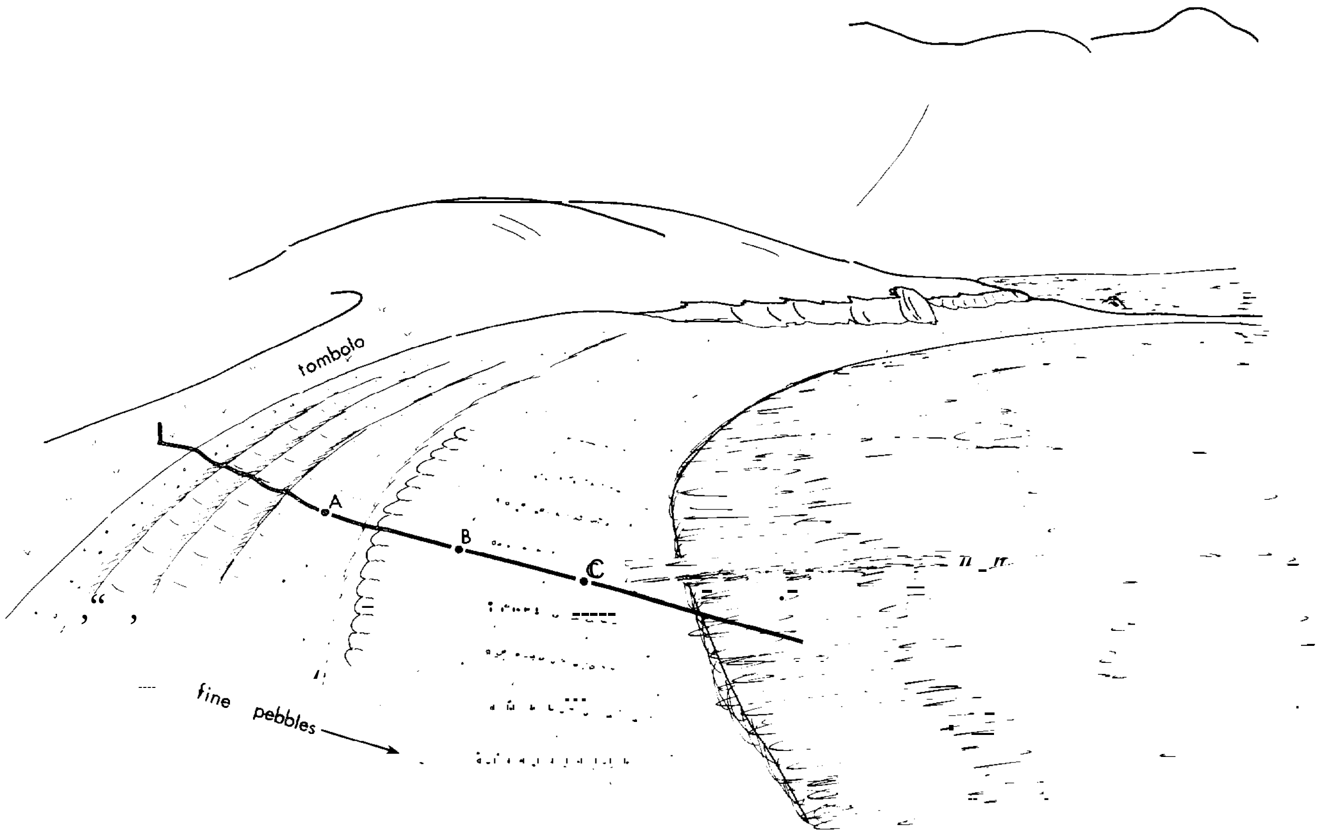


Figure 15. Profile site KPD-115 located on the Southern Uganik Passage. This profile is composed of nearly pure fine gravel and granules. It is quite simple with a slightly convex upward shape. There are four separate small berms (visible as algal swashlines on the ground photo). Above the berms is a partly vegetated low storm berm. The lower beach face has well developed gravel stripes. This type of gravel beach is very common in the better developed pocket beaches exposed to moderate to low energy. These beaches are usually quite well sorted. The relatively coarse nature of the sediments makes these beaches vulnerable to oil spills due to percolation of oil into the substrate and retention there. Note the very poorly developed beach on the lagoon side of the tombolo, with very low wave energy, (aerial photo) .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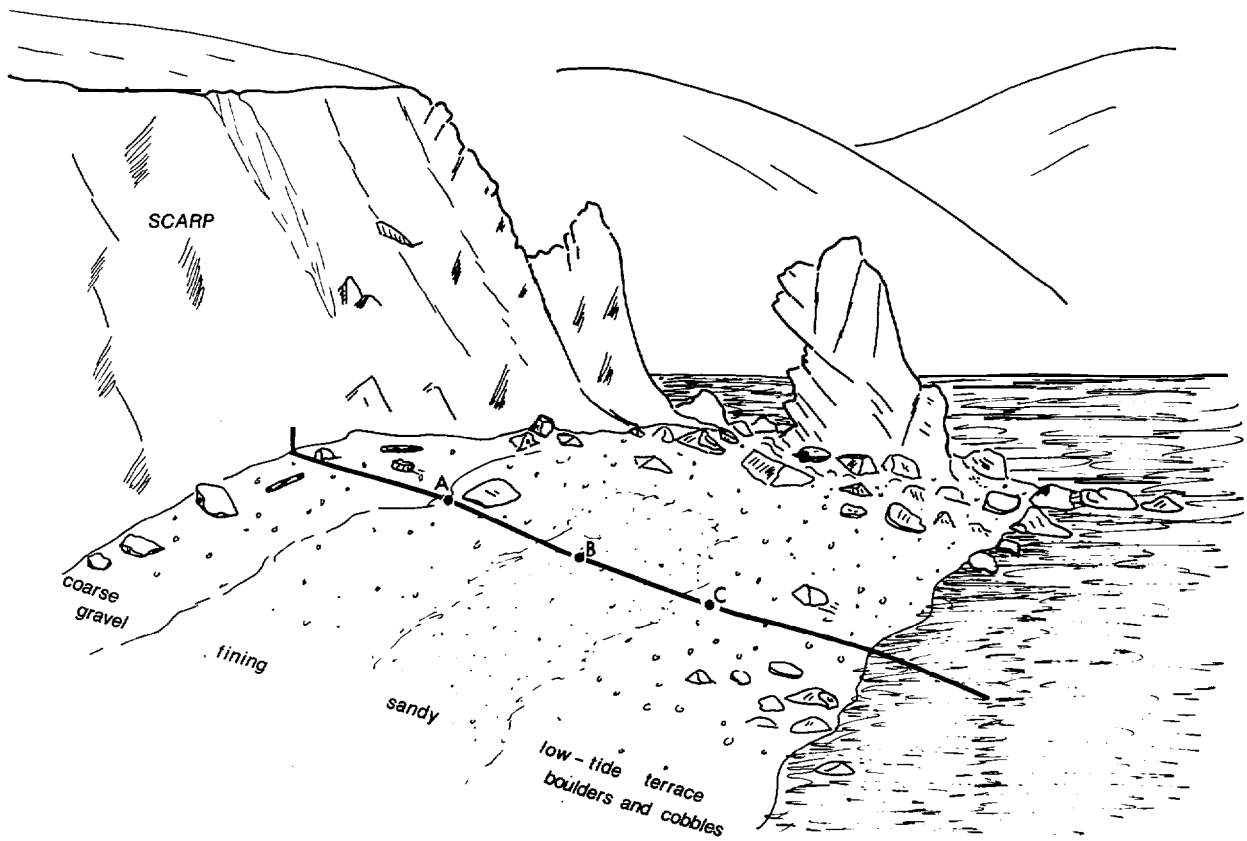
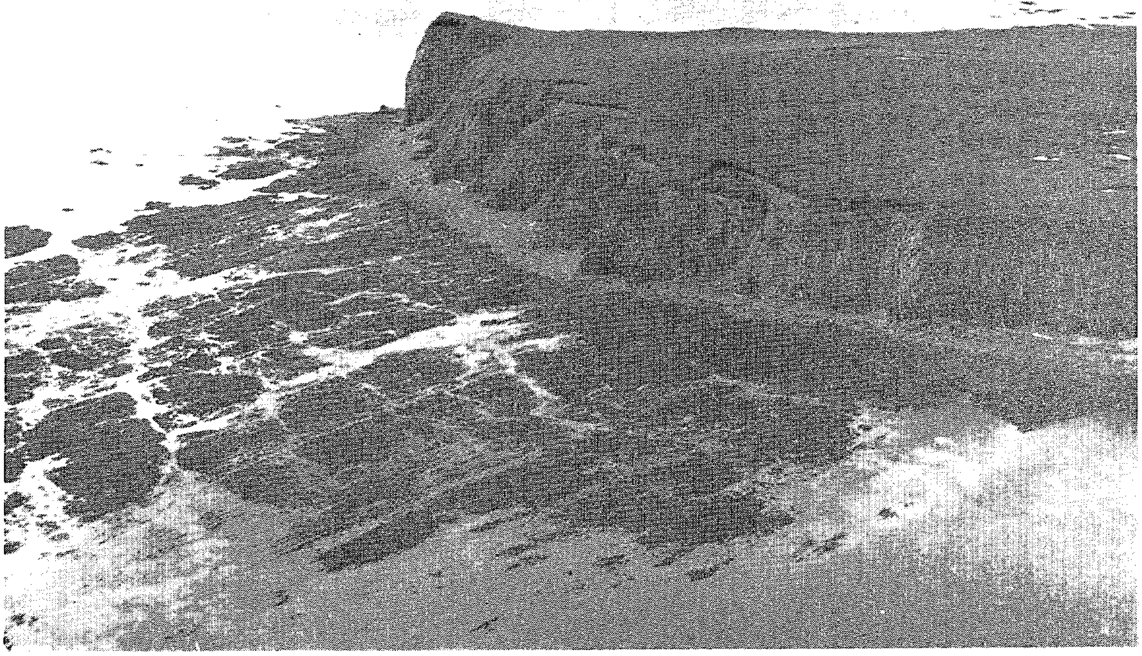


Figure 16. Profile site KPD-27 located in Malina Bay. This is a low to moderate energy rock scarp into quartz diorite with a poorly sorted beach face. The beach face is finest in the center (mostly sand) and coarsens toward the top (coarse gravel berm) and toward the water line where there is a steep short boulder-cobble low tide terrace. The lower energy is not great enough to move the sediments at the base of the beach face and thus they have a very heavy coating of algae and encrusting intertidal fauna. The rock stack behind the helicopter appears black at its base due to heavy mussel accumulations. The low wave energy and coarse grain size make this beach vulnerable to oil spills. However, during major storms, most of the beach sediment, will be moved about, aiding natural cleaning. There is a large kelp bed just offshore.



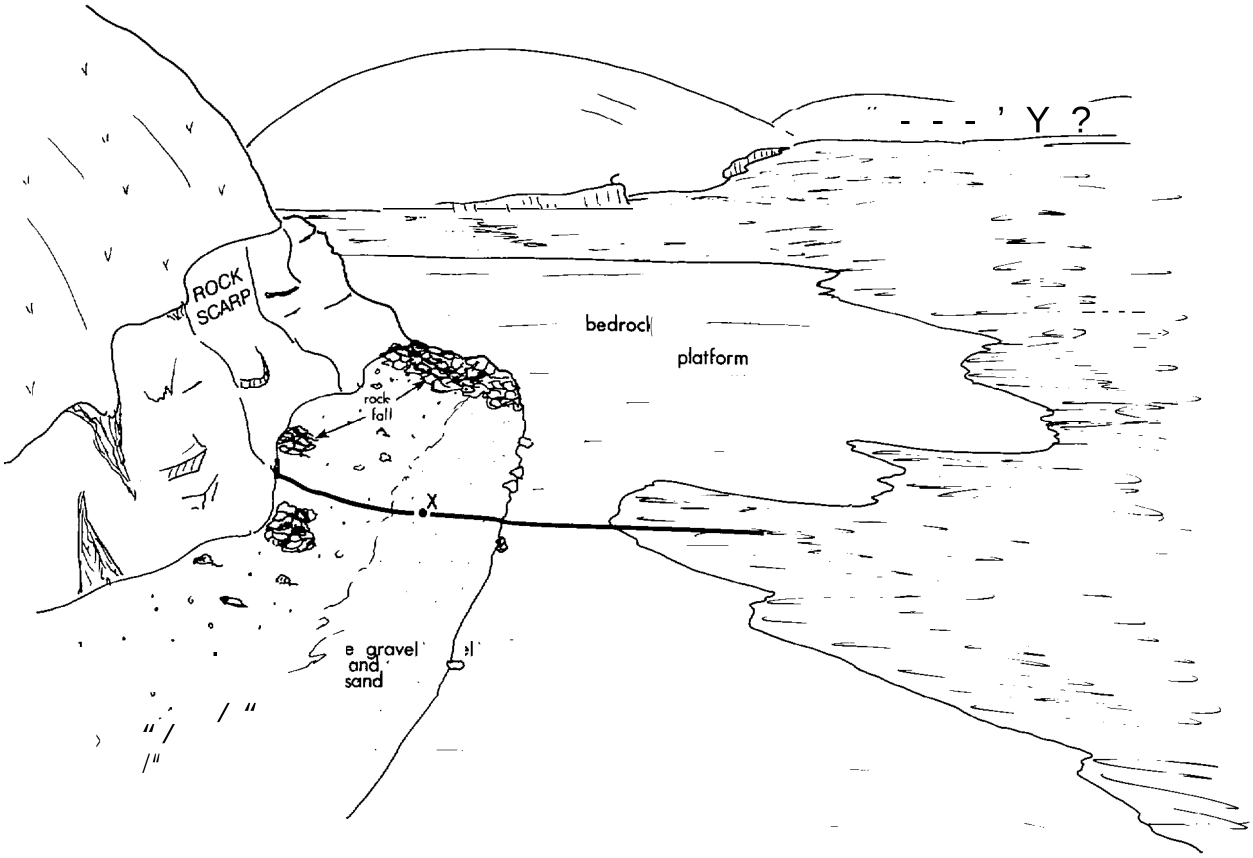
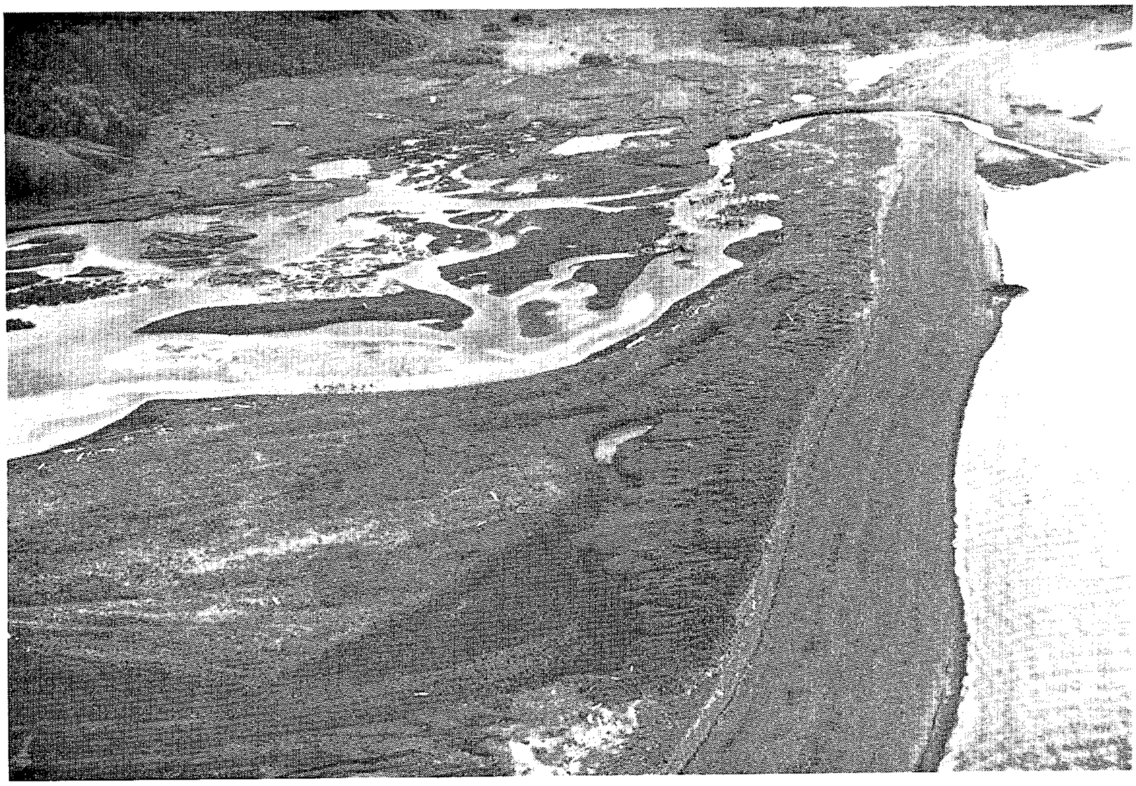


Figure 17. Profile site KDP-81 located on the Geese Channel. This location has one of the best developed wave cut platforms into bedrock in the Archipelago. The rock type is greywacke standing at a relatively steep angle. That results in a very irregular platform, with numerous tidal pools (see ground photo). The bedding planes in the rock are particularly evident in the aerial photograph. Note that about 90% of the intertidal zone is on the platform. Just below the scarp is a poorly sorted beach face of boulders, gravels and sand. Most of these sediments are rounded indicating fairly high wave energy. The entire beachface is less than 30 m wide. Rock platforms of this type generally have quite low oil residence times due to their impermeable character and high wave energy. The coarse beach face is more sensitive. Very heavy intertidal biota coats the bedrock.



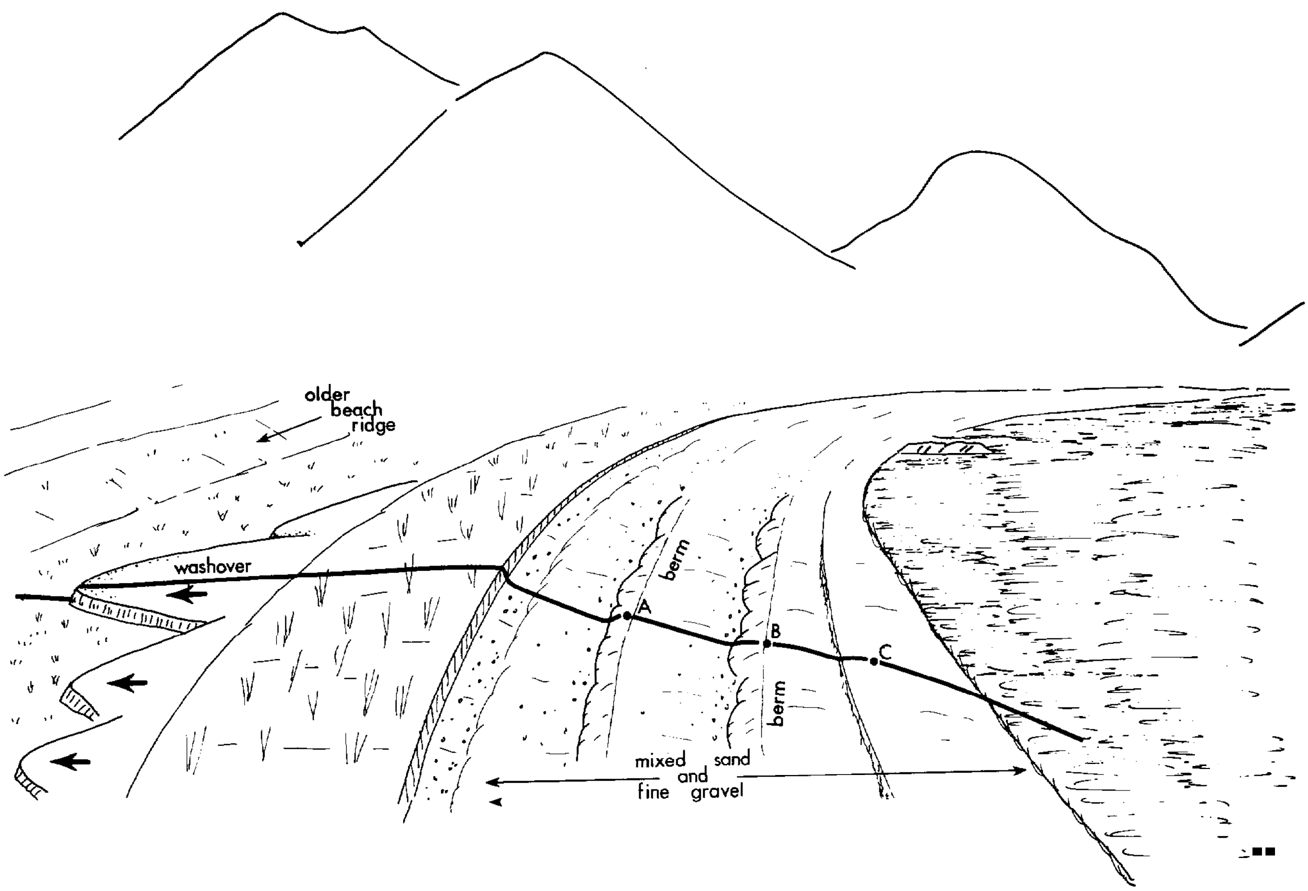
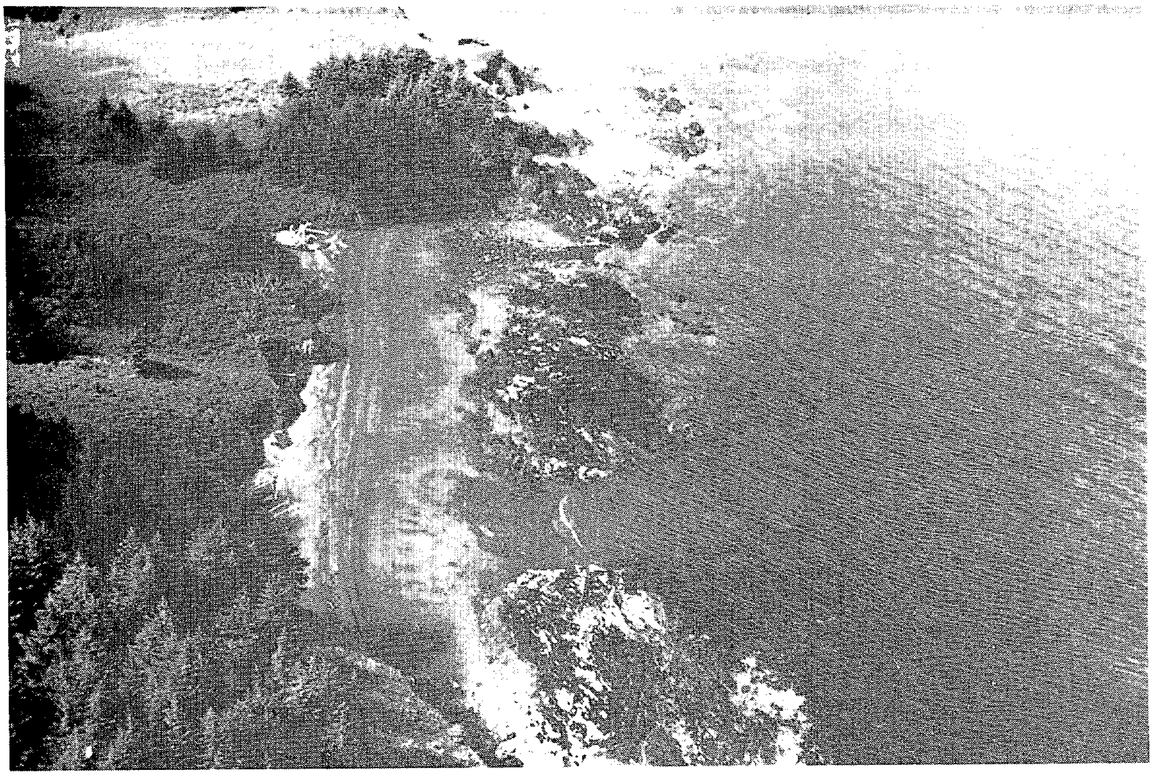


Figure 18. Profile site KDP-89 located on the Sitkalidak Strait. The profile is located on the seaward side of a large cuspate spit. The area is very interesting with a nicely developed washover terrace backing a gravel and sand beach face. The washover, composed mostly of gravels and granules is migrating landward over a marsh behind the active beach face. It appears that the washover material has been transported over the top of the spit without being deposited on the vegetated top. Well behind the active beach face is a series of earlier beach ridges associated with a relict recurved spit complex. The beach face itself has three berms on it, each one with a very steep landward face. Oil Spill Vulnerability is about 6 or 7 due to the coarse grain size and thus long term retention potential.



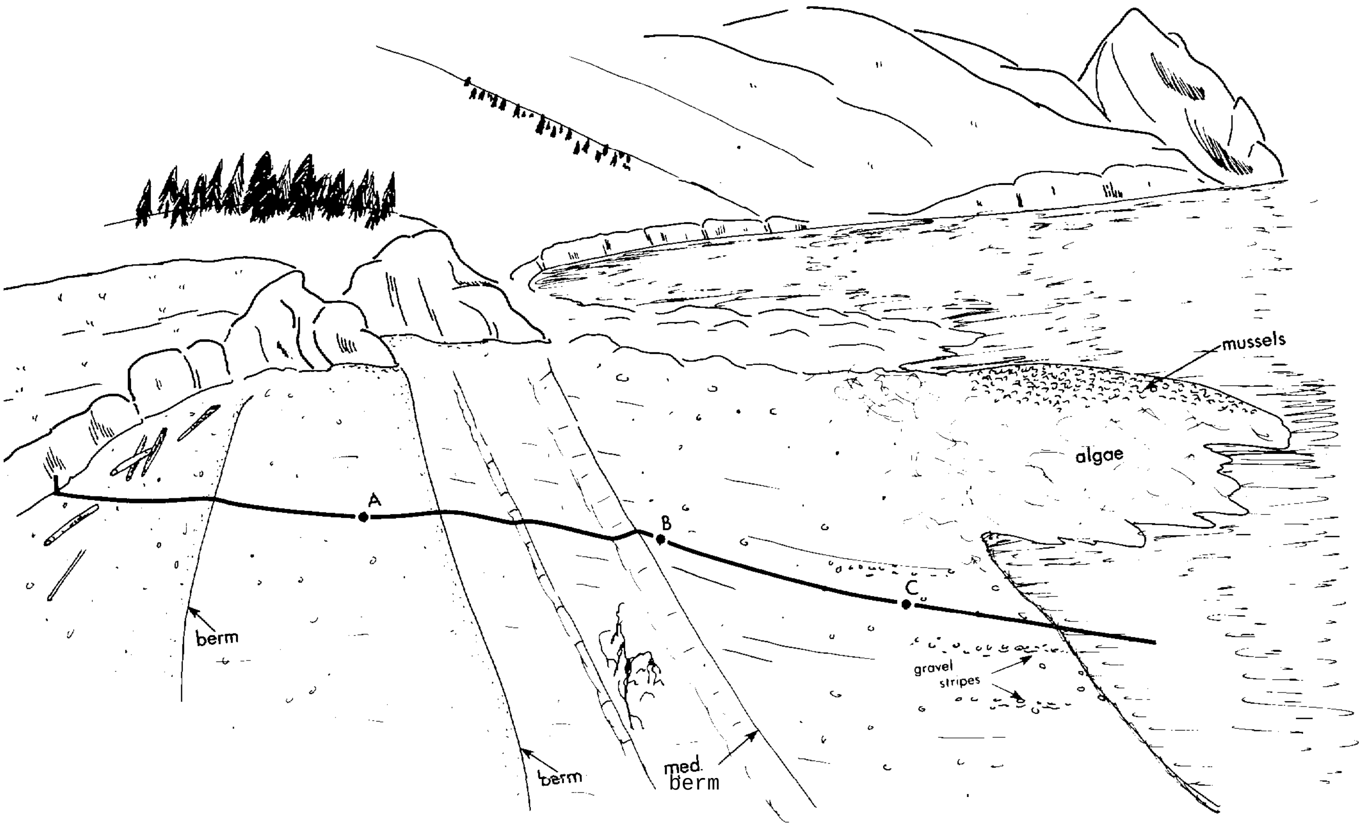
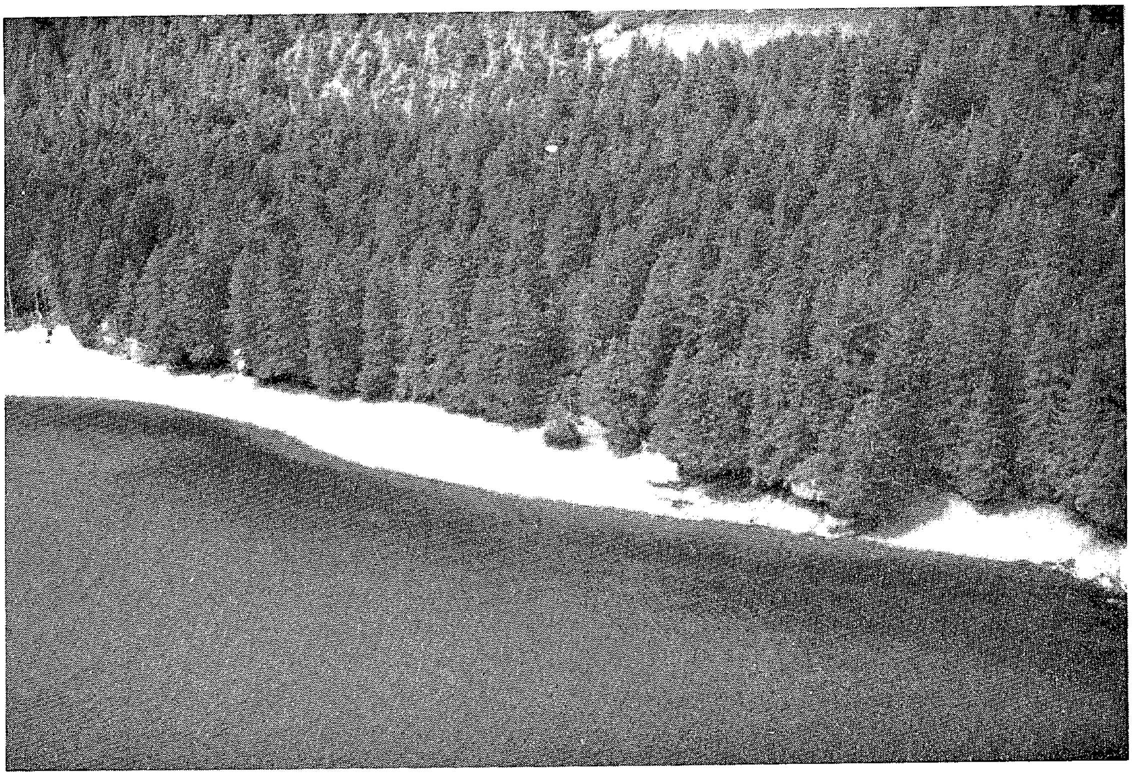


Figure 19. Profile site KDP-29 located in Malina Bay. This profile shows a very typical moderate energy gravel pocket beach. The pocket is located between two rocky headlands. Bedrock outcrops at the base of the beach face across most of the pocket beach indicating that the gravel is in fact only a thin veneer of sediment on bedrock. All exposed bedrock has a heavy biotic cover. Fronting the scarp is a high level storm berm composed mostly of discoidal gravels and granules. As usual, there is a log accumulation on top of the storm berm. The beach face is quite uniform and gets coarser as the water line is approached. Prominant gravel stripes occur at the base of the beach face where it intersects the rock platform. The OSVI is about 6 or 7 due to the coarse grain size.



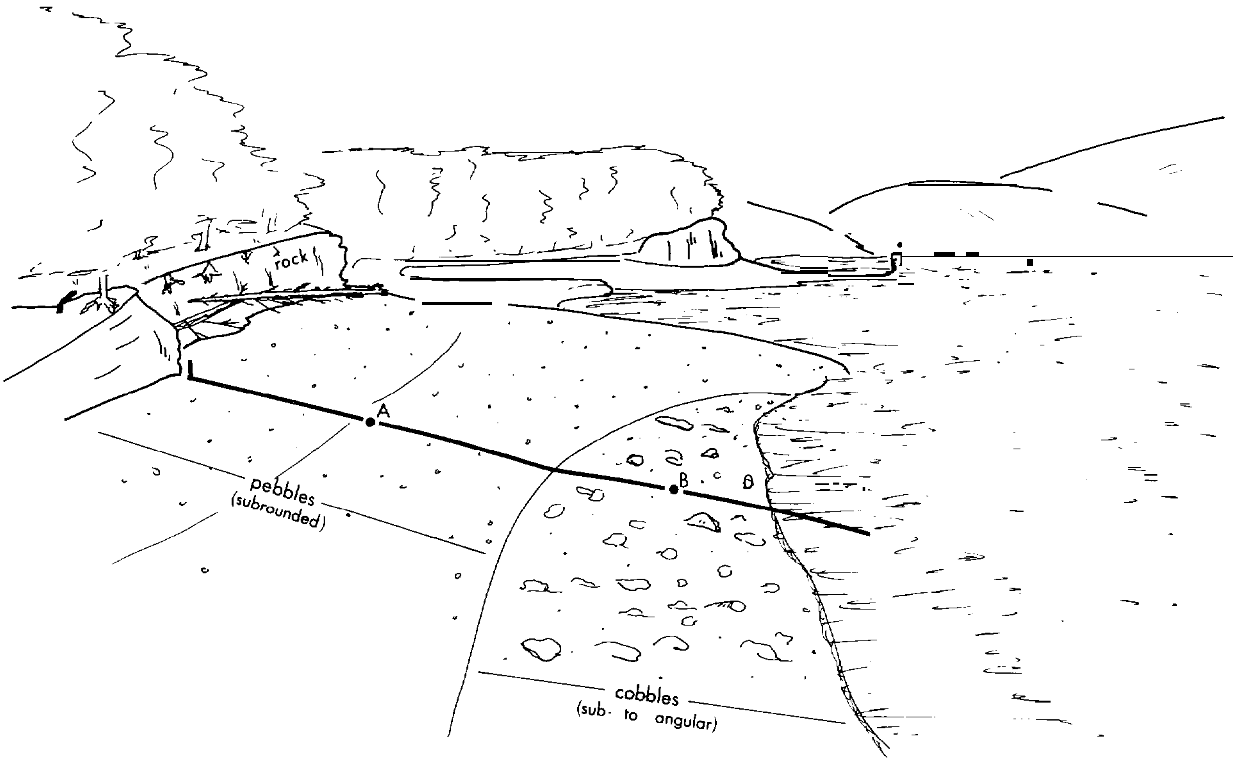
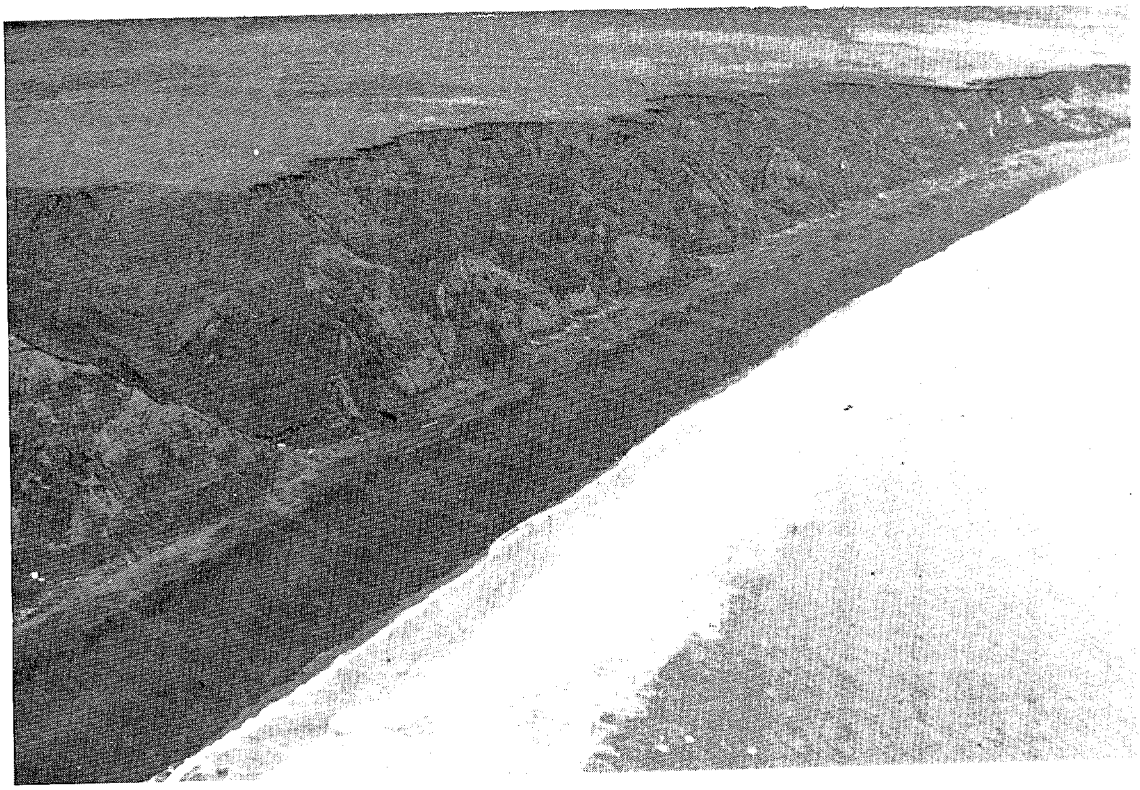
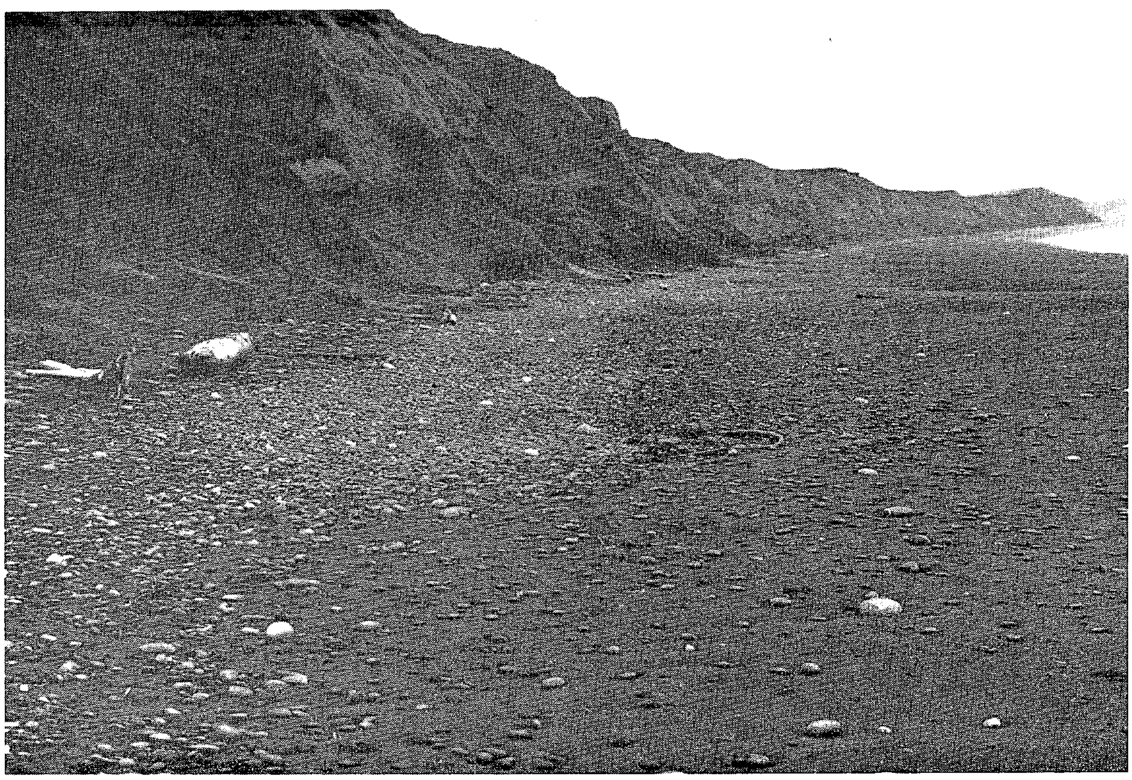


Figure 20. Profile site KDP–35 located on Lost Timber Point. This profile shows a low energy gravel beach, The low energy is attested to be the vegetation growing almost to the spring high tide line. Further, all of the gravels on the beach face are subangular to angular and, in general, covered with barnicles and algae (indicating very little movement by waves). The beach sediments ranging from sand to gravels with some larger, are perched on a bedrock platform. A scarp into that bedrock is present behind the beach face. The profile is narrow and simple. Dead trees backing the profile indicate earthquake downwarp. Most areas of this type are classified as OSVI 6 - 8 depending on grain size of beach sediment and wave energy.





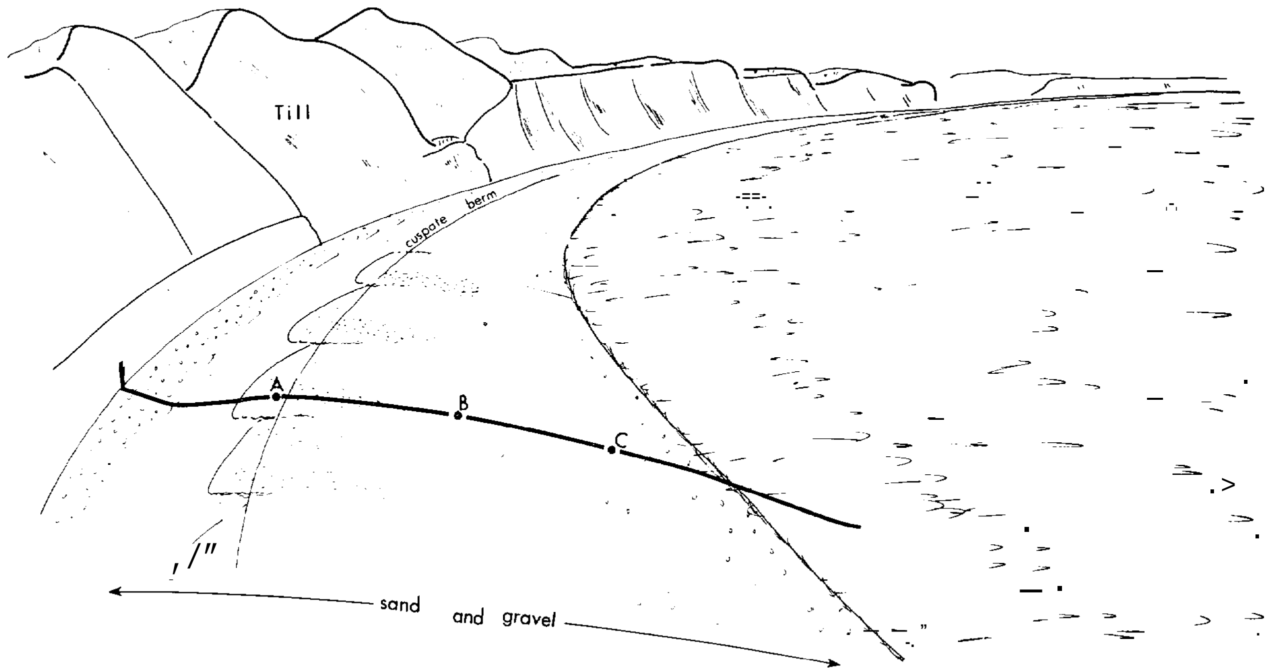


Figure 21. Profile site KDP-67 located just east of Ayakulik Island. This profile shows a typical sand and gravel beach face fronting a till scarp. Wave energy here is high, thus the finer sediments (clays and silts) have been removed. Beach faces in these areas are broad and strongly convex upward. In general, they are coarser at the top of the beach face and finest in the middle. These beaches are the most uniform and long in the study area, stretching for many miles with very little change. Shoreline environments of this type fall in the #6 slot of the OSVI and have very low biota populations.

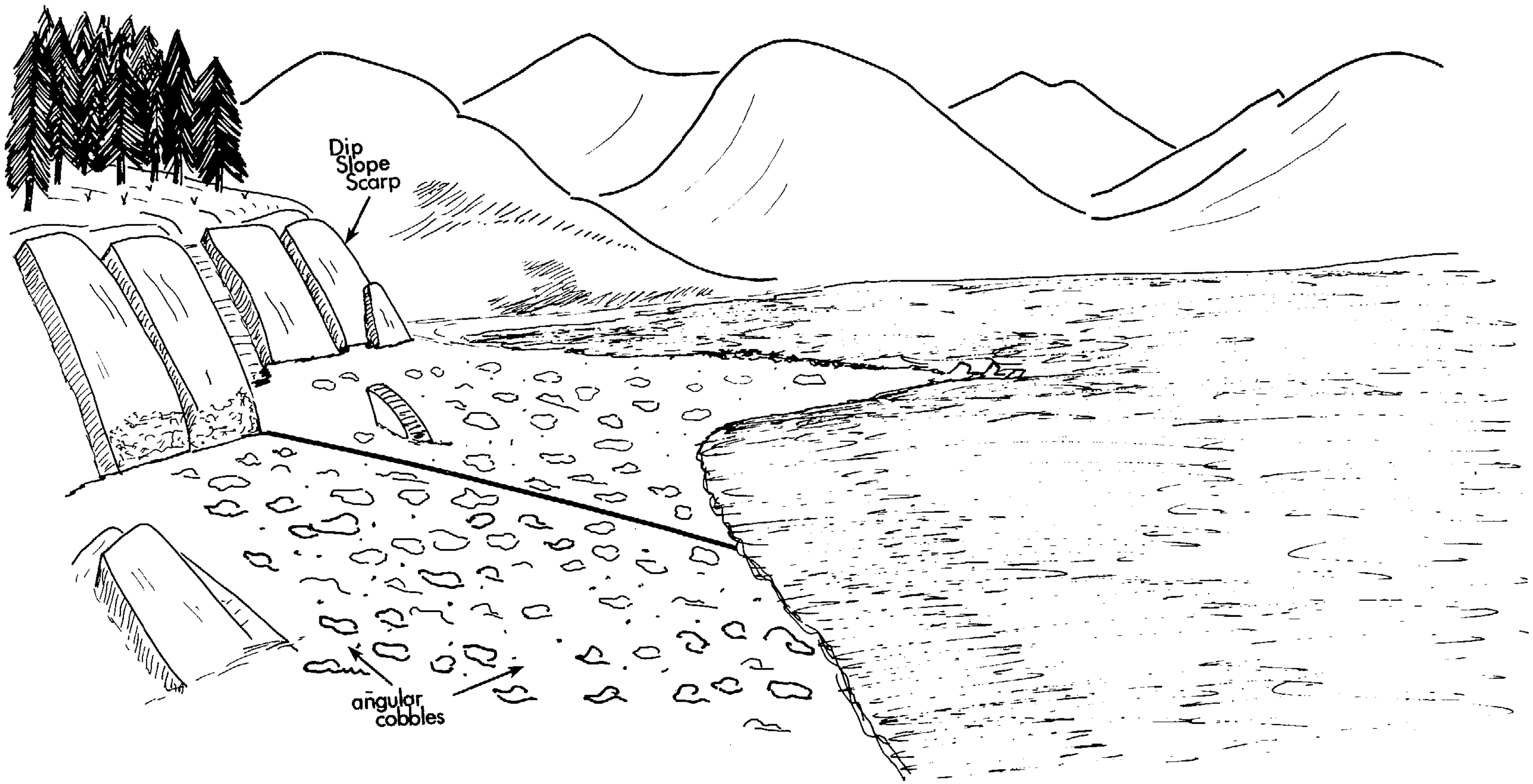
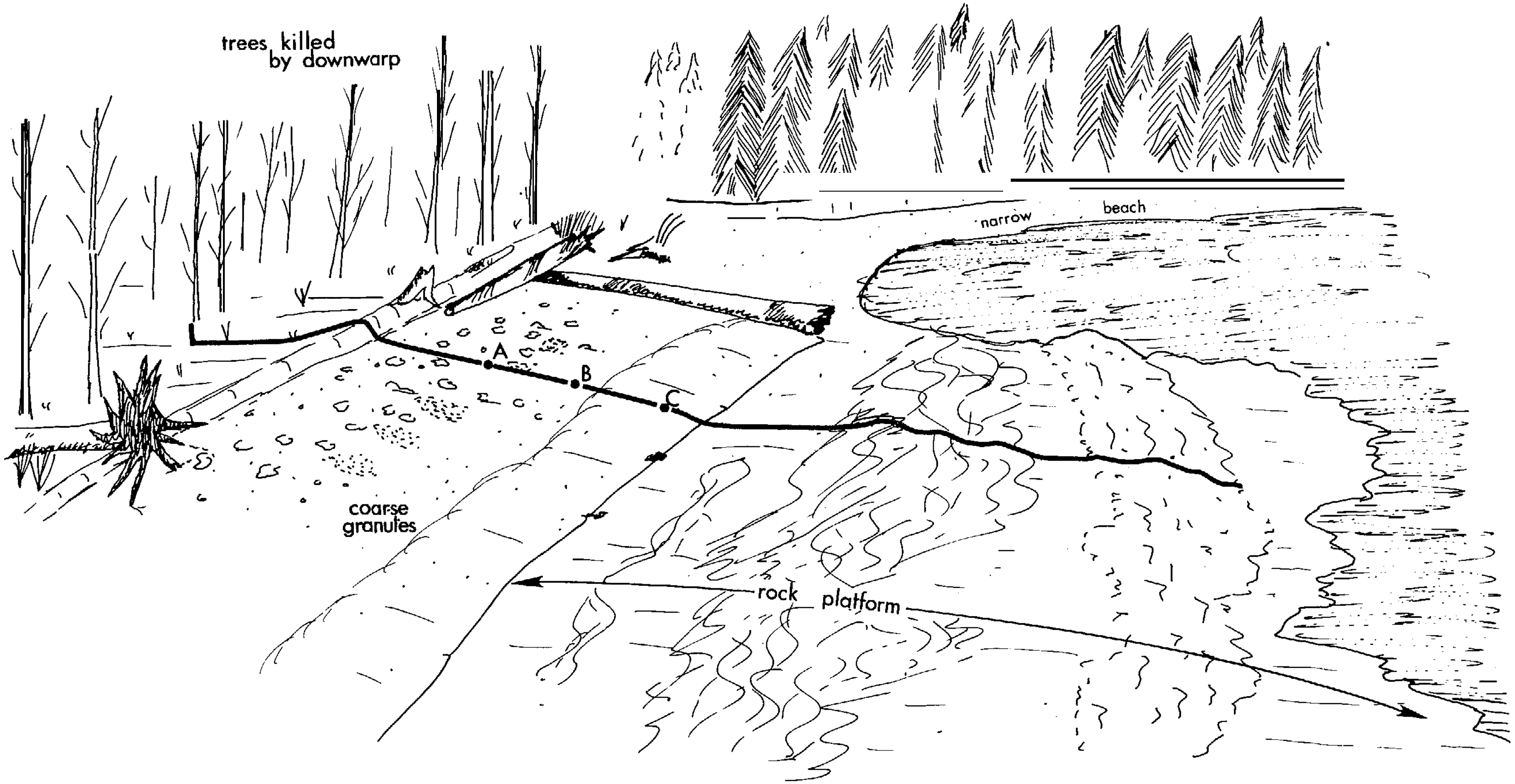

Dip
Slope
Scarp
angular
cobbles

Figure 22. Profile site KDP-31 located on the Raspberry Strait. This is a very simple, very coarse grained, low to moderate energy beach fronting a "Dip Slope" scarp into slate and argillite. This particular rock unit is standing nearly vertically and breaks very easily along bedding planes forming large angular boulders and gravel. Wave energy then smooths them to be mostly sub-angular. Note the very distinct fining trend in boulder-gravel size from the base of the scarp to the water line. Intertidal communities have almost completely covered the sediments on the lower beach face. The profile is quite short and very steep. The oil spill vulnerability of an area like this will depend on the wave energy. In general these areas fall into classes 7 and 8. If exposed, they tend to fall into 1 or 2.



trees killed by downwarp
A
B
C
narrow beach
coarse granules
rock platform

Figure 23. Profile site KDP-1 located on Afognak Point. This profile is a low energy gravel and sand beach on a bedrock platform. The back part of the profile has a developing storm berm which is actively migrating into the forest. It has not yet reached equilibrium following the downwarp of the Good Friday Earthquake of 1964. Many dead trees line the top of the profile, attesting to salt water intrusion. The upper beach face is a poorly sorted featureless sand and gravel accumulation which abuts a boulder-cobble covered bedrock platform at the base of the beach face. Although this area has rather low energy, especially during the summer, it still has been classified as a wave cut platform and given a #2 OSVI rating. Storms evidently impact this area rather frequently.

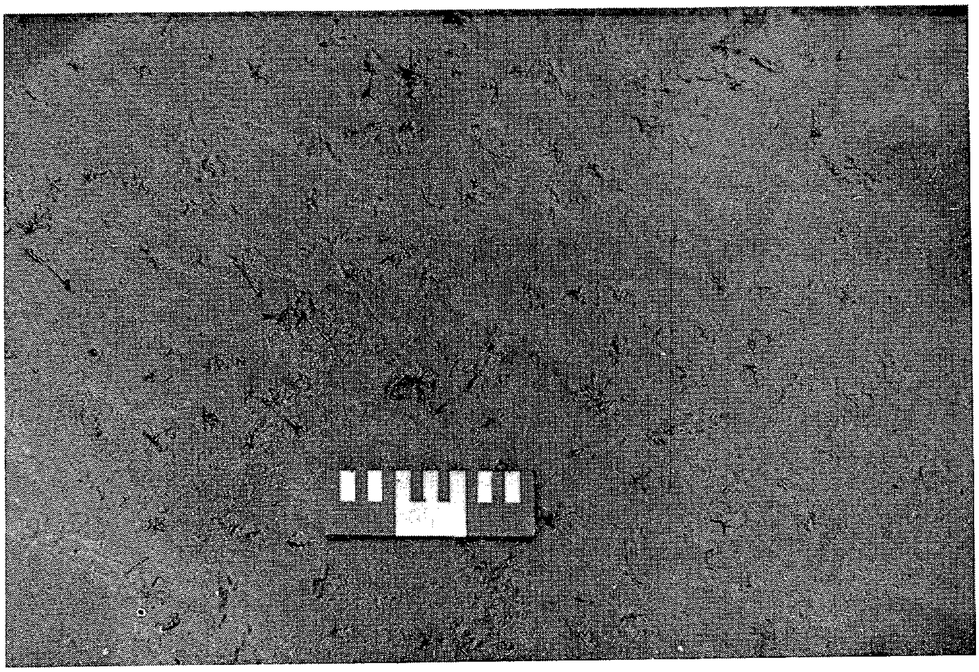
Beach Sediments

Since the Oil Spill Vulnerability Index is partly a function of beach sediment grain size, and since the Kodiak Archipelago has such an incredible variety of sizes and shapes of sediments, this section will, very briefly, depict some of that variety. Sediment grains size is a function of a number of parameters:

1. Source; whether it is a source rock in a scarp, like slate yielding boulders and gravel or a till deposit yielding unconsolidated clays, sands and gravels or a river yielding mature sands and gravels. Source is the most important single factor. It will dictate the range of sediment sizes available.
2. Wave energy; high wave energies will eliminate, through winnowing, the finer grain sizes of silts, clays and sometimes fine sand. In the same context, very low wave energies will permit the deposition of these finer sediments forming tidal flats and marshes. In some cases, a consistent wave approach active on a variable source (glacial till) will form a series of different beach types down drift of the source. There will generally be a fining trend away from the source. Thus a pure gravel-cobble beach occurs just down drift; a fine gravel beach further down drift and eventually a gravel and sand beach. In essence, wave energy will act as a sorting mechanism, separating grain sizes and depositing them in areas where they are in equilibrium with the incoming wave energy.
3* Rock type; certain rock types, due to their physical properties, behave in specific, predictable patterns once on a beach face. Slates

and bedded metamorphic and sedimentary rocks will always yield platy gravel shapes, while intrusive rocks will usually yield equant shapes. Certain rock species, like quartz, due to their extreme hardness, have very long life spans while others, less resistant to abrasion, like feldspar, are rapidly eliminated from active beaches.

The following 9 figures illustrate most of the sediment types found on Kodiak area beaches.



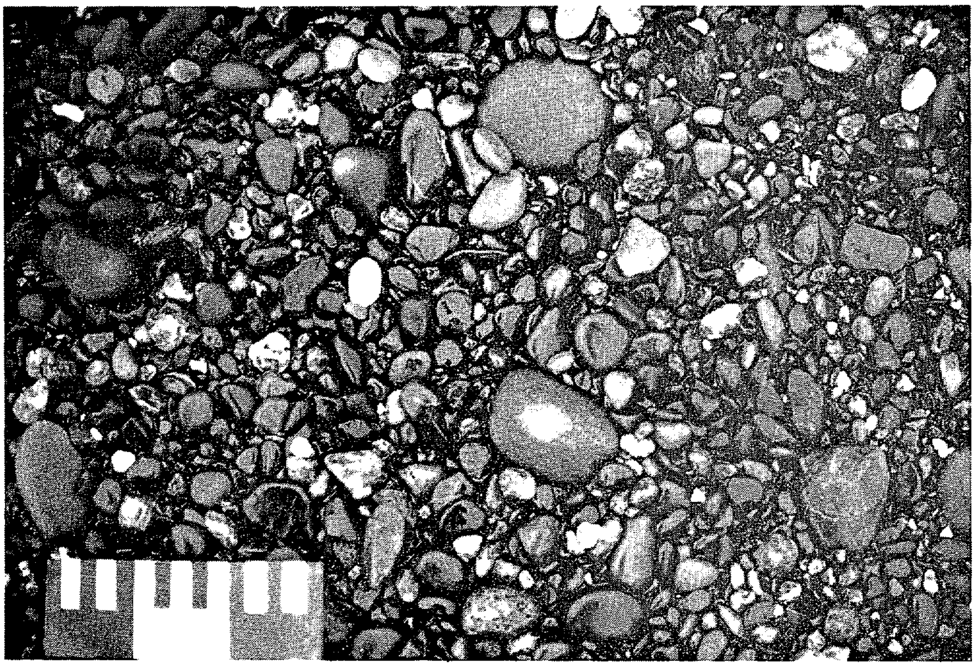
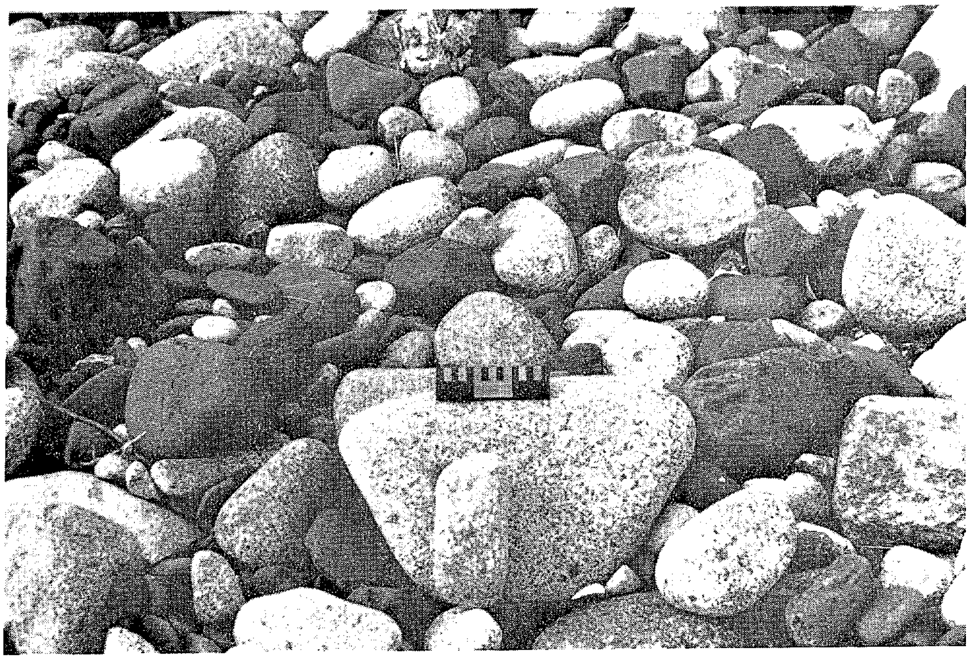


Figure 24 (above left). Typical mud flat sediments. These areas are composed of silts, clays and sometimes fine sand. They often have heavy infaunal communities, as in this photo. The very fine grain size does not permit the penetration of heavier fuel types during a spill. In general, the contaminants are refloated with each tide. Scale is 15 cm long.

Figure 25 (opposite left). Sandy beach face fronting a till source. These beaches are usually quite wide and strongly convex upward. Since the sediment is quite fine, and these areas are often exposed to high wave energy, the continual movement of sediments results in fairly rapid cleaning by natural processes. Oil can however percolate into the beaches and become buried during depositional beach cycles.

Figure 26 (above). A fairly well sorted fine gravel and granule beach. The good sorting will permit deep penetration of spilled oil and fairly long retention periods. Note the equant, round to subround character of these gravels (greywacke).



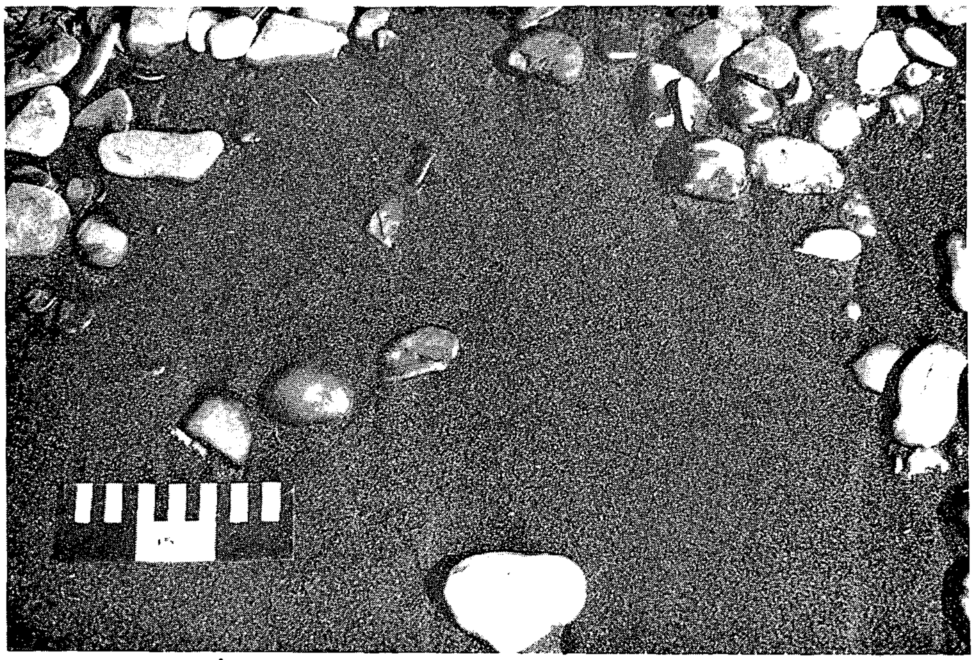


Figure 27 (above left). A typical fairly well sorted boulder-cobble coarse gravel beach sediment. Note the rounded to well rounded nature of most of the material and to total lack of fine sediment. This type of beach will absorb enormous quanities of spilled oil and hold them for long periods. These beaches fall into the #7 slot on the OSVI regardless of their exposure to waves.

Figure 28 (left). A boulder beach perched on bedrock. Fairly low wave energy is responsible for the angular to subangular shape of the boulders. Boulders of this size are generally not moved by wave activity and thus are usually covered with intertidal biota when near the low water line. All these boulders are locally derived.

Figure 29 (above). An example of a sand and often gravel beach face. Sometimes these sediments are mixed randomly but more after there is a coarsening of sediment with depth and in many cases a coarsening toward the top and bottom of the beach face. The OSVI would be #6.

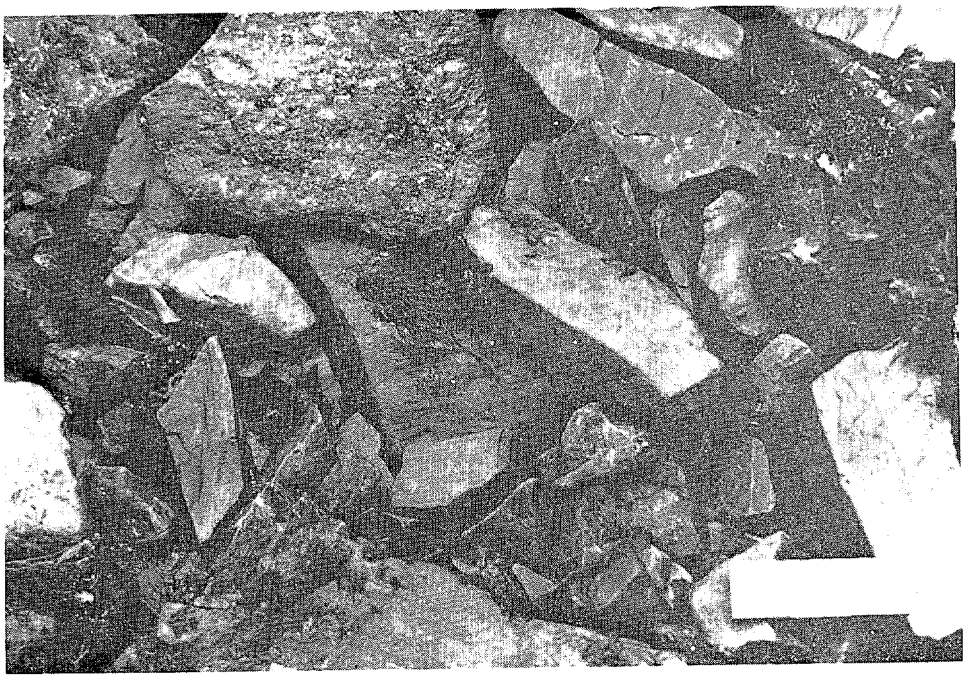


Figure 30 (above left). Very immature locally derived boulders and gravel. Their angular shape and barnicle and algal coatings indicate very low wave energy. The combination of low energy and coarse porous grain size would give this area a high OSVI of 7 or 8. Beaches of this type are very common on Afognak Island.

Figure 31 (left). This shows the effect of very high wave energy on a boulder-cobble beach face. Note the well rounded character of the boulders and the coarsening of the boulders toward the water lines. Again, coarse grain size and resultant percolation and retention of spilled oil give this beach face a #7 OSVI rating.

Figure 32 (above). A very low wave energy mixed gravel and granule beach face. The low energy has resulted in only slight rounding of the gravels which have a considerable barnicle encrustation indicating that they are moved infrequently. This type of beach is common in many of the fjords and sheltered areas.

OIL SPILL VULNERABILITY

Introduction

With the ever increasing demand for petro-products, and the continued pricing policy of the OPEC, Alaska will remain in the forefront of petroleum exploration. With oil prices rising at their current rates, even the very hard to produce "deeper shelf" oil will become economically feasible. Thus, if there are economic quantities of oil on the Kodiak Archipelago shelf, they will soon be found and produced. This will place the shoreline of Kodiak and surrounding islands in a position to receive potential oil spills. The extreme weather and tectonic setting of the area makes it even more likely to suffer the effects of blowouts, pipeline ruptures, tanker grounding and so forth.

The primary purpose of this study has been to supply baseline data regarding shoreline geomorphology and how that morphology may interact with potential oil spills. Of primary importance is the ranking of coastal environments with regard to the longevity of spilled contaminants. Thus, the primary product of our research is a set of 47 standard U.S.G.S. Quadrangle base maps at a 1:63,360 scale. These 47 topo sheets cover all of Kodiak, Afognak and the Trinity Islands. Each map has a color coded overlay which classifies the shoreline into 1 of 10 subclasses, described in this section. Even at that scale (1 inch = 1 mile) there are considerable areas left open to question since the coastal morphology of this diverse study area can change dramatically in a few tens of feet. Due to this extreme complexity (4,270 km of shoreline where classified), it is impossible to display the classification adequately in a report of this size without raising printing and drafting costs to an unreasonably high figure.

In Appendix 3, of this report, all 47 base maps have been listed. Under each base map, the 10 subclasses of the "Oil Spill Vulnerability Index" are listed with the number of shoreline kilometers falling into each class for that base map. There is also a summary section which lists the totals for each OSVI for the larger 1:250,000 topographic sheets (there are 5 for this study area). In addition to the total shoreline kilometers in each of the OSVI ratings, this summary section given the percentages of these figures for both that base map and the total study area. Thus, we find that Afognak base map (1:250,000 scale) has 189.1 km of shoreline of class #1 (exposed rock headlands). That figure represents 14.7% of the Afognak shoreline but it represents 50.2% of all the #1 OSVI shorelines. Another example: On Kodiak we find that 5.4 km are classified as #5 (exposed tidal flats), which is only 0.2% of the Kodiak shoreline but 100% of class #5 for the study area. Finally, there follows a "Grand Total" sheet. This page lists the total shoreline kilometers for each base map and the percent of the total study area. It then lists the total shoreline kilometers for each class and the percent of the total study area. Even though detailed maps do not accompany this report, inferences regarding the vulnerability of various areas can be obtained from the Appendix 3.

Our group has been studying oil spills and doing baseline analysis of various coastal areas for about 4 years. There is currently available a large number of publications dealing with specific spills (Blount, 1978; Blount and Gundlach, 1977; Gundlach and Hayes, 1977; Gundlach, Fischer and Stein, 1977; Gundlach, Ruby and Blount, 1977; Gundlach et. al., 1977; Hayes and Gundlach, 1975; Hayes et. al., 1976; Ruby et. al., 1977) as well as many dealing specifically with our coastal work in parts of Alaska (Gundlach et.al., 1977; Hayes, Michel, and Brown, 1977; Ruby and Hayes, 1978; Hayes et.al., 1976; Nummedal and Stephen, 1976; Nummedal, Stephen and Ruby, 1977; Nummedal and Ruby, 1979; and a number of Annual and Progress Reports to OCSEAP). Those reports detail the controls that beach morphology, grain size and incoming energy can have on oil spill behavior and longevity. A number of the reports address the potential impacts of spills on various of the Alaskan marine assemblages. These earlier results will not be repeated in this report. They strongly support the concept that physical degradation of spilled oil is directly related to the marine energy in the spill environment. Table 2 from Rashid (1974), gives strong supportive quantitative data in this regard.

Table 2 Chemical and physical characteristics of original and residual Bunker C oils extracted from sediments collected in Chedabucto Bay 3½ years after the Arrow spill (from Rashid, 1974).

Characteristics	Bunker C oil Original[a]	Stored sample	Low energy coast	Moderate energy coast	High energy coast
Hydrocarbons (%?					
Saturated	--	26	25	23	18
Aromatic	--	25	24	24	16
Total hydrocarbons	73.1	51	49	47	34
Ratio of saturate to aromatic	—	1.04	1.04	0.96	1.12
Non-hydrocarbons (%)					
Asphaltenes	16.3	20	22	23	22
Resins and NSOs	10.6	29	29	30	&4
Total of non-hydrocarbons	26.9	49	51	53	66
Hydrocarbons/. non-hydrocarbons	2.72	1.04	0.96	0.88	0.52
Physical properties					
Specific gravity	0.950	0.963	0.9953	0.9765	0.9823
Viscosity (cP)		19.584	28.600	1210.000	3640.000

[a] Task Force Operation Oil Report, 1970

Cold Water Spills

There is abundant literature dealing with case studies of the numerous major and minor oil spills that have taken place in the coastal waters of the lower 48 states and around the world. Predictive models for oil spill dispersal, spreading, bio-degradation and physical degradation have been developed from these studies. The sub-arctic areas, however, have been to a large extent omitted due to the difficulties inherent in any study of these environments and a general lack of actual oil spills in these environments from which to base detailed case studies. The Arrow oil spill in Chedabucto Bay, Nova Scotia, probably comes closest to a comparative model for the sub-Arctic. However, the clean-up effort and later studies (Owens and Drapeau, 1973; Owens, 1973; Drapeau, 1973; Owens, 1971; Owens and Rashid, 1976), made very little reference to the special problems encountered as a result of the colder environment (i.e. oil on ice and snow; ice-oil interaction with beach sediments; oil dispersal in heavily iced environments, etc.) . Our investigation of the Buzzards Bay oil spill (Ruby et.al., 1977) and the Ethyl H. spill in the frozen Hudson River, have given new insight into the extremely limiting effects of oil spills in ice-choked waters.

Further, evaporation losses and biodegradation are slower in colder environments. Biodegradation can be reduced as much as 90% in water of $0^{\circ}C$ when compared to water of 25°C (Robertson, 1972). Isakson et.al., (1975) states that burning may be the only feasible method of cleaning oil spills in iced areas; however, this may represent a trade of one type of pollution for another. During the Buzzards Bay spill clean-up, burning was an effective method for cleaning oil which was not accessible from the shore. Only a small amount of particulate matter resulting from the fires was noticed.

Finally, intense tidal currents and winds in the study area can disperse the spilled oil in an unpredictable manner, making it nearly impossible to recover before it impacts on nearby shorelines. Drapeau et.al., (1970) concluded that it is not feasible to recover or disperse oil slicks in regions of high tidal currents.

Environmental Vulnerability to Oil Spills

This scale has been devised on the basis of actual spill analysis and a careful study of the literature. It is based primarily on the longevity of oil in each sub-environment, which is generally a function of the intensity of the marine processes, sediment grain size and transport trends. The biologic sensitivity has also been utilized to modify the ratings of various environments.

Coastal environments are listed and discussed below in order of increasing vulnerability to oil spills.

Oil Spill Vulnerability Scale

1. Straight rocky headlands:

Most areas of this type are exposed to maximum wave energy. Waves reflect off of the rocky scarps with great force, readily dispersing the oil. In fact, waves reflecting off the scarps at high tide tend to generate a surficial return flow that keeps the oil off the rocks (observed at the Urquiola site in Spain and the Amoco Cadiz spill in France, see Figure 6). Even if oiled, natural cleaning will only require a few days or weeks. No human intervention is necessary. Almost 9% of the study area falls into this class. They occur in many different areas, always exposed.

2. Eroding wave-cut platforms:

These areas are also swept clean by wave action. All of the areas of this type at the *Metula* site had been cleaned of oil after one year. The rate of removal of the oil is a function of wave climate and the irregularity of the platform. In general, no clean-up measures are needed for this type of coast. However, there are large biologic populations in these areas. Most of these areas, 16.5% of the study area occur on Kodiak and Afognak Islands in highly exposed areas.

3. Flat, fine-grained sandy beaches:

Beaches of this type are generally flat and hard packed. Oil that is emplaced on such beaches will not penetrate more than a few centimeters at most. Usually the oil will be deposited on the surface of the sand where it can be removed by elevated scrapers or other road grading machinery. Furthermore, these types of beaches change slowly, so sand deposition and resultant burial of oil will take place at a slow rate. If left to natural processes, these beaches will be cleaned within several months. This type of beach is very rare in the study area representing only 0.7% of the shoreline.

4. Steeper, medium to coarse-grained sandy beaches:

On these beaches, the depth of penetration would be greater than for the fine-grained beaches (though still only a few centimeters), but rates of burial of the oil would be greatly increased. Based on our earlier studies, it is possible for oil to be buried as much as 50-100 cm within a period of a few days on beaches of this class. In this situation, removal of the oil becomes a serious problem, since removal of the oiled sediments will often result in large scale erosion, as the beach changes into a new equilibrium state. This was a common problem encountered during the cleanup of the Arrow spill in Chedabucto Bay, Novia Scotia (Owens and Rashid, 1976). Another problem is that burial of the oil preserves it for release at a later date when the beach erodes as part of the natural beach cycle, thus causing longer term pollution of the environment. This class represents only 0.1% of the study area,

5. Impermeable exposed tidal flats:

One of the major surprises in the study of the Metula site was the discovery that oil had not remained on the mud flats. At the Urquiola site, oil was observed as it became refloated with rising tides on the mud flats. Penetration of the oil is prevented by the extremely fine sediment size, saturated with water. Therefore, if an oiled tidal flat is subject to winds and currents, the oil will tend to be removed, although not at the rapid rate encountered on exposed beaches. Mechanized clean-up is considered impossible. These are often areas of high biologic importance. These areas are very rare in the study area due to a lack of fine sediment. They represent only 0.1% of the total study area.

6. Mixed sand and gravel beaches:

On beaches of this type, the oil may penetrate several centimeters, and rates of burial are quite high (a few days in Spain). Any attempt to remove the oiled sediment will result in considerable erosion. This type of beach is the second most common in the study area, representing 22.1%. These beaches occur where till or glacial deposits are being reworked by marine processes and as pocket beaches between headlands. The longevity of the oil at the Metula site, particularly on the low-tide terraces and berm top areas, attests to the high susceptibility of this type of beach to long-term oil spill damage. Natural cleaning may require many years.

7. Gravel beaches:

Pure gravel beaches allow the oil to penetrate to considerable depth (up to 45 cm in Spain). Furthermore, rapid burial is also possible. A heavily-oiled gravel beach will be impossible to clean up without completely removing the gravel. Natural cleaning will be quite slow for this type of beach; the exact time required will depend on the intensity of the marine processes. Pure gravel beaches are quite common in the study area representing almost 15% of the shoreline. They occur mostly as pocket beaches and fronting rock scarps. In some cases they can be quite long.

8. Sheltered rocky headlands:

Our experience in Spain indicates that oil tends to stick to rough rocky surfaces. In the absence of abrasion by wave action, oil could remain on such areas for years, with only chemical and biological processes left to degrade it. They usually have gravel beaches associated with them and for the purposes of this study, sheltered gravel beaches are classified with sheltered rocky headlands. They represent the largest single class or 34.2% of the study area. Most of these areas are on Afognak Island and in the fjords on Kodiak Island.

9. Protected estuarine tidal flats:

If oil reaches a quiet, protected estuarine tidal flat, it will remain there for long periods because natural cleaning progresses at an extremely slow rate. Because of the low intensity of marine process parameters, removal of the oil will have to be accomplished by natural chemical and biogenic processes. This will take many years, dependent on the amount of oil deposited. Because of their high biologic populations, these environments are very sensitive to the toxic effects of oil. These areas are rare in the study area occurring only at fjord heads and at river mouth estuaries.

10. Protected estuarine salt marshes:

In sheltered estuaries, oil from a spill may have long-term deleterious effects. We observed oil from the Metula on the salt marshes of East Estuary, in the south shore of the Strait of Magellan, that had shown essentially no change in 1½ years. We predict a life span of at least 10 years for that oil. These areas are extremely important biologically, supporting large communities of organisms. These areas are generally associated with the protected tidal flats (#9) and are also rare, representing only 1.2% of the study area.

Applications to the Kodiak Archipelago

Using the vulnerability classification just described, it is possible to make a few generalizations regarding the Kodiak area and its reaction to potential oil spills. In general, the area is quite high risk. More than 73.8% of the shoreline falls in classes 6 - 10. These classes will have a spill longevity of a year or two to more than 10 years. The remaining 26.2% of the shorelines fall into classes 1 - 5 which are considerably lower risk areas where spilled oil would generally be expected to be cleaned by natural processes within a year. A closer analysis (see Table 3) shows that actually the shoreline classification is bimodal. In other words a large percent of the shoreline falls into classes 6, 7 and 8 while most of the remainder falls into classes 1 and 2. Classes 3, 4, 9 and 10 represent only 3.5% of the shoreline combined. Thus, there is a clustering of very low risk shorelines and moderately high risk shorelines.

Unfortunately, the Kodiak system is very complex and the higher rish areas do not lend themselves well to being protected during a spill. In many instances, a low risk rock scarp will lie just seaward of a large embayment with high risk pure gravel beaches. The fact that the environments change so frequently and rapidly along the shoreline, makes the entire island a fairly high risk area. The indented (fjord) character of the islands will act as "oil traps" for floating oil. Oil will tend to be moved deeper into the fjords rather than to be flushed out. In general this will result in an oiling of increasingly sensitive environments, since higher risk, lower energy classes are located deeper in fjords and embayments. Additionally, there are long periods of relatively low wind and wave energy, especially during the summer. A spill during one of these periods could prove particularly devastating since many of the areas classed 1 and 2 would become 7 and 8. Thus, Table 3 should be viewed as a "minimum" spill damage in the event of a large spill.

Since the Oil Spill Vulnerability Index is based partly on the longevity of potential oil spills within each of the subenvironments, the following guidelines are given:

OSVI	Spill Longevity
1 + 2	A few days to a few weeks
3 + 4	A month to six months
5 + 6	Six to 24 months
7 + 8	A year or two to as much as 8 years
9 + 10	Up to ten years

These figures are highly dependent on the wave energy during the spill and partly dependent on the temperature. They can vary and are meant to be estimates only. They give a relative indication of the longevity from one environment to another.

TABLE 3

Km of Shoreline	% of Shoreline	Discussion	Classes
1083.2	25.3	Oil easily removed by wave action. Some problems in areas of gravel accumulation and in tidal pools. Pocket beaches may be particularly hard hit. Do not recommend human intervention once oil is on beach.	1 + 2
38.6	0.9	Generally low risk areas and quite rare in the study area. Fine sands and mud tidal flats will not permit much penetration of oil. Low wave energy areas will require as much as a year for natural cleaning. Mechanized cleaning on sand beaches is quite feasible but represents a very small area. Recommend no human effort in these areas.	3 - 5
942.4	22.1	Sand and gravel beaches represent a large percent of the shoreline and tend to be relatively high risk beaches. They permit rather deep burial of oil and can retain oil for about 2 years, especially if it is emplaced high on the beach face (as during a spring tide). Mechanized clean up can be very difficult due to low bearing strength of the sediments. Removal of sediments may accelerate erosion.	6
634.2	14.9	Pure ravel beaches will permit immediate deep burial of oil. Retention periods, especially in a lower wave energy area can be many years. Mechanized clean up will be impossible without removal of sediment and increased erosion. The increased erosion, may not be of particular importance in uninhabited areas.	7
1462.0	34.2	Sheltered rock headlands and their associated gravel pocket beaches will be highly damaged in the event of a spill. They occur primarily in fjords and on the very irregular areas on Afognak Island. These areas should receive first protection priority in the event of a	8

TABLE 3 (cent)

Km of Shoreline	% of Shoreline	Discussion	Classes
		spill. All possible means should be used to prevent oil from entering these areas (booms, skimmers, etc). Once these beaches are oiled, expect severe biological damage, deep penetration, difficult clean up and longevity up to 8 years.	
109.8	1.6	These bayhead and river mouth systems are highly vulnerable. They are, however, rare in the study area. Further, they occur in areas which will receive maximum protection as discussed above. If oiled, bio-damage will be extreme, recovery slow and spill longevity up to 10 years.	9 + 10

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APPENDICES

APPENDIX 1. Grain Size Analysis - shows results of both sieve and settling tube grain size analysis and later computer synthesis.

APPENDIX 2. Profile Site Descriptions - describes the location, sediment composition, bedrock composition, wave energy, sample types and locations as well as the general beach morphology, depositional and erosional features and biotic abundance of each of the profile sites.

APPENDIX 3. Oil Spill Vulnerability and Coastal Morphology - shows numerically the kilometers of shoreline which fall into each of the 10 sub environments described in the text of this report. The first section shows a breakdown of each topographic sheet (1:63,360 scale). The second section shows the totals for each full scale topographic sheet (1:250,000) and the grand totals for the entire study area.

APPENDIX 4. Profile Plots - computer plots of all profile sites at a 1:5 vertical exaggeration.

APPENDIX 1

Kodiak and Afognak Island Beach Sediment Samples

Station Number	Mean Grain Size (ϕ)	Standard Deviation (ϕ)
KDP1a	1.413	0.749
KDP1b	0.568	0.748
KDP1c	0.524	0.678
KDP1 mean	0.835	0.725
KDP3a	1.876	1.418
KDP3b	2.509	1.235
KDP3C	0.470	1.666
KDP3 mean	1.618	1.106
KDP 5a	1.745	0.473
KDP5b	2.273	1.142
KDP5C	0.810	0.649
KDP5 mean	1.609	0.754
KDP7b	-2.413	1.926
KDP 9	Rocky headland - no samples	
KDP11	Rocky headland - no samples	
KDP13a	2.314	1.644
KDP13b	2.937	2.322
KDP13c	1.276	1.748
KDP13 mean	2.176	1.905
KDP15b	1.402	1.589
KDP17a	1.035	0.697
KDP17b	2.200	0.744
KDP17c	1.532	1.070
KDP17 mean	1.589	1.837
KDP19	Rocky headland - no samples	
KDP21b	-3.700	0.867
KDP23a	-1.516	1.182
KDP23c	-1.265	0.489
KDP23 Dune sample	0.792	1.273
KDP 23 mean (excluding dune sample)	-1.391	0.836
*KDP25a	-1.794	1.097
*KDP25b	-2.615	0.929
*KDP25c	-2.733	1.057
KDP25 mean	-2.381	1.03

Station Number	Mean Grain Size (ϕ)	Standard Deviation (ϕ)
KDP27a	1.469	1.415
KDP27b	-2.405	1.321
KDP27c	-2.428	1.272
KDP27 mean	-1.123	1.336
KDP29a	-3.502	0.598
KDP29b	-2.235	0.690
KDP29c	-2.942	1.709
KDP 29 mean	-2.893	0.999
KDP31	Rocky headland - no samples	
KDP33a	-3.322	0.922
KDP33b	-2.575	0.868
KDP33C	-3.513	0.712
KDP33 mean	-3.136	0.834
KDP35a	-2.161	1.337
KDP35b	-1.801	.2.268
KDP35 mean	-1.981	1.803
KDP37b	-2.429	1.982
KDP39b	-2.004	1.507
KDP41a	3.925	0.245
KDP41b	-1.956	1.273
KDP41c	2.129	1.097
KDP41 mean	1.366	0.872
KDP43a	-4.620	0.349
KDP43b	-3.406	0.841
KDP43 mean	-4.013	0.595
KDP45a	-4.560	0.468
KDP45b	-4.835	0.418
KDP45c	-2.793	1.947
KDP45 dune	-2.821	0.721
KDP45 mean (excluding mean dune sample)	-4.063	0.944
KDP47a	-2.610	2.008
KDP47b	-2.098	1.135
KDP47C	-1.853	2.014
KDP47 mean	-2.187	1.719
KDP49	Rocky headland - no samples	
KDP51a	-1.805	1.702
KDP51b	-2.066	1.834
KDP51c	-0.884	2.027
KDP51 mean	-1.585	1.854

Station Number	Mean Grain Size (ϕ)	Standard Deviation (ϕ)
KDP53	Rocky headland - no samples	
KDP55b	-2,331	0.989
KDP57a	-2.296	0.590
KDP57b	-2.154	0.649
KDP57c	-2.116	0.860
KDP57 mean	-2.189	0.700
KDP59a	-2.397	1.575
KDP61a	-3.113	1.782
*KDP61b	-2.571	1.170
KDP61 mean	-2.842	1.476
KDP63	Cobble spit - no samples	
KDP65b	2.611	1.532
		1.002
KDP67a	-0.844	1.208
*KEP67b	-1.686	1.105
KDP67 mean	-1.265	
KDP69a	2.122	0.687
KDP69b	1.514	0.532
KDP69c	0.024	0.827
KDP69 mean	1.220	0.682
KDP71a	0.824	0.525
KDP71b	1.325	0.545
KDP71c	1.209	0.731
KDP71 mean	1.119	0.600
KDP73a	-1.183	2.241
KDP73b	-1.942	1.048
KDP73c	-2.517	1.454
KDP73 mean	-1.880	1.581
KDP75a	-3.476	0.449
KDP75b	-2.976	0.700
KDP75 mean	-3.226	0.576
KDP77	Rocky headland - no samples	
KDP79a	2.168	0.08″0
KEP79b	0.366	1.443
KDP79c	1.386	0.981
KDP 79 mean	1.307	0.834
KDP81b	-1.855	1.726

Station Number	Mean Grain Size (ϕ)	Standard Deviation (ϕ)
KDP83a	-3239	2.065
KDP83b	-1.923	2.003
KDP83 mean	-2.581	2.034
KDP85b	0.560	0.733
KDP87	Rocky headland - no samples	
KDP89a	-1.846	1.146
KDP89b	-1.527	0.853
KDP89c	-1.557	1.353
KDP89 mean	-1.643	1.117
*KDP91a	-2.975	1.-09
*KDP91b	-3.068	1.555
KDP91 mean	-3.020	1.310
*KDP93a	-2.603	1.294
KDP93b	-2.807	0.392
*KDP93c	-1.958	1.590
KDP93 mean	-2.450	1.094
*KEP95a	-1.903	2.260
KDP95b	-2.893	1.083
*KEP95c	-1.940	1.367
KDP95 mean	-2.250	1.570
KDP97a	0.586	0.554
KDP97b	1.169	1.141
KDP97c	-0.075	1.367
KDP97 mean	0.840	1.020
*KDP99a	-2.170	1.885
KDP99b	-1.330	1.713
KDP99c	-1.864	0.878
KDP99 mean	-1.788	0.825
KDP101b	-1.640	1.868
KDP103b	-2.043	1.610
*KDP105a	-2.328	1.877
*KDP105b	-1.912	1.760
KDP105 mean	-2.120	1.318
KDP107	Rocky headlands - no samples	
KDP109a	-1.843	1.030
KDP109b	-1.600	1.210
KDP109 mean	-1.722	1.120
KDP111	-3.803	

Station Number	Mean Grain Size (o/)	Standard Deviation (ϕ)
KDP113a	-3.803	1.008
KDP113b	-0.744	0.894
KDP113c	-2.080	0.863
KDP133 mean	-2.209	0.922
*KDP115a	-1.847	1.021
KDP115b	-2.002	1.431
KDP115 mean	-1.925	1.226
KDP117a	0.743	0.976
KDP117b	3.309	0.560
KDP117c	2.542	1.159
KDP117 mean	2.198	0.897
KDP119a	0.887	1.269
KDP119b	0.354	0.728
KDP119c	-2.085	1.840
KDP119 mean	-0.281	1.279
KDP121a	-1.810	0.479
KDP121b	-1.885	1.021
KDP121c	-2.059	0.604
KDP121 mean	-1.918	0.701
KDP123a	-1.425	0.525
KDP123b	-1.371	1.035
KDP123c	-1.651	0.857
KDP 123 mean	-1.482	0.806
KDP125b	-2.735	1.583
KDP127a	-2.915	0.974
*KDP127b	-2.838	1.762
KDP127c	-2.523	1.213
KDP127 mean	-2* 759	1.316

* Indicates a **polymodal** sample.

APPENDIX 2

KDP1 :

1. Location:

0.5 km east of Afognak Point, 57°51'30"N, 152°47'30"W.

2. Body:

Basically, a low energy rock platform with a veneer of granule-gravel beach on the landward one half of the platform. An active low, poorly developed storm berm is currently building and migrating landward into the forest. That action is the result of the downwarp associated with the Good Friday Earthquake of 1964. Numerous dead trees line the upper beachface - resulting from salt water intrusion due to downwarping. Beach is quite narrow and of only moderate steepness. Two primary zones 1) Granules on bottom ½ of beachface; 2) Granules and medium to coarse discoid gravel. Rock platform is generally devoid of sediment and covered with very heavy intertidal life.

3. Energy and Rock Type:

Generally rather low energy. Rock type and beach sediments - shale, slate and greywacke.

4. Sample Index:

At the upper storm berm - cobbles and some large pebbles. Discs abundant. Black metamorphic sand underneath. At the high tide swash line, gravel 2-5 cm with a few large, 30 cm, cobbles.

A Sample - taken from the base of the cobble toe and gravel zone. Some sand here mixed in with the pebbles and very small cobbles.

B Sample – Loose 1/2 cm pebbles here with black sand underneath.

C Sample - Larger pebbles, 1-2 cm, black sand underneath. Also much shell material.

The shape changes from disc to bladed (from top to base of beachface), not dramatically as discs do show up near LTT. Everything is fairly angular, not equant.

KDP3:

1. Location: West side of Kazakof Bay.

2. Body:

This side of the bay is composed of steep low rock scarps (10-15 ft. high) and small pocket beaches. Rock scarps have well developed biotic zonation. There are many sea caves and arches. The profile runs across a nicely developed, moderately sloping beach of platey, black, low-ranked metamorphic rock. The beach has a grain size zonation with a fine zone between the spring high tide swash and the last high tide swash. It then coarsens to the waterline where there is a step. It also coarsens toward the upper beachface. Very abundant intertidal life on the low tide terrace and rocks.

3. Energy and Rock Type:

Generally quite low energy. Sediment and rock type - low-ranked metamorphic.

4. Sample Index:

Sediment sample - black sand with about 25% coverage of gravels of shale or greywacke and a little sandstone. L = 2-3 cm. 2 samples taken at 2 depths. Top 5 cm, KDP3A; 5-10 cm, KDP3A2. The bottom sample is much coarser, about 60% pebbles and cobbles – medium sand. All pebbles platy and disc shaped. The deeper part is coarser. Sand deposited on top.

B Sample - No change with depth. The sand is medium and covers 75% of this area. Pebbles and cobbles make up the other 25%. Still platy but better rounded than A. Cobbles' long axis up to 5 cm in size. Pebbles 1/2 cm, max. L axis.

C Sample - No change with depth. Sand is medium with some shell material - 70% sand, covered with small pebbles, I = 3 cm and cobbles, I = 13 cm, making up remaining 25%.

KDP5:

1. Location: 3 km north of Cape Kostromitinof.

2. Body:

This profile is located on an open seaward facing headland. Most of the shoreline has high scarps (approx. 50' high). The profile is located on a pocket beach of medium-coarse sand. The surface is covered by scattered discoidal pebbles. There is a high berm and storm berm, both covered with logs . Basically, this is a slightly erosional pocket beach at the head of the embayment. Profile backed by dense forest. Not much biotic population.

3. Energy and Rock Type:

Relatively high energy - Sediment and rock type - low-rank metamorphic- shale and slate.

4. Sample Index:

The sand is medium to coarse, 1ϕ. 15 cm = L shale or slate discs scattered on surface. Fairly well rounded. Sample A - medium to coarse sand with some 15 cm = L discs, slate or shale. Sample B - same as A, but pebbles only 5 cm = I. Sample C - same as B, but pebbles better rounded.

KDP7 :

1. Location: 5 km northwest of Peril Cape, 58°10'18"N, 152°10'50"W.

2. Body:

Photo station only - high scarps with no landing potential even for helicopter. High vertical scarp. Scarp is very irregular. Very low energy rocky shoreline. Small pocket beaches are poorly sorted and coarse grained. Some lower scarp areas with sea caves and stacks. There are numerous rock slides introducing very coarse and immature (angular) material onto the beach.

3. Energy and Rock Type:

Low energy area - Rock type, low-rank metamorphic rocks.

KDP9:

1. Location: East side of Izhut Bay, 58°12'28"N, 152°12'20"W.

2. Body:

Located in a crenulate bay composed of pure gravel, with a variety of grain sizes. Coarsest up high on storm berm and at low tide terrace near step. Fines in middle beachface. Large number of dead trees backing profile, killed by downwarp salt water intrusion. Gravel is very homogeneous in composition - hard black low-rank fine-grained metamorphic rock. Granules generally elongated and discoidal. Not much biotic population. Very clean and well-sorted gravels will result in great oil penetration. Some small washovers backing storm berm. Multiple berms on beachface.

3. Energy and Rock Type:

Generally lower energy – Rock type, low-rank metamorphic.

4. Sample Index:

A sample - 5 cm to 2 cm L axis, some larger at high tide swash line. B sample - slightly smaller. C sample - similar to A, butter rounded and more bladed. With depth here, no sand - a little gravel, 5%. But the cobbles are smaller as we dig below the surface.

KDP11:

1. Location: Western exposed side of Tonki Cape Peninsula, 58°16'15"N, 151° 57'50"W.

2. Body:

Very irregular section of low rock scarps (10-15 ft. high) exposed to open Gulf of Alaska waves. Mostly coarse poorly developed beaches up high, perched on bedrock platforms. Profile runs across a berm composed of pebbles with a boulder-cobble low-tide terrace covered with algae. Irregular bedrock knobs stick up through the beach and all over the platform. The beach is steep and very clean due to high energy. All gravels and cobbles are well rounded.

3. Energy and Rock Type:

Relatively high energy - Rock type – slate.

4. Sample Index:

Sample A - taken from in front of the berm at the upper beachface. Generally pebble and cobble with some boulders. I = 6 cm. Sample B - from the middle beachface is much the same, except some smaller pebbles and larger cobbles are found here. Also a gravel underneath this sample. Poor sorting. Sample C - this is from the low tide terrace. Cobbles, boulders and pebbles. Very large grain size and poor sorting. Underneath the later material is some granule and coarse sand. The low tide terrace has bedrock outcropping. All sediments are very well rounded with the berm being more disc-like and the beachface and low tide terrace more bladed.

KDP13:

1. Location: East side of Tonki Bay, 58°20'19"N, 152°07'00"W.

2. Body:

Located in a small embayment with a mixed sand - cobble beach fronting a rock scarp. There is a small stream and valley just off the profile to the north with a cobble beach just past that. The profile itself is very straight and simple, showing no distinctive patterns. Irregular patches of coarse gravel, fine cobbles, pebbles and sand cover the surface. The sediments are very well rounded and black. There is a small storm berm with logs on it just behind the stream. A step is apparent at the base of the beachface and a spectacular arch just to the south. Low biotic population on this profile except for the rock arch.

3. Energy and Rock Type:

Moderate energy - Rock type - slate-greywacke.

4. Sample Index:

Sample A is from the upper beachface and it is entirely large to small pebbles, well rounded with a granule and coarse (1.5ø) sand base. A few boulders and cobbles outcrop here. Sample B is from the middle beachface and is much like A, except smaller pebbles, but more cobbles and boulders, also more sand and granule material, poorly sorted. Sample C is from the lower beachface. This is pure pebbles, granule and 1.0 to 0.5ø coarse sand. Better sorting than A or B.

There is a loose step in front of the beachface that is comprised of well-rounded pebbles and granule. Very little sand there. The low tide terrace is similar to the beachface with many boulders. The cobbles and boulders on the beachface average I = 15 cm, with some much larger. There is not much of a shape change on the beach; all sediments are fairly well rounded, especially on the beachface. Many bladed with some equant shapes. Some well rounded discs on and behind the berm up against the scarp.

KDP15:

1. Location: 1 km west of Posliedni Point, 58°25'43"N, 152°17'50"W.
2. Body:

This is a typical rock headland in the Seal Islands area, facing the open Gulf of Alaska. The profile is very simple; it runs down this steep, very coarse-grained beach which is perched on a bedrock platform outcropping at the waterline. The beachface is covered by boulders with a mean size of 100 cm. Most are subangular to subround. Heavy algal coating on bottom 1/3 of profile. The rock scarp backing the profile is quite irregular, with mounds of dipping bedrock.

3. Energy and Rock Type:

High energy - Rock type, higher grade metamorphic rocks, schist and turbidites.

KDP17 :

1. Location: Big Waterfall Bay, 58°24'19"N, 152°31'40"W
2. Body:

This is a small pocket beach between two rock headlands. There are a number of bedrock outcrops in the beachface indicating that the beachface is perched on a bedrock platform. There is a small stream which crosses the profile to the southeast. The area is backed by a dense forest on a high (30') rock scarp. There is a narrow perched berm covered with logs up high, just forward of the scarp. Then a coarser upper beachface composed of granules with scattered mixed gravel and some sandy patches. There is a sharp toe onto a low tide terrace of granule and fine gravel with considerable medium and coarse gravel. Relatively light biota covering the rocks, even on the lower part of the low tide terrace. The headlands surrounding this pocket beach have a very heavy covering of algae, mussels, barnacles, limpets, snails etc.

3. Energy and Rock Type:

Moderate energy - rock type, slatey shale.

4. Sample Index:

Sample A - zone of pure 0.5ø sand. Sample B - on the broad low tide terrace - an unsorted mixture of pebbles, granules and coarse sand. The lower low tide terrace is mostly granule, sand and small pebbles. Grain size is smaller here than the upper and mid low tide terrace. The rounding is fair throughout, and there is no shape change. The composition is mostly of argillite or slate. Many other rock types are found though - greenstone and quartz. Only barnacles are found as the wave energy is moderate to high.

KDP19A:
KDP19B:

1. Location: Perevalnie Islands,
19A - 58°39'05"N, 152°18'45"W
19B - 58°38'25"N, 152°20'00"W.

2. Body:

These are very high shear rock scarps. They have a heavy algal coating. Not many barnacles or mussels - just algae. There are very large "house size" boulders at the base of these scarps. No pocket beaches. This area is highly exposed.

3. Energy and Rock Type:

Very high energy - Rock type, metamorphic (slate and shales).

KDP21

1. Location: Cape Newland, 58°39'05"N, 152°39'05"W.

2. Body:

This is a purely rock profile, run across a rock headland which protects a pocket beach to the south. The profile starts on clean dry rock with effluent of ground water from bedding planes. It then crosses a band of snails, then there is a very sharp contact with a *Fucus* zone, which is 1 m wide (vertically). Below that is a 1.5 m wide band of barnacle sand mussels. Then, below that, the rocks are totally covered by algae. There is a series of these small pocket beaches and rock projections along this shoreline section. Most of the pocket beaches are perched on bedrock platforms. The area is relatively sheltered. Productivity here is very high.

3. Energy and Rock Type:

Low energy - Rock type, greenstone with chert.

4. Sample Index:

Sample X - taken from a granule zone in a small tide pool. This sample approximates the sediment type of the pocket beach to the south.

KDP23:

1. Location: 1 km south of Black Cape, 58°24'14"N, 152°52'55"W.

2. Body:

A gravel-sand pocket beach with headlands on both sides. Behind the profile is a scarp into bedrock capped by a section of glacial outwash. There is a well-developed storm accumulation of coarse gravel, boulders, and logs at the base of the scarp. The broad middle beachface is composed of sand and granules with scattered gravels and cobbles. There are numerous algae swash lines on the beach. At the base of the beachface is a low tide terrace cut into bedrock (wave cut platform) with scattered gravels and boulders on it. Biota is not too high due to continued movement of the sediments. The rock headlands have very heavy accumulations of mussels. There is a large kelp bed offshore. Sediment size coarsens and becomes better rounded as the base of the beachface is approached.

3. Energy and Rock Type:

Moderate energy – Rock type, mostly pillow lava, quartz diorite, chert, greenstone, volcanics and various intrusive.

KDP25:

1. Location: Inner southern shore - Paramanof Bay, 58°17'13"N, 152°50'15"W.

2. Body:

Profile is run at the perimeter of a pocket beach below a 100′ rock cliff. There has been a large rock fall onto the beachface and into the water, where it is covered with algae, etc. The beachface is mostly mixed gravel and granules. It is very short and very steep. There are large boulders from rock fall all over the beach. There are no sediment trends on this beach.

3. Energy and Rock Type:

Low to moderate energy - Rock type, volcanics and metamorphic.

KDP27 :

1. Location: North side Malina Bay, 58°14'25"N, 153°04'30"W.

2. Body:

The profile is backed by a high (greater than 300 ft.) scarp into quartz diorite with well-rounded zeolites. At the base is a perched berm of coarse gravel and cobbles with scattered logs. From there, the sediments fine to the center of the beachface where it is mostly sand and fine gravel. All gravel is equant and subround to well rounded. Toward the toe of the beachface, the sediments get coarser very rapidly. Then there is a boulder-cobble low tide terrace, which is quite steep and short. There are rock falls to the east and west, and a large stack to the east. The rocks on the rock falls and low tide terrace have heavy algae and barnacle cover. A kelp bed is just offshore. Sediment rounding is very good throughout the entire beachface and a typically good shape gradation exists. Disc to rollers as one approaches the waterline.

3. Energy and Rock Type:

Low to moderate energy - Rock type, mostly quartz diorite.

KDP29:

1. Location: South shore - Malina Bay, 58°11'52"N, 153°02'42"W.

2. Body:

A classic gravel profile perched on a bedrock platform. There is a high level storm berm fronting a low scarp. The storm berm is composed of granules and pebbles (4-5cm diameter), mostly discoidal with some scattered logs on top. There are a few very minor berms on the upper beachface. Then it levels out, and gets coarser with well-developed gravel stripes. It is quite coarse and equant - to roller shaped at the waterline. The rock platform projects out from beneath the beachface just to the west of the profile. It has a heavy mussel and algal coating.

3. Energy and Rock Type: Moderate energy, rock type is variable.

4. Sample Index:

Sample A is taken from behind the largest berm in front of the storm berm and about 15 yards from the scarp. It is mainly pebbles of all sizes and shell material, also a little coarse gravel and small (I = 6 cm) cobbles. Pebbles are all well-rounded and are mainly disc-shaped with a few equant, bladed and rollers mixed in.

Sample B is taken from the last high tide line which is a small berm. It is entirely small pebbles and large gravel – good sorting here.

Sample C is taken from the lower middle beachface where the profile has flattened out. The shape here is mainly equant and rollers with some bladed. Sorting is poor with small cobbles, pebbles, granule and coarse (0.5ϕ) sand shell material.

The grain size gets larger toward the waterline. Larger cobbles in the water, but the sorting gets poorer. Behind the largest berm, grain size gets larger, but sorting also gets poorer. Behind the large berm, there is no sand, only gravel pebbles and small cobbles. Much shell material is also found there.

KDP31:

1. Location: Raspberry Strait, north shore, 58°06'15"N, 153°04'00"W.
2. Body:

A small rock headland with the bedrock nearly vertical. This is a dip-slope type of beach. The profile is made up of angular to subangular cobbles (25-30 cm in diameter). There is a zone of barnacles up high, then a clean zone, then a thick zone of *Fucus*. The beach is very steep and homogeneous. Very simple profile. Uniformly coarse grained.

3. Energy and Rock Type:

Moderate energy - Rock type, argillite, slate and some schist.

KDP33:

1. Location: Malina Point, 58°02'25"N, 153°21'53"W.
2. Body:

There is a large headland here with a beautiful multi-berm gravel beach just to the north where we ran the profile. The beachface has three primary pebble berms. Sediments are slightly coarser in the berm runnels and at the toe of the beach. All gravels are pure, well rounded, well sorted and fine. Beach is quite steep. Gravel composition is variable. The storm berm is covered with logs and coarse gravel. Most gravel is disc shaped.

3. Energy and Rock Type:

Moderate energy - Rock type, quartz diorite and argillite.

4. Sample Index:

Sample A - between middle and seaward berm - large pebbles, small pebbles, well rounded, disc-shaped. Sample B - upper beachface - pebbles and granule. Sample C - lower beachface sandy gravel, loose pebbles and small pebbles.

KDP35 :

1. Location: Lost Timber Point, 57°59'25"N, 152°59'10"W.
2. Body:

A low bedrock scarp with narrow flat stretches of beach. Beach material is mixed sand and gravel. Gravel is subangular to subround, black and platy. Beach has two zones: 1) a flat beachface zone and, 2) a flatter low tide terrace made of cobbles to sand. The cobbles are angular and covered with barnacles, mussels and algae. Very simple profile backed by 10′ scarp into sedimentary rock. Trees are falling off of the scarp indicating downwarp effect of earthquake.

3. Energy and Rock Type:

Low energy - Rock type, argillite and slate.

4. Sample Index:

Sample A - upper beach, has large and small pebbles underlain by a gravel and coarse sand made up of rock fragments. Sample B - lower beachface, is cobbles, pebbles and boulders of various sizes. The boulders are small. This is underlain by gravel and 1.0ϕ sands. Very poor sorting. The shape is mainly rollers with a few equant and bladed.

KDP37 :

1. Location: 2 km north of Seiba Point, 57°58'15"N, 153°16'45"W.
2. Body:

Profile on a small gravelly spit indicating transport to the SW. The top of the spit is grassy with some overwash material. There is a very low scarp into argellite slate next. Then there is a high level berm of medium gravel and an upper beachface of sand. There is a smaller berm next, made of pure gravel, all well rounded, platy to discoidal in shape. This berm is cuspate with sandy patches in the bays. The grain size increases from there to the waterline (about 15-20 cm in diameter at waterline). Then they are roller shaped, well rounded argillite fragments. Rock headlands have typical heavy bio-coatings.

3. Energy and Rock Type:

Moderate to high energy - Rock type, argillite slate - low rank metamorphics.

4. Sample Index:

Sample A - just above high water mark - berm. Discs and bladed, large pebbles with a gravel and sand underneath. Sample-B - just below high water mark - berm - large and small pebbles with gravel and sand underneath. Sample C - lower beachface - slate cobbles with a few dioritic cobbles. Small and large pebbles with gravel and sand underneath.

KDP39 :

1. Location: Just southeast of Rolling Point, 57°51'20"N, 153°06'45"W.

2. Body:

This profile is on the sheltered side (east) of the point. It is a small pocket beach in a receded bedding plane erosion zone. There are a number of them in the area. The profile is moderately steep, composed of angular to subangular platy cobbles. Very homogeneous composition (slate - argellite). There is a prominant sandy zone in the middle beach. The lower half of the beachface is covered with the typical intertidal life. This is a poorly-sorted beach.

3. Energy and Rock Type:

Low energy - Rock type, slate, argillite.

4. Sample Index:

Beachface is large platy boulders and cobbles on a coarse (1.0 to 0.5ϕ) sand - Sample A. The sand is also platy rock fragments and shell material. Sample A was taken from there. Sample B - the middle beachface is large pebbles with a coarse sand and small pebble base. Some loose cobbles are also mixed in. Sample C – the lower beachface is all cobbles and boulders with pebbles and shell material. Underneath is some coarse sand rock fragments,

KDP41:

1. Location: lower west side of Terror Bay, 57°42'12"N, 153°10'35"W.

2. Body:

This station is located at the head of Terror Bay. There is a large fan delta and tidal flat complex associated with the Terror River. There are very broad mussel flats on swash bars fronting the river. The station has heavy marsh grass all over the surface of the inner bars (the high parts); the lower parts are covered with an algal mat layer. Beneath the algal cover is a sand and gravel river bar. The sediments are coarser than expected down low (mud would be more typical, but this is sands and granules). There is a definite decrease in grain size as you approach the delta edge. There is not much infauna here, surprisingly.

3. Energy and Rock Type:

Low energy - Rock type, highly mixed river sediments.

4. Sample Index:

Sample A is from the algal mat. Sample B is from the coarse material below it. Sample C is from the lower part of the marsh. Closer to the river mouth, the marsh sediment is much finer here and mussels and *Fucus* growth are very extensive.

KDP43:

1. Location: Uganik Bay, 4 km north of Rock Point on outer Northeast Arm 57°48'03"N, 153°27'45"W

2. Body:

This is a small pocket beach about 100 m wide. It is narrow and uniform, located between two rock headlands. Backing the beachface is a rock scarp into slate (5' high). There is a high level berm of coarse discoidal gravel, then on the middle beachface there are a number of smaller berms of fine gravel with algal swash lines on them. From there, the material coarsen again to the water line; where there are scattered larger boulders. The rock headlands are heavily coated with typical intertidal algae and encrusting life. Most sediments are well sorted and well rounded.

3. Energy and Rock Type:

Moderate energy - Rock type - mostly slate - argillite with chert, greenstone, and quartz diorites.

4. Sample Index:

Sample C – lower beachface – granules, fine gravel and some larger gravel and cobbles.

KDP45:

1. Location: Uganik Bay, south shore of East Arm, 57°42'25"N, 153°28'55"

2. Body :

This is a small crenulate beach indicating transport to the NE. The profile is very highly concave upward, being very steep on the landward side. There is a low scarp up high with some aeolian activity behind it (mostly carbonate fragments, barnicle frags.). There is minor storm overwash gravel up there also. The entire profile has discoidal gravel scattered on the surface. Mostly black sand and gravels. The most striking feature is the very discoid shape of gravels. The coarsest gravels occur on the low flat portion of the profile, finer in mid-beachface then coarse up high. Heavy algal cover on bottom ¼ of profile. Under the lower beach is a sand – gravel mix. Most of the sand is 0.0 to 1.5 ∅ rock fragments.

3. Energy and Rock Type:

Low-moderate energy. Rock type: quartz diorite, slate and schist.

4. Sample Index:

Sample A – The top unit was a pure pebble unit, below it, a mixture of coarse unsorted fragments that make up a coarse sand. Some pebbles were also mixed in sample KDP45, top; and bottom KDP45 1 and 2; this sample was taken from the small loose pebble interface. Sample B - is mostly pebbles with a gravelly sand underneath mixed with pebbles. Sample C - is a mixture of large and small pebbles and gravel with a coarse sand and gravel underneath which is also mixed with pebbles.

We sampled the pebble berm and upper smaller pebble beachface, also a relict dune KDP45D.

KDP47 :

1. Location: 3 km west of Broken Point, 57°52′35″N, 153°39′35″W.

2. Body :

Located in a small embayment which has a highly indented shoreline eroding into glacial till. It is flanked on both sides by bedrock headlands, The beach is steep, a mix of sand and gravel typical of reworked glacial material. There are two gravel berms at the base of the scarp. From there, the profile slopes off uniformly in a long gentle slope with a step that was above water when the profile was run. The rock headlands have heavy intertidal biota.

3. Energy and Rock Type:

Moderate to high energy - Rock type - quartz diorite and schist, greenstone, slate. Very variable gravel composition.

4. Sample Index:

Sample A - appears to be pure pebbles. Av. I = 1-2 cm, but under the surface layer is a mixture of pebbles and sand. Volumetrically about 75% cobbles; 25% sand. The sand is about 1ϕ.

Sample B - located mid-beachface, we go from pebbles to gravel and pebbles. Sand is also found here (1.0ϕ).

Sample C - the grain size of the sand is slightly coarser than the berm on upper beachface 0.5ϕ. Scattered small and medium pebbles as well as much gravel here, about

60% sand

30% gravel

10% pebble

KDP49:

1. Location: 3 km north of Chief Point, 57°43'50"N, 153°55'40"W

2. Body:

Profile is run in a pocket beach backed by a lower rolling topography. This particular pocket is rather sheltered. There is a low scarp up high fronted by a coarse gravel zone. Then there is a zone of coarse sand over cobbles all perched on a bedrock platform. The rest of the profile is a long irregular rock platform covered with subangular to subround cobbles all covered with zoned epifauna. Start with a zone of Fucus and numerous small snails, then heavy mussel accumulation, getting larger seaward with a Mya looking clam burrowed in. Further out there is a pink bryozoan and many starfish, limpets, urchins, snails, hermit crabs, etc.

3. Energy and Rock Type:

Low to moderate energy - Rock type: schist, greenstone and slate.

4. Sample Index:

Sample A - mixed coarse sand and shell fragments with moderate sized

cobbles lying on top. Average cobbles I = 7 cm; L = 15 cm. The sand is black.
Sample B - large cobbles and schist bedrock. The cobbles mainly schist and greenstone with some slate. Cobbles are I = 15 cm.
Sample C – same as B.
All the cobbles are subangular. Cobbles and rocks on the berm are also subangular, but not that disc like. No shape change but a size change from small cobbles on the berm to sand and cobbles and pebbles on the upper beachface to coarse gravel and cobbles and bedrock on the lower beachface.

KDP51 :

1. Location: Inner Spiridon Bay, 57°36'15"N, 153°35'50"W

2. Body:

A small pocket beach opposite two rock islands with connecting tombolos and gravel beaches. Thus this beach is highly protected. The gravels on the beach are very immature (discoid and angular to the water line). The pocket is partly protected by the rock scarps. The profile starts at the base of a low scarp backed by a valley. It crosses a narrow berm of fine and medium gravel with scattered logs. Then it crosses a steep beachface with numerous algal swash lines. Heavy intertidal life on bottom 1/3 of profile.

3. Energy and Rock Type:

Very low energy – Rock type: slate

4. Sample Index:

Sample A - beachface, small gravel with granule base. Most of beachface is similar.

KDP53:

1. Location: North side of Zachar Bay, 57°35'35"N, 153°48'30"W

2. Body :

This beach has three sharp zones. The beach is backed by a partly vegetated scarp into slate. Fronting this is a fine gravel-sand zone, then a coarse gravel-boulder mid-beach, then a boulder-cobble lower beachface covered with typical biota. The pocket is 100 m long and 30 m in width. It is not steep due to very poor sorting.

3. Energy and Rock Type:

Low to moderate energy - Rock type: argillite - slate

4. Sample Index:

The entire mid and lower beachface covered with barnacles. Sub-angular slate and/or argillite cobbles. The sorting is poor. A distinct grading of material toward the sea is obvious. Grain size gets larger seaward. Under the cobbles is mainly granule and small pebbles. Some qtz, greenstone and possibly sandstone cobbles are found in very small numbers on the beachface. A smooth steady slope exists along the entire beach.

KDP55:

1. Location: Southern eastern shore of Amook Bay, 57°25'22"N, 153°48'40"W

2. Body :

This is a very well developed discoid gravel beach. The beach is broad and steep. There is a scarp into slate backing the beach. Upper beachface is fine and medium gravel, then medium to coarse gravel then coarse gravel, finally near the water line its mostly boulders. The biota is highly zoned: 1) Barnacles, 2) mussels and barnacles, 3) mussels, 4) algae, 5) total coverage with many starfish. The gravel at the base of the beachface is slightly better rounded, still very platy.

3. Energy and Rock Type:

Low energy - Rock type: slate.

4. Sample Index:

The upper beachface and berm is well sorted - small discoid pebbles with a granule base. Some qtz is mixed in at the mid beachface. Only sample was A – upper beachface. B and C are photo samples.

KDP57 :

1. Location: Inner west shore of Uyak Bay, 57°20'50"N, 153°48'34"W

2. Body :

Located on a small mid-bay-spit. This spit is very high and very steep, composed of fine to medium gravel. The beachface is quite uniform. Transport is out of the bay. The opposite side of the spit (facing north) is composed of coarser gravel on a rock platform. This beach has quite high energy considering its location. There are a few relict beach ridges on storm berms on the top of the spit, heavily vegetated. May be indicators of uplift. Most of this beach is well sorted and underlain by granules.

3. Energy and Rock Type:

Moderate energy - Rock type: shale, slate and argillite.

4. Sample Index:

Sample A - upper beachface - pure gravel

Sample B - mid–beachface - pure fine gravel

Sample C - lower beachface pure gravel – slightly coarser.

KDP59 :

1. Location: Middle west shoreline of Uyak Bay, 57°35'22"N, 153°58'00"W

2. Body:

Small pocket beach between two bedrock projections, backed by a low scarp into slate. Just at the base of the scarp is an accumulation of fine gravel and sand. The sediment coarsens toward the waterline. There are a lot of boulders on the beachface. Down low, its mostly coarser gravel on a gravel-granule foundation. The rock projections have heavy biotic coating. This section of shoreline has relatively high wave energy. In general beaches on the western shorelines of these fijords have broader beaches, better sorted, better developed berms and less encrusting biota; all indicators of higher energy than the east sides.

3. Energy and Rock Type:

Moderate energy - Rock type - slate

4. Sample Index:

Sample A - upper beachface - 1.0ø sand and granule mix with gravel on surface.

Sample B - photo sample - platy subangular cobbles and mixed gravel.

Sample C - photo sample - same as B but coarser.

KDP61:

1. Location: 4.5 km southwest of Rocky Point, 57°38'28"N, 154°17'00"W

2. Body :

Profile is backed by a 150-200′ granodiorite scarp, which is vegetated in some places. There is no indication of recent rock fall at the base of the scarp. There is a small stack 150 m to west. Fronting the scarp is a gravel zone, then a sandy zone, followed by a fine to medium gravel berm. In front of the berm is another sandy area which intersects amixed gravel berm top overwash of a second gravel berm. From that point to the water line, the sediments coarsen rapidly. At the water line are mostly large boulders (0.5 - 1.0 m diameter), with coarse gravel and cobbles. There is a large kelp bed offshore. Much less biota on the rocks here, due to wave energy and sediment supply.

3. Energy and Rock Type:

High energy - Rock type - granodiorite and some slate.

4. Sample Index:

The beach material is well rounded with many equant and roller shaped gravels and cobbles at the lower beachface, and bladed and discs on the berms.

Sample A - sandy area up high.

Sample B - 2nd berm top overwash - gravel on granule - sand mix.

Sample C - boulder – cobble terrace with considerable granules and gravel.

KDP63 :

1. Location: Spit fronting - Sturgeon River, 57°32'05"N, 154°33'05"W

2. Body :

Open beach is pure gravel and cobbles. Profile is backed by shallow lagoon - tidal flat with heavy en-grass and an organic mud bottom. The beach on the lagoon side is fine gravel and organic mud; from there it slopes up on a steep slip face of the washover terrace. On the top of the washover is a storm berm covered with logs. The beachface has three berms. The top one is the largest, composed of pure gravel. Middle one is finer and bottom one is coarsest (medium to coarse gravel). The final berm intersects a boulder-cobble low tide terrace. There is a kelp bed offshore. All sediments are well rounded quartz diorite.

3. Energy and Rock Type:

Very high energy with occasional violent storms - Rock type - quartz diorite.

4. Sample Index:

Samples - all gravel of various sizes.

KDP65:

1. Location: 5 km north of Gurney Bay, 57°19'48"N, 154°45'05"W

2. Body:

This is a slightly sheltered rocky coast, however, it does get high energy at times. The beach is fairly complex but basically dominated by large boulders on a narrow wave cut platform with bedrock outcropping all over. There are scattered pockets of gravels, cobbles and sand. The rock scarp backing the profile is very irregular with many stacks. Intertidal life coats these scarps heavily. The profile is relatively flat and littered with boulders (3-4 m long axis). The boulders have considerable biota: mussels, large and small barnacles, starfish, limpets, algae, snails and so forth, very diverse.

3. Energy and Rock Type:

Moderate energy - Rock type - quartz diorite, slate and greenstone.

4. Sample Index:

The beach material under the boulders and cobbles is all pebbles, granules and 0.0ϕ coarse sand.

Sample X - taken midway through the profile. It is a sample of pebbles, gravel and coarse sand. The average size of the beach material is 2-3 cm, pebbles and all sizes down to sand. Cobbles and boulders are very abundant also.

KDP67:

1. Location: Just landward of Ayakulik Island, 57°12'40"N, 154°33'00"W

2. Body:

Located on a wide glacial till plain. The scarp is high (70-80') into muddy till. The profile contains one simple convex upward berm with incipient cusps . There is a complex zone of sand, granules and gravel on the berm surface. The bays of the cusps are sand and granules, the horns are coarser gravels. There is also a zone of coarser gravel just beneath the scarp, and at the step. There appears to be a wave cut platform just offshore with a sandy ridge on it. Relatively steep profile.

3. Energy and Rock Type:

High energy - Rock type - highly varied of glacial origin.

4. Sample Index:

Sample A - berm top - sand, granules and fine gravel.

Sample B – mid-beachface – mostly granules with scattered mixed gravel.

Sample C - lower beachface - granules and mixed gravel and cobbles all are well rounded and generally equant.

KDP69:

1. Location: 3 km southeast of Low Cape, 56°59’OO”N, 154°28'15"W

2. Body:

This profile is basically a wave cut platform into till with a well developed beach on” top of it. The profile is backed by a low (10’ high) scarp into outwash sediments (distal, mostly silts). At the base of the scarp is a narrow upper beachface of boulders and cobbles with logs on top. Then there is a sandy zone with fine and medium gravel. This zone intersects the low tide terrace which has sandy incipient ridges on it. The low tide terrace is covered with boulders and cobbles (left by the retreating scarp) on a sand base. Relatively light biota. This beach is quite broad and highly zoned with regard to grain size.

3. Energy and Rock Type:

High energy - Rock type - very variable-glacial source

4. Sample Index:

Sample A - upper beachface - fine sand

Sample B - mid-beachface - fine sand with gravels on top.

Sample C - lower beachface on ridge – medium sands.

All sediments are well rounded especially at the base of the beachface.

KDP71:

1. Location: Akhiok Bay near Sea Plane Base, 56°56'20"N, 154°10'22"W

2. Body :

This area is extremely sheltered. There are many flat islands just offshore. This peninsula is flat topped and covered with tundra. There is a low scarp into slate and shale. The beachface is very narrow. Sediments tend to fine toward the waterline. There is a uniform offshore slope. The bottom is muddy with many shale clasts. All sediments are angular indicating no reworking - no energy. Very numerous clams offshore. The islands are very similar to this area.

3. Energy and Rock Type:

Very low energy - Rock type - slate and shale.

4. Sample Index:

All beach material is angular, mostly coarse gravel and cobbles (10-15 cm = I).

KDP73 :

1. Location: East side Moser Peninsula just west of Fox Islands, 56°59’30”N, 154°03'05"W.

2. Body :

This profile is located on a small cuspate spit. The top of the spit is highly vegetated with a relict storm berm. The present storm berm is also vegetated, indicating infrequent but violent storms. The beachface is pure gravel with some sand behind neap berm, which has a well developed berm top overwash. There is a strong fining trend from the top to the bottom of the beachface. The top has coarse discoid argillite gravel. The bottom has fine equant gravel. The beach is clean, very low biota due to active sediment movement.

3. Energy and Rock Type:

Moderate to high energy - Rock type - argillite and quartz diorite.

4. Sample Index:

Sample A - just seaward of storm berm - coarse gravel and cobbles.
Sample B - neap berm crest - fine gravel.
Sample C – coarse gravel and cobbles with gravel ribbons.

KDP75:

1. Location: North shoreline of Alpine Cove, 57°08'30"N, 153°45'35"W

2. Body :

This is a small low wave energy pocket beach. It has a very narrow beachface (25 m). The beachface is composed of fine and medium platy subangular greywacke gravel, with granules beneath. There is a small scarp cut into a vegetated flat at the top of the profile. The beachface has numerous algal swash lines. The gravels are very well sorted. Offshore slope is quite steep. Relatively low biota.

3. Energy and Rock Type:

Low energy - Rock type - greywacke and some quartz diorite.

KDP77:

1. Location: Southern Hepburn Peninsula; Portage Bay, 56°47'48'N, 153°53'50"W

2. Body :

The profile is backed by a low scarp into till. At the base of the scarp is a layer of reducing algae which is decaying on top of a wave cut platform into the till. The middle beachface has boulders and gravel resting on bedrock. So this profile is very simple: a wave cut platform cut into till which overlies bedrock. Relatively high biota.

3. Energy and Rock Type:

Moderate energy - Rock type - bedrock is slate; gravels and cobbles are shale, argillite and diorite.

4. Sample Index:

Sample A - Till scarp with slate and argillite gravels.

Sample B - boulders and cobbles and gravel on bedrock platform. Most are subround.

KDP79:

1. Location: Alitak Bay just north of Seaborg Bay, 56°53'28"N, 154°58'40"W

2. Body :

This profile runs across a small spit that encloses a stream. There is a 2 "m high scarp down to the stream from the spit top. The spit slopes gently upward to the crest. The beachface has considerable algal swashes on it. Beach composed of sand and gravels, Lower beachface is mostly gravel and granules. There is a low ridge on the low tide terrace. This is a broad depositional beach. Relatively low biota due to sediment and wave energy. Steep beachface, flat low tide terrace.

3. Energy and Rock Type:

Moderate energy - Rock type - variable, introduced from stream.

4. Sample Index:

Sample A – spit crest, mostly sand with some scattered mixed gravel.

Sample B - mid-beachface - mostly pure granule.

Sample C - low tide terrace - fine gravel, granules and 1.0ϕ sand.

Most of the beach is underlain by sand. Gravels are mostly fine and well rounded.

KDP81:

1. Location: Geese Channel about 15 km southwest of Old Kaguyak Bay, $56^{o}49'55''N$, $153^{o}46'25''W$

2. Body :

Profile backed by high rock scarp, partly vegetated. The profile is on a very broad bedrock platform. Bedrock is standing vertically to 45° angle. There is a rock fall at the base of the scarp (boulders and cobbles are well rounded indicating high wave energy). There is a series of algal swash lines on a fine and medium gravel and sand lower beachface. There is a prominant toe down to the rock platform. The beachface is only 30 m wide. The platform has very heavy intertidal life and numerous very rich tidal pools.

3. Energy and Rock Type:

Moderate to high energy - Rock type - greywache.

4. Sample Index:

Sample X - taken from gravel - sand lower beachface. Mostly subangular gravel.

KDP83 :

1. Location: Kaguyak Bay - north shoreline, $56^{o}54'55''N$, $153^{o}41'25''W$

2. Body :

Profile is backed by a high vegetated scarp. At base is a poorly developed storm berm composed of boulders and gravel which fines seaward. Logs are scattered on storm berm. Storm berm face is composed of medium and coarse well rounded gravel. The beachface is mostly medium and fine gravel and sand. There is a well developed step onto a boulder-cobble low tide terrace covered with abundant fauna. The profile is bounded on both sides by rock ramparts with stacks. "There are islands just offshore.

3. Energy and Rock Type:

Moderate energy - Rock type - slate.

4. Sample Index:

Sample A - high tide swash line, gravels and cobbles with coarse sand.

Sample B – mid beachface medium and fine gravel and sand.

Sample C - lower beachface, fine and medium gravel and sand.

B and C are mostly 0.0ϕ sand. Scattered bedrock boulder outcrops all over.

KDP85:

1. Location: Kiavak Bay, 57°01'50"N, 153°35'15"W

2. Body:

Very high scarp backs the profile. At base is a high level berm of very coarse gravel and cobbles and boulders with scattered logs. There is a cuspate berm with coarse gravel horns and sandy bays. Bedrock platform outcrops at the base of the beachface. The bedrock has fairly heavy biota. Very poor sorting on the beachface. All gravels etc. are subrounded.

3. Energy and Rock Type:

Moderate to high energy - Rock type - greywacke.

4. Sample Index:

Sample B - mid beachface in a sandy area (1.0ϕ).

KDP87 :

1. Location: 2 km north of Cape Kasiak, 57°04'33"N, 153°29'00"W

2. Body :

Profile is backed by a high vegetated scarp. There are two berms of granules with fine to coarse gravels. There are large angular boulders (l-3 m diameter) at the base of the scarp from rock falls. The beachface has incipient cusps with zones of coarse gravel and sandy areas. The beachface is steep until it intersects the low tide terrace which is quite flat and composed of boulders and cobbles. There is a prominent zonation of the biota on the L.T.T. (very heavy and diverse).

3. Energy and Rock Type:

Moderate to high energy - Rock type - greywacke and argillite.

4. Sample Index:

Sample A - upper berm face - mixed gravel.

Sample B - mid lower beachface - sandy patch in horn.

Sample C - lower beachface - sand, granule and mixed gravel.

Most gravels are subangular.

KDP89 :

1. Location: Sitkalidak Strait, north shoreline, near Three Sisters Rocks, $57^{o}12'55''N$, $153^{o}09'10''W$

2. Body :

Profile located on seaward side of large cuspate spit. This profile is very interesting with a large washover sequence on the back side, possibly a function of the earthquake downwarp. The washover terrace has migrated landward over a low marsh area. Most of the washover material has gone over the top of this spit without being deposited on top. The beachface is quite complex. There is a minor berm up high composed of medium gravel. There are two other larger berms on the mid beach face. Then two have very steep landward faces. Then there is a very minor granule berm just above the waterline. Most of the material is mixed sand and gravel with granules predominating. There are three zones of coarser material. One just below a low scarp cut into the vegetated spit top, and then two behind the larger berms. A classic transgressive profile.

3. Energy and Rock Type:

Low to moderate energy - Rock type - slate with some schist and diorite.

4. Sample Index:

Sample A upper large berm - subround platy to discoidal gravel.

Sample B - lower large berm - subround mixed gravel (I = 6 cm).

Sample C – lower beachface - mostly granules.

KDP91:

1. Location: Inner southern shoreline of Kiliuda Bay, 57°18'15"N, 153°10'35"W

2. Body:

Profile is run on a small spit composed of discoidal platy gravel. There is a small scarp down to a lake behind the spit. The spit top is made of pure discoid gravel, mostly fine. The beachface has a series of small berms with algae swash lines. Most of the beachface is uniform of slope and grain size. There is a slight coarsening trend as the waterline is approached. At the base of the beachface there is a narrow low tide terrace. There is a light algal cover on the larger gravels and cobbles on the low tide terrace.

3. Energy and Rock Type:

Low energy - Rock type - slate and argillite.

4. Sample Index:

Sample A – upper berm - mostly fine discoid gravel, well sorted and angular.

Sample B - mid beachface - coarse angular gravel, fine gravel and granules.

Sample C - coarse gravel and granules. Grain size increases seaward but sorting decreases.

KDP93 :

1. Location: Western outer shoreline of Boulder Bay, 57°16'45"N, 152°47'30"W

2. Bodv:

This profile is exposed to open Gulf of Alaska waves. There is a high shear rock scarp (500' high) backing the profile with "room size" boulders at its base (rock fall). There is considerable fine and medium gravel thrown up between the boulders. Fronting this is a berm of medium very well rounded gravel. The beachface is steep, composed of sand and granules. There are two large rock falls into waterline on each side of this beach. They have a moderate coating of biota, but the beach here is quite clean due to energy and sediment.

3. Energy and Rock Type:

Very high energy - Rock type – greenstone and argillite.

4. Sample Index:

Sample A - berm, medium gravel, well rounded.

Sample B - mid beachface coarse gravel on a granule base.

Sample C - lower beachface - fine well sorted and rounded gravel.

KDP95:

1. Location: Middle southern shoreline of Ugak Bay, 57°27'40"N, 152°46'50"W

2. Body:

Profile is located on the updrift end of a large cuspate spit-delta complex. The profile is backed by a low scarp cut into a old aluvial fan terrace, highly vegetated. The profile is complicated, starting with a sandy high berm, followed by a well developed gravel berm. Fronting that is another sandy zone and then a sharp crested fine gravel berm. The profile then flattens out across a gravel-sand ribbon area. It then coarsens to the water line.

3. Energy and Rock Type:

Moderate to low energy - Rock type - variable, shale, slate, argillite, diorite.

4. Sample Index:

Sample A - upper fine gravel, granule sand berm.

Sample B - sharp crested gravel granule berm.

Sample C - lower beachface, mixed sand and gravel.

KDP97:

1. Location: Large pocket beach 2 km east of Shark Point, 57°27'15"N, 152°33'50"W

2. Body:

Profile has a small river backing it with a large washover terrace into the river. There are two major log accumulations on the profile - one vegetated storm berm and one on the river side probably the result of storm surge during storms. The overwash terrace has a pea gravel ablation surface on a black volcanic - metamorphic sand. The beachface is steep at the top, then flattens out in an area of ground water rills. Most sediment is black sand with scattered mixed gravels. There is a general fining trend from the washover terrace to mid beachface, then a coarsening trend to the waterline.

3. Energy and Rock Type:

Moderate energy - Rock type - metamorphic rock fragments.

4. Sample Index:

Sample A - upper beachface - sand and granules.

Sample B - mid beachface - same.

Sample C - lower beachface - same.

Most sand is about 1.5ϕ.

KDP99:

1. Location: 1.5 km north of Sequel Point, 57°34'15"N, 152°11'55"W

2. Body:

Profile is a very simple narrow beach fronting a high rock scarp. The beachface has three zones, 1) mixed gravel beneath scarp, 2) granule area in mid beachface and, 3) mixed gravel lower beachface. All this is perched on a bedrock platform which outcrops at the waterline.

3. Energy and Rock Type:

Very high energy - Rock type - argillite.

4. Sample Index:

Sample A - base of scarp - mixed gravel on a granule - coarse sand base.
Sample B - the mid beachface pure granule with some very coarse sand. Well sorted.
Sample C - lower beachface, similar to upper beachface. Pebbles with a granule base. Good overall sorting on this beach, also well rounded.

KDP101:

1. Location: 1 km southwest of Broad Point on the Gulf of Alaska shoreline, 57°40'45"N, 152°24'20"W

2. Body:

Profile is backed by a high scarp into interbedded shale, slate and sandstone. Beachface is short and steep. There is discoid gravel up high, it fines in the middle of the beachface and becomes coarser and more equant at the base of the beachface. There is a large stack to the south. Only a moderate coating of biota.

3. Energy and Rock Type:

Low energy - Rock type - slate, shale, sandstone.

4. Sample Index:

Sample A - coarse - fine gravel, angular and discoid.

Sample B - mid beachface - mixed gravel with granules and sand.

Sample C - lower beachface - slightly coarser than B.

KDP103 :

1. Location: 250 m south of Gibson Cove, 57°46'30"N, 152°26'50"W

2. Body :

This profile is partly man-altered, located near the Gibson Cove Cannery. There is a high scarp into slate and a beachface which is mostly a bedrock platform covered with the typical intertidal life of these protected areas. The platform is partly covered at the top and middle by angular gravel to boulders of slate, all locally derived.

3. Energy and Rock Type:

Low energy - Rock type - slate.

4. Sample Index:

Samples - all photos - coarse gravel to boulders of angular to subangular discoidal slate.

KDP105 :

1. Location: Course Point, 57°53'45"N, 152°28'00"W

2. Body :

This is a small pocket beach opposite Spruce Island. It is surrounded by a 60′ high rock scarp. The beachface is narrow, covered with logs and algae swashlines. It is composed mostly of mixed gravel to sand on bedrock. Beachface is very steep. Rock scarps and stacks have zoned biotic cover. Large kelp bed offshore.

3. Energy and Rock Type:

Low to moderate energy - Rock type - argillite with shale interbeds.

4. Sample Index:

Sample A - upper beachface, subround discoid gravel with some granules and sand.

Sample B - mid beachface, slightly coarser and covered with algae swash.

Sample C - lower beachface, well sorted, well rounded gravel, mostly bladed and roller shaped.

KDP107 :

1. Location: East side of Sharatin Bay, 1 km south of Three Pillar Point, 57°50'43"N, 152°42'55"W

2. Body :

The profile is backed by a low scarp into phylite-slate which is overlain by outwash sand and gravel. The beachface is mostly mixed gravels and boulders of slate, some scattered intrusive gravels (glacially derived). Rounding increases sharply toward the waterline. Mostly subangular at base of scarp. This is a small delta just to the south of the profile and a stack to the north. The biota is not particularly rich here, rather low energy. The beachface sediments form a veneer on a bedrock platform.

3. Energy and Rock Type:

Low energy - Rock type - slate-phylite with variable glacially derived gravel.

4. Sample Index:

All photo samples of mixed gravels and boulders.

KDP109 :

1. Location: Western shore of Kizhuyak Bay, 57°50'07"N, 152°53'35"W

2* Body:

Profile backed by a low (10′ high) scarp into slate and shale which is overlain by till and outwash sediments. Fronting the scarp is an upper beachface of fine gravel and sand overlain by angular boulders and cobbles which become better rounded toward the waterline. There are numerous large boulders (1 m diameter) which are very heavily coated with encrusting biota. This beach is perched on a wave cut platform into bedrock. Sediments are generally quite coarse, mostly coarse gravel and cobbles.

3. Energy and Rock Type:

Low energy - Rock type - slate, shale and glacial variety (quartz, quartz diorite, intrusive).

4. Sample Index:

All samples are photos. Mostly boulders, cobbles and mixed gravel with some granules beneath, all on bedrock. Most beach sediments are platy and sub-angular.

KDP111 :

1. Location: Eastern shore of Whale Island, 57°57′30″N, 152°44'05"W

2. Body:

Profile backed by a 4m scarp into argillite with intrusive dikes and bedded welded tufts, There is a prominant bedrock projection to the north, all covered with heavy intertidal life. About 90% of this profile is on bedrock covered in places with a thin veneer of gravels. There is strong evidence of downwarp here, dead trees at top of scarp falling onto upper beachface. The larger boulders are covered with algae etc. There are many small gravel - sand pocket beaches in this area, which are very clean. The area shows many signs of the Good Friday Earthquake downwarp.

3. Energy and Rock Type:

Moderate to high energy - Rock type - argillite and intrusive

4. Sample Index:

All samples are photos. Mostly cobbles and gravels on the bedrock with some pockets of sand or granules.

KDP113 :

1. Location: Eastern, north shore of Marmot Island, $58^{o}14'45''N$, $151^{o}47'20''W$

2. Body :

The profile is fairly typical of this area, being backed by a low scarp into low ranked metamorphic rock. The beachface is quite narrow and steep, composed of sand and gravel. It is coarser up high at the berm just below the scarp. The berm has incipient cusps on its face. There is a well developed step onto the bedrock platform at the base of the profile. Large knobs of bedrock protrude through the beachface. The bedrock platform is very irregular, and knobby with many tidal pools. It is coated with heavy intertidal life, Fucus is most common; not too much encrusting forms.

3. Energy and Rock Type:

Moderate to high energy - Rock type - slate, greywacke.

4. Sample Index:

Sample A - just below berm - rounded bladed pebbles and small cobbles. Under this is a coarse sand and granules.

Sample B - mid beachface, granule and very coarse sand.

Sample C - lower beachface. Pebbles and granule.

The pebbles and small cobbles are well rounded and bladed. There is little change along the profile. Below the berm, the pebbles get smaller and the middle beachface is granule and very coarse (0.0 to 0.5ϕ) sand.

The lower beachface is pebbles and granules with some bedrock boulders outcropping.

KDP115:

1. Location: North shoreline of the Southern Uganik Passage, 57°49'45"N, 153°19'15"W

2. Body :

This area is occupied by a series of relict drumlins which have been eroded. Some are rock covered. The shoreline has been straightened out and faces the Alaska Peninsula. The profile itself is located on a tombolo. The beachface is composed of pure fine gravel with some sand. 'There are four separate small berms. the highest is composed of medium discoidal gravel (10 cm diameter). The lowest berm is very cuspate. Below that berm, the beachface flattens out and is covered by very well developed gravel' stripes or ribbons (wave length 4.8 m and about 30 cm high).

3. Energy and Rock Type:

Low to moderate energy - Rock type - argillite and' slate.

4. Sample Index:

Sample A – the seawardmost berm, the smallest berm. I-t is mostly pebbles - small ones and composed of mostly argillite or slate and a few qtz pebbles. 1.0ϕ sand and gravel underneath.

Sample B - from the coarse part of a gravel striation. Pebbles on top with sand, granule and shell material below.

Sample C - lower beachface, sand and pebbles with a few small pebbles. Some granule material. The sand is coarser (1.5ϕ) but more abundant than the upper beachface. The sorting is very poor.

The pebbles at the 4 berms are all subrounded and disc shaped with good sorting. The beachface is sand and pebbles with many gravel and pebble striations.

KDP117 :

1. Location: Northwest shoreline of Tugidak Island, 56°32'25"N, 154°38'50"W

2. Body :

Profile fronting a till scarp. The beachface is dominated by sand with scattered gravels and cobbles on surface. Profile starts at berm at the base of the scarp. There is an accumulation of logs on this berm. There is an irregular berm below the high berm. The berm face has well developed ground water rills. Below that berm, the beachface intersects a wave cut platform into till which is littered with erratics. The till has a good percentage of sand, granules and gravel. It is a very wide platform and quite irregular with algae growing on the outer edge.

3. Energy and Rock Type:

Moderate to high energy - Rock type - very variable.

4. Sample Index:

Sample A - upper beachface - mostly sand with scattered gravel.
Sample B - middle beachface - mostly sand (1.5ϕ) and gravel.
Sample c - lower beachface - same as B.
Most gravel is well rounded and equant. There are no grain size trends on the beachface.

KDP119 :

1. Location: Southern shoreline of Tugidak Island, 56°29'45"N, 154°33'45"W

2. Body:

This a depositional profile. There is a broad series of beach ridges over a dead scarp, well behind the active beachface. The beach ridges are very long parallel just like the present berms, and ridge and runnel system.

The profile is very complex with three berms and a well developed ridge and runnel system. The high storm berm is composed of sand and gravel with a sharp face. There are low dunes behind the berm. The second berm is large and highly cuspate with gravelly horns, The lowest berm is sandy and not too high. There is a deep runnel with a high ridge just seaward.

3. Energy and Rock Type:

High energy - Rock type - mixed sand.

4. Sample Index:

Sample A - upper berm face - sand.

Sample B - cuspate berm face - coarse sand with some fine gravel.

Sample C - lower beachface - sand with granules.

The beachface below the third berm is about 90% sand and 10% well rounded equant to bladed pebbles. Some pebbles are quite large here.

KDP121 :

1. Location: Northwest side of Sitkinak Island, 56°36'12"N, 154°04'25"

2. Bodv :

This profile is a strong indicator of uplift. The profile starts at a small lake, fronting a large vegetated hill with a relict scarp in it. Fronting the lake is a relict beach ridge spit of gravel and granules, all heavily vegetated. Seaward of that are three other vegetated beach ridges. The lake occupies what used to be a lagoon. Transport was toward the north. The beachface has a well developed storm berm covered with logs and fine and medium gravel (equant). The beachface is made of gravel and granules with a few algae swashlines. There is a broad spring tide berm in the middle beachface. The lower beachface is almost pure granules.

3. Energy and Rock Type:

High energy - Rock type - variable.

4. Sample Index:

Sample A - storm berm, pure gravel and granules.

Sample B - lower berm, sand with scattered mixed gravel and granules.

Sample C - lower beachface, well sorted fine gravel and granules.

KDP123 :

1. Location: Southeastern Sitkinak Island, 56°29'50"N, 154°03'00"W

2. Body:

The profile is backed by a high rock scarp into argillite and greywacke, with numerous rock falls at its base. There is a poorly developed mixed gravel berm fronting the scarp. Many angular cobbles and boulders are found on the berm. The beachface slopes steeply to a boulder-cobble low tide terrace. The boulders are large (1 m diameter) and well rounded, The terrace is quite narrow.

3. Energy and Rock Type:

High energy - Rock type - argillite, sandstone, greywacke.

4. Sample Index:

Beach material is very variable, poorly sorted and of variable shape.

KDP125:

1. Location: Southeast shore of Sitkalidak Island, 57°00'18"N, 153°14'30"W

2. Body :

This profile is backed by a very broad uplifted terrace about 80′ higher than the present one. It goes on for many kilometers. There is a sharp scarp into the bedrock to the upper beachface. At the base is a perched berm of coarse gravel and boulders with logs. Then there is a very steep beachface of poorly sorted boulders to sand and mixed gravel. At its base is a narrow zone of well rounded boulders and cobbles on a bedrock platform. The bedrock platform is irregular with many tidal pools and very abundant intertidal life.

3. Energy and Rock Type:

High energy - Rock type - argillite.

4. Sample Index:

Sample A - upper berm, gravel and cobbles.

Sample B - mid beachface finest material, coarse sand and mixed gravel.

Sample C - boulder cobble zone - all well rounded and equant.

KDP127 :

1. Location: Cape Barnabas, 57°09'00"N, 152°52100"

2. Body :

Profile is backed by a high scarp into mudstone. There is a perched berm at the base of mixed gravel (well rounded). The berm is highly irregular. This pocket beach is about 200 m wide. Beachface is narrow and perched on a bedrock platform. Very heavy life on platform.

3. Energy and Rock Type:

Very high energy - Rock type - mudstone and greywacke.

4. Sample Index:

Sample A - upper beachface - medium and coarse gravel.

Sample B - mid beachface - sand and granules with mixed gravel.

Sample C - lower beachface - same as B.

APPENDIX 3

Afognak A-O + B-O

Class	Km of Shoreline
1	11.7
2	32.5
3	
4	
5	
6	13.3
7	12.5
8	
9	
10	

Afognak A-1

Class	Km of Shoreline
1	36.6
2	
3	
4	
5	
6	5.8
7	12.5
8	55.8
9	
10	

Afognak A-2

Class	Km of Shoreline
1	27.4
2	
3	
4	
5	
6	10.8
7	14.2
8	54.1
9	
10	

Afognak A-3

Class	Km of Shoreline
1	10.8
2	
3	
4	
5	
6	
7	40.0
8	54.9
9	
10	

Afognak A-4

Class	Km of Shoreline
1	29.1
2	
3	
4	
5	
6	25.8
7	75.8
8	5.0
9	
10	

Afognak A-5

Class	Km of Shoreline
1	5.0
2	
3	
4	
5	
6	13.4
7	
8	
9	
10	

Afognak B-1

Class	Km of Shoreline
1	
2	45.8
3	
4	
5	
6	
7	16.7
8	94.9
9	1.7
10	

Afognak B-2

Class	Km of Shoreline
1	14.2
2	14.2
3	
4	
5	
6	
7	32.5
8	76.6
9	
10	

Afognak B-3

Class	Km of Shoreline
1	23.4
2	25.9
3	
4	
5	
6	
7	30.9
8	126.9
9	
10	

Afognak B-4

Class	Km of Shoreline
1	8.3
2	
3	
4	
5	
6	
7	7.5
8	
9	
10	

Afognak C-1 + C-2

Class	Km of Shoreline
1	22.6
2	15.0
3	
4	
5	
6	
7	6.7
8	20.0
9	
10	

Afognak C-2 + C-3

Class	Km of Shoreline
1	
2	47.6
3	
4	
5	
6	
7	3.3
8	108.6
9	
10	

Kodiak A-3

Class	Km of Shoreline
1	9.2
2	12.5
3	
4	
5	
6	11.7
7	7.5
8	
9	
10	

Kodiak A-4

Class	Km of Shoreline
1	
2	42.6
3	5.9
4	3.3
5	
6	87.7
7	25.1
8	
9	11.7
10	10.9

Kodiak A-5

Class	Km of Shoreline
1	13.4
2	30.9
3	
4	
5	
6	44.3
7	10.0
8	24.5
9	
10	1.6

Kodiak A-6

Class	Km of Shoreline
1	
2	1.7
3	
4	
5	
6	22.5
7	
8	60.7
9	1.7
10	8.3

Kodiak B-1 + B-2

Class	Km of Shoreline
1	
2	55.1
3	
4	
5	
6	29.2
7	
8	
9	
10	

Kodiak B-3

Class	Km of Shoreline
1	1.2
2	36.7
3	
4	1.0
5	0.7
6	43.4
7	34.2
8	
9	2.5
10	1.7

Kodiak B-4

Class	Km of Shoreline
1	
2	3.3
3	
4	
5	
6	21.7
7	23.9
8	
9	2.2
10	5.0

Kodiak B-5

Class	Km of Shoreline
1	
2	
3	
4	
5	
6	
7	
8	
9	8.4
10	2.5

Kodiak B-6

Class	Km of Shoreline
1	
2	
3	
4	
5	
6	
7	49.3
8	41.8
9	2.2
10	

Kodiak C-1

Class	Km of Shoreline
1	1.7
2	23.3
3	
4	
5	
6	15.0
7	
8	
9	
10	

Kodiak C-2

Class	Km of Shoreline
1	10.9
2	22.2
3	
4	
5	2.5
6	25.1
7	
8	20.0
9	5.0
10	5.0

Kodiak C-3

Class	Km of Shoreline
1	
2	1.7
3	
4	1.1
5	
6	2.5
7	23.5
8	
9	2.2
10	3.7

Kodiak C-4

Class	Km of Shoreline
1	
2	
3	
4	
5	
6	
7	1.7
8	25.9
9	1.2
10	

Kodiak C-5

Class	Km of Shoreline
1	3.3
2	2.7
3	
4	
5	
6	10.9
7	5.0
8	67.7
9	6.7
10	6.7

Kodiak c-6

Class	Km of Shoreline
1	20.9
2	12.5
3	
4	
5	
6	27.6
7	46.3
8	60.1
9	1.7
10	3.3

Kodiak D-1

Class	Km of Shoreline
1	
2	25.1
3	
4	
5	
6	4.5
7	
8	5.3
9	
10	

Kodiak D-2

Class	Km of Shoreline
1	1.7
2	53.4
3	
4	
5	
6	24.2
7	8.4
8	93.5
9	1.2
10	4.5

Kodiak D-3

Class	Km of Shoreline
1	
2	44.3
3	
4	
5	
6	7.0
7	77.7
8	23.4
9	
10	2.3

Kodiak D-4

Class	Km of Shoreline
1	18.4
2	17.9
3	
4	
5	
6	53.8
7	9.2
8	79.3
9	
10	

Kodiak D-5

Class	Km of Shoreline
1	
2	34.2
3	
4	
5	
6	45.1
7	19.2
8	20.0
9	
10	

Kodiak D-6

Class	Km of Shoreline
1	11.7
2	2.5
3	
4	
5	
6	9.2
7	8.3
8	
9	
10	

Kaguyak c-6

Class	Km of Shoreline
1	
2	22.5
3	
4	
5	
6	17.4
7	
8	
9	5.0
10	

Kaguyak D-5

Class	Km of Shoreline
1	8.3
2	11.7
3	
4	
5	
6	5.0
7	2.5
8	
9	
10	

Kaguyak D-6

Class	Km of Shoreline
1	31.6
2	
3	
4	
5	
6	89.0
7	
8	30.8
9	
10	2.6

Trinity Islands C-1

Class	Km of Shoreline
1	
2	19.1
3	5.8
4	
5	
6	70.7
7	2.5
8	37.4
9	4.2
10	2.5

Trinity Islands B-2 + C-2

Class	Km of Shoreline
1	
2	
3	18.3
4	
5	
6	39.9
7	
8	30.8
9	
10	

Trinity Islands B-3 + C-3

Class	KM of Shoreline
1	
2	
3	
4	
5	
6	26.7
7	
8	
9	
10	

Trinity Islands D-1

Class	Km of Shoreline
1	7.5
2	29.1
3	
4	
5	
6	45.0
7	
8	86.6
9	
10	

Trinity Islands D-2

Class	Km of Shoreline
1	
2	
3	
4	
5	
6	15.5
7	
8	6.7
9	
10	

Karluk A-1

Class	Km of Shoreline
1	
2	
3	
4	
5	
6	5.8
7	13.4
8	72.4
9	2.5
10	

Karluk A-2

Class	Km of Shoreline
1	1.0
2	
3	
4	
5	
6	29.2
7	1.7
8	26.7
9	
10	

Karluk B-2

Class	Km of Shoreline
1	
2	5.0
3	
4	
5	
6	6.7
7	1.0
8	7.0
9	
10	

Karluk B-3

Class	Km of Shoreline
1	26.7
2	
3	
4	
5	
6	24.2
7	
8	11.2
9	
10	

Karluk C-1

Class	Km of Shoreline
1	
2	15.0
3	
4	
5	
6	11.2
7	2.0
8	11.7
9	
10	

Karluk C-2

Class	Km of Shoreline
1	20.0
2	0.6
3	
4	
5	
6	1.6
7	9.2
8	21.7
9	
10	

AFOGNAK

Class	Km	% Afognak	% Total Study Area
1	189.1	14.7	50.2
2	181.0	14.0	25.6
3			
4			
5			
6	69.1	5.4	7.3
7	252.6	19.5	39.8
8	596.8	46.3	40.8
9	1.7	0.1	2.8
10			
Total	1290.3	100.0	

KODIAK

Class	Km	% Kodiak	% Total Study Area
1	92.4	4.7	24.5
2	422.6	21.4	59.8
3	5.9	0.3	19.7
4	5.4	0.3	100.0
5	3.2	0.2	100.0
6	485.4	24.4	51.5
7	349.3	17.7	55.1
8	522.2	26.3	35.7
9	46.7	2.4	77.7
10	44.6	2.3	89.7
Total	1977.7	100.0	

KAGUYAK

Class	Km	% Kaguyak	% Total Study Area
1	39.9	17.6	10.5
2	34.2	15.1	4.8
3			
4			
5			
6	111.4	49.3	11.8
7	2.5	1.1	0.4
8	30.8	13.6	2.1
9	5.0	2.2	8.3
10	2.6	1.1	5.2
Total	226.4	100.0	

TRINITY ISLANDS

Class	Km	% Trinity Islands	% Total Study Area
1	7.5	1.7	2.0
2	48.2	10.8	6.8
3	24.1	5.3	80.3
4			
5			
6	197.8	44.1	21.0
7	2.5	0.6	0.4
8	161.5	36.0	11.0
9	4.2	0.9	7.0
10	2.5	0.6	5.0
Total	448.3	100.0	

KARLUK

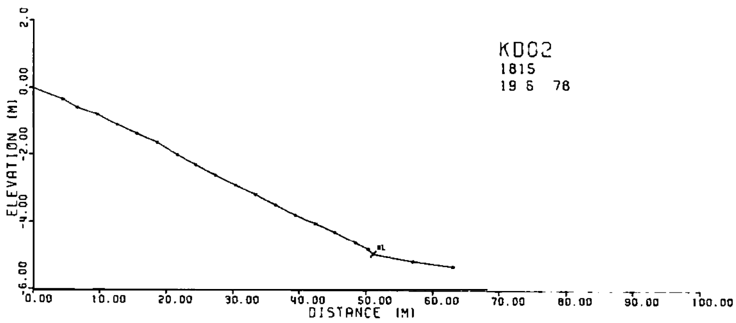
Class	Km	% Karluk	% Total Study Area
1	47.7	14.6	12.7
2	20.6	6.3	2,9
3			
4			
5			
6	78.7	24.0	8.4
7	27.3	8.3	4.3
8	150.7	46.0	10.3
9	2.5	0.8	4.2
10			
Total	327.5	100.0	

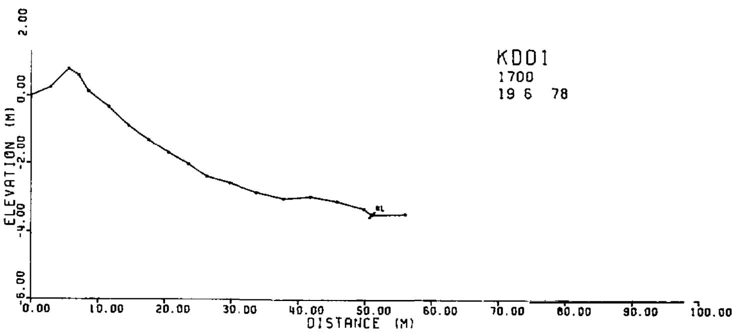
GRAND TOTALS

Base Maps	Total Shoreline Kms	% of Total
Af ognak	1290.3	30.2
Kodiak	1977.7	46.3
Kaguyak	226.4	5.3
Karluk	327.5	7.7
Trinity Islands	448.3	10.5
Grand Total	4270.2	100.0

Class	Total Shoreline Kms	% of Total
1	376.6	8.8
2	706.6	16.5
3	30.0	0.7
4	5.4	0.1
5	3.2	0.1
6	942.4	22.1
7	634.2	14.9
8	1462.0	34.2
9	60.1	1.4
10	49.7	1.2
	4270.2	100.0

APPENDIX 4


KD02
1815
19 6 78
ELEVATION (M)
DISTANCE (M)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1700
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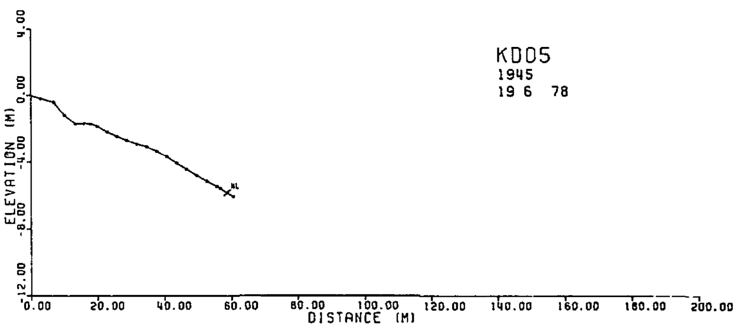
DISTANCE (M)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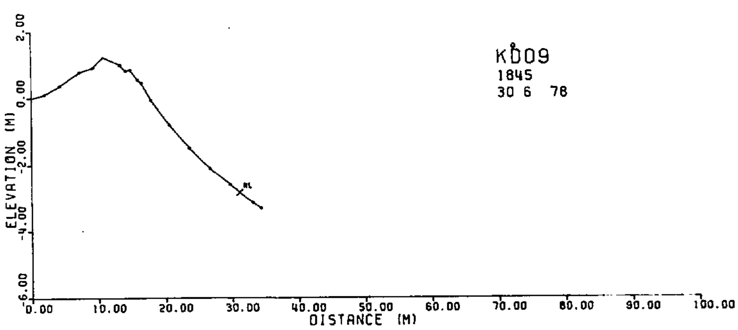
DISTANCE (M)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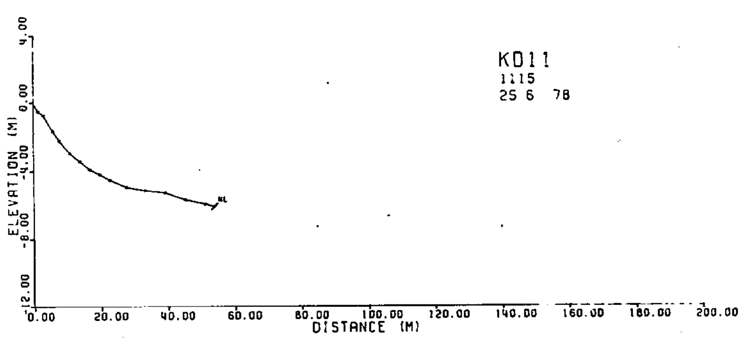
DISTANCE (M)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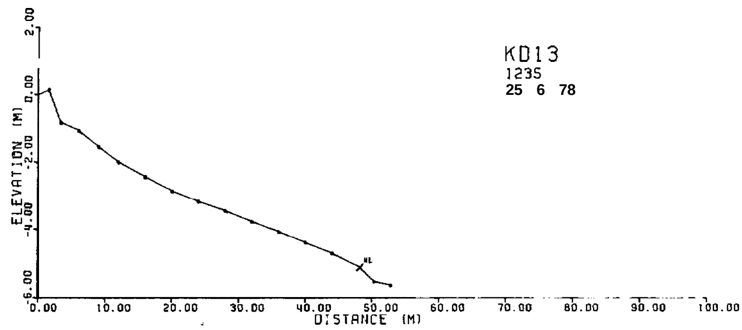
DISTANCE (M)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1235
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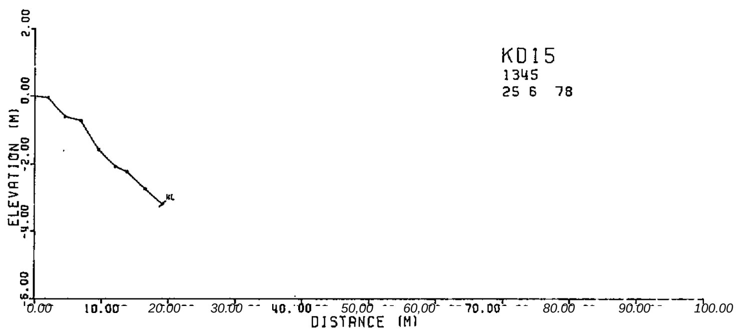
DISTANCE (M)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1345
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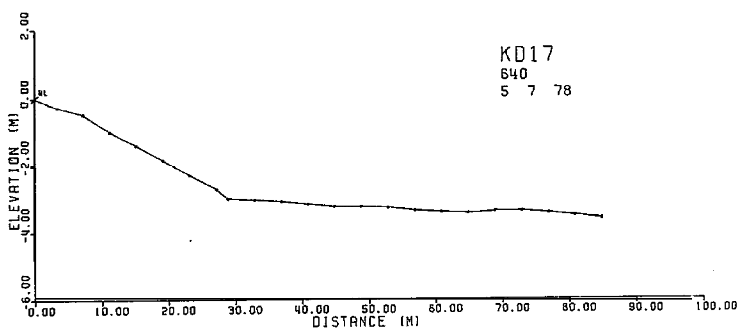
ELEVATION (M)
DISTANCE (M)


KD17
640
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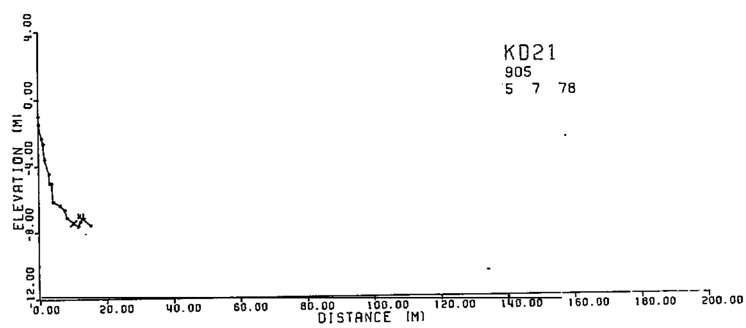
DISTANCE (M)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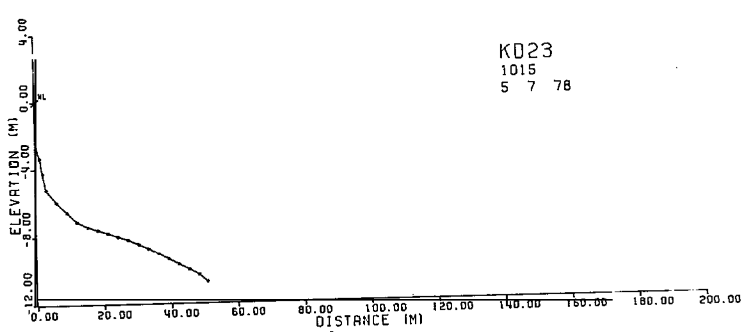
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1015
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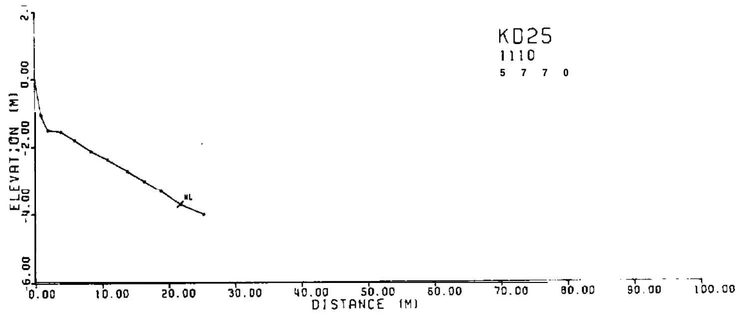
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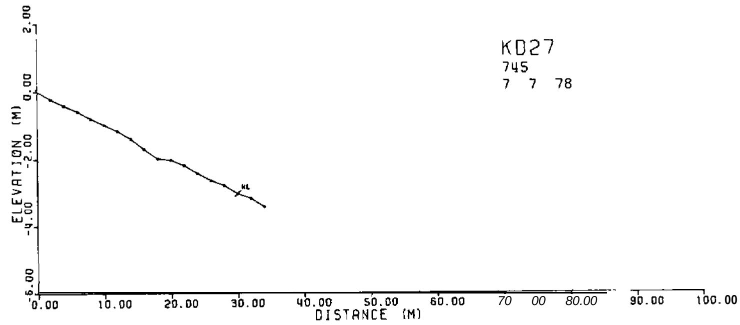
DISTANCE (M)
WL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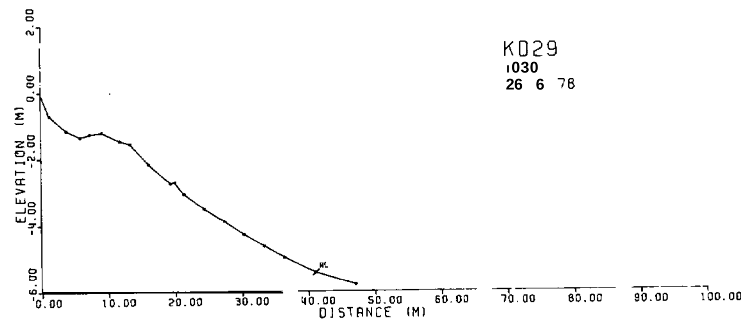
DISTANCE (M)
WL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DISTANCE (M)
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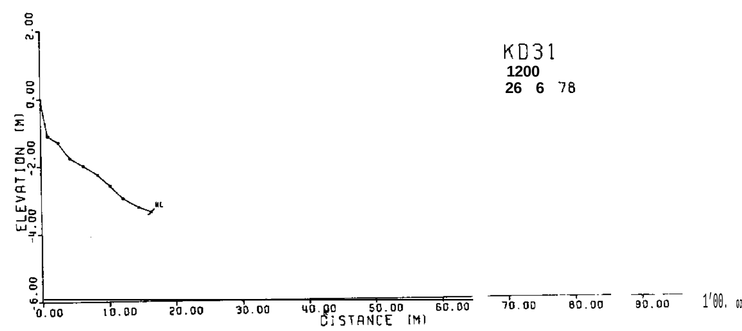
KD31
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DISTANCE (M)
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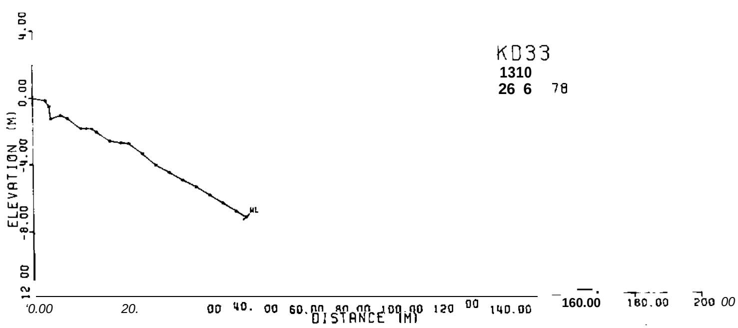
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DISTANCE (M)
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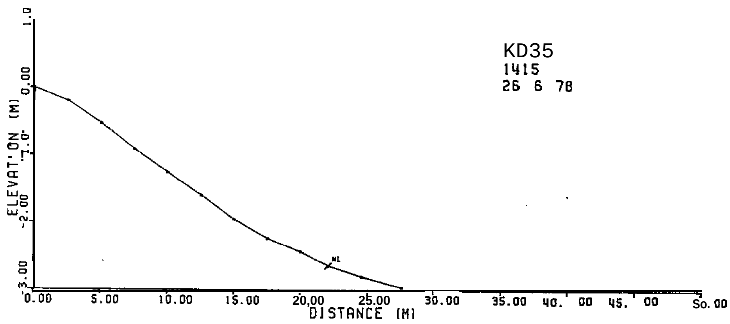
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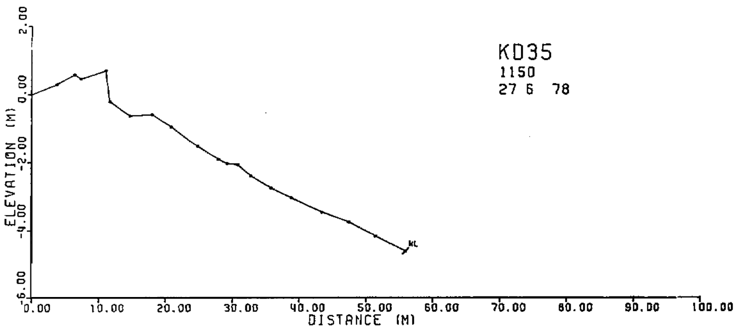
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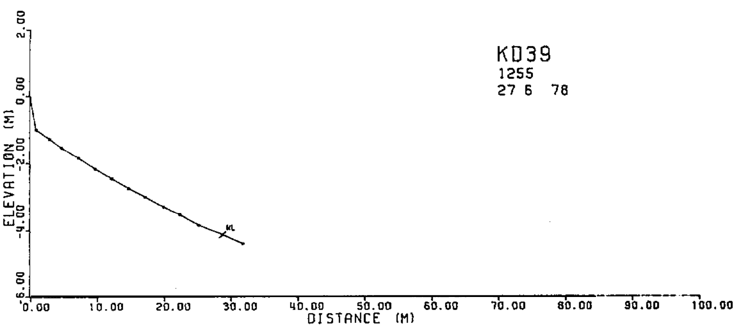
DISTANCE (M)
WL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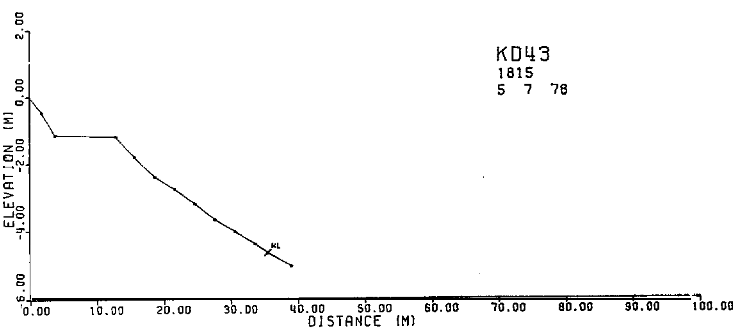
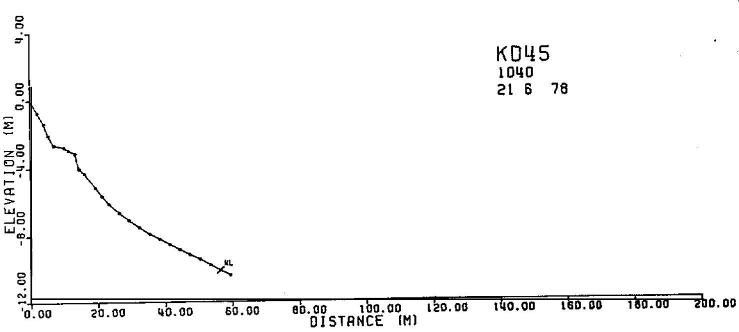
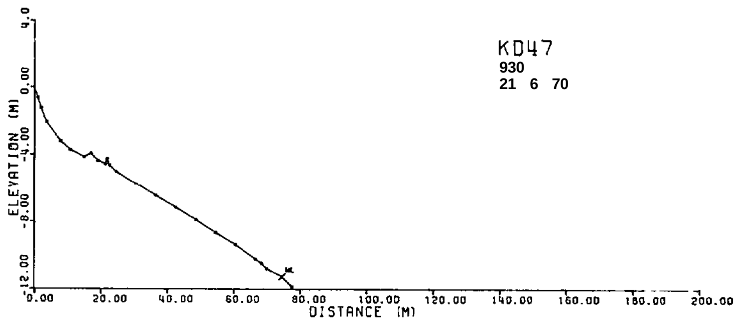
ELEVATION (M)
DISTANCE (M)
WL


KD43
1815
5 7 78
ELEVATION (M)
DISTANCE (M)
WL


KD45
1040
21 6 78
ELEVATION (M)
DISTANCE (M)
WL

4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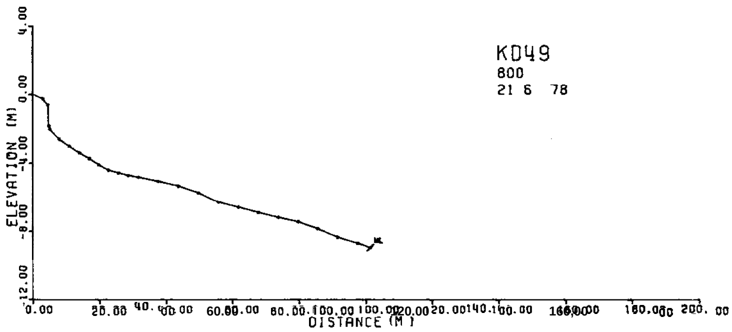
180.00
200.00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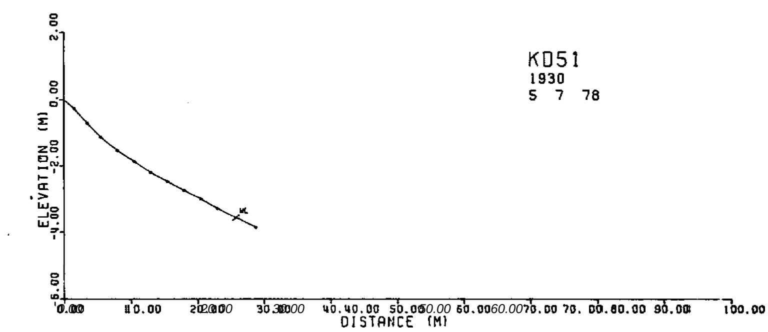
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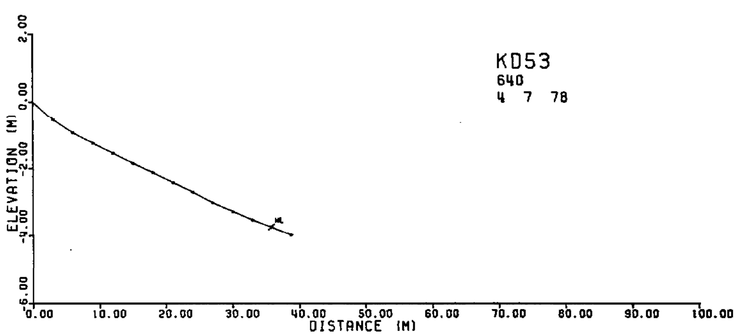
DISTANCE (M)


KD53
640
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DISTANCE (M)
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20.00
30.00
40.00
50.00
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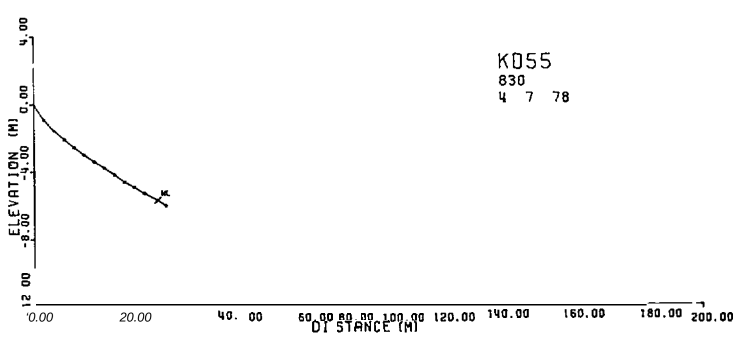
80.00
90.00
100.00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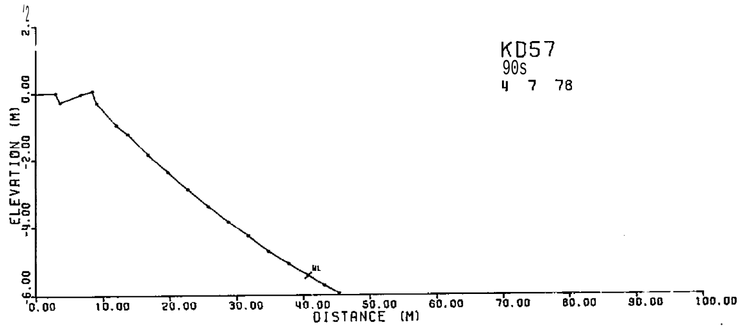
ELEVATION (M)
DISTANCE (M)


KD57
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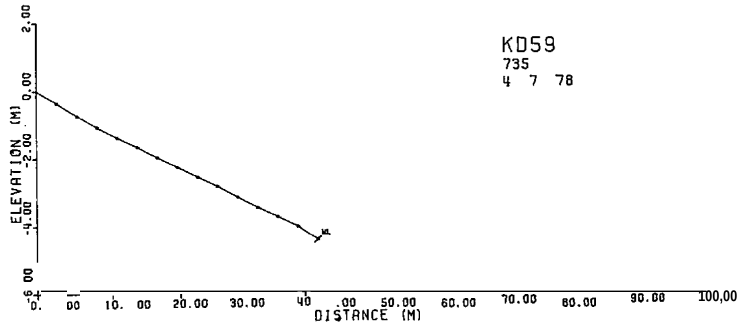
KD59
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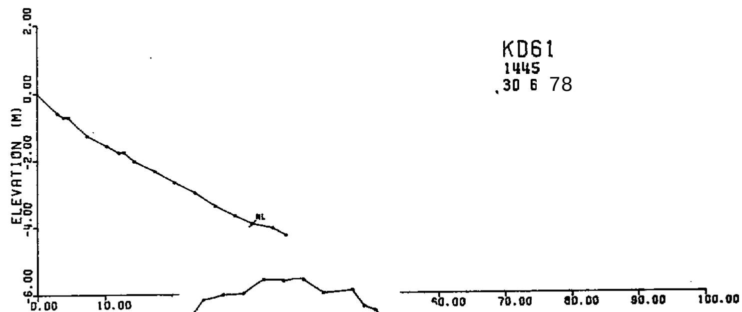
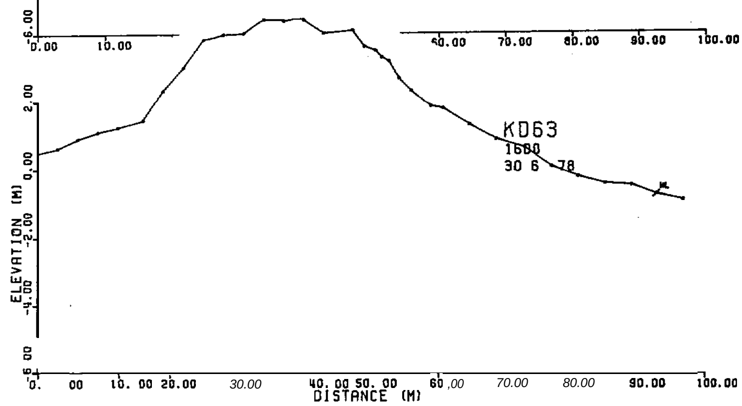

KD61
1445
30 6 78
ELEVATION (M)


KD63
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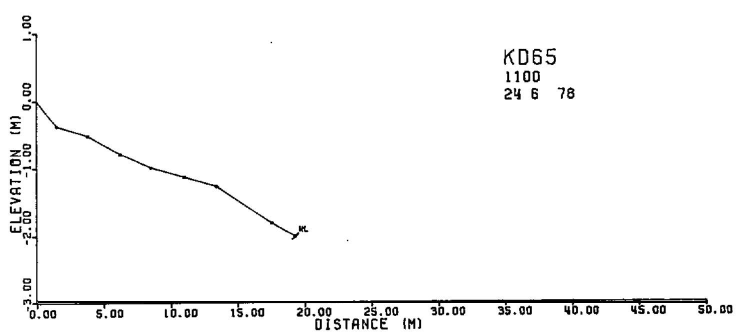
DISTANCE (M)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24 6 78
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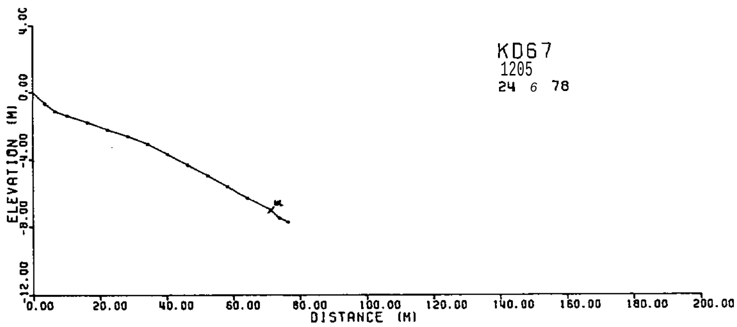
DISTANCE (M)


KD67
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24 6 78
ELEVATION (M)
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100.00
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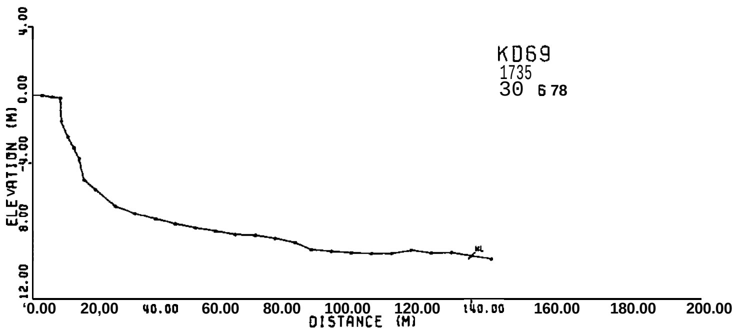
180.00
200.00


KD69
1735
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60.00
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160.00
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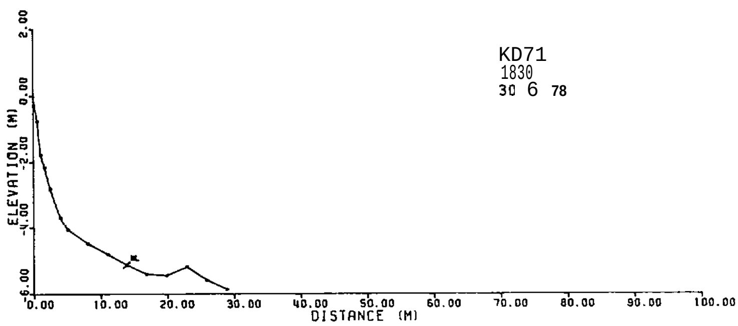
200.00


KD71
1830
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30.00
40.00
50.00
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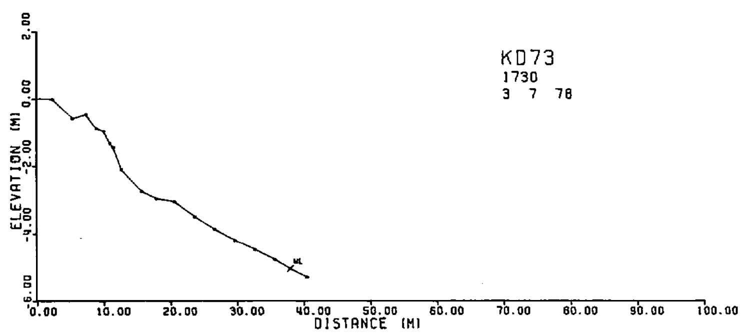
80.00
90.00
100.00


KD73
1730
3 7 78
ELEVATION (M)
DISTANCE (M)
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20.00
30.00
40.00
50.00
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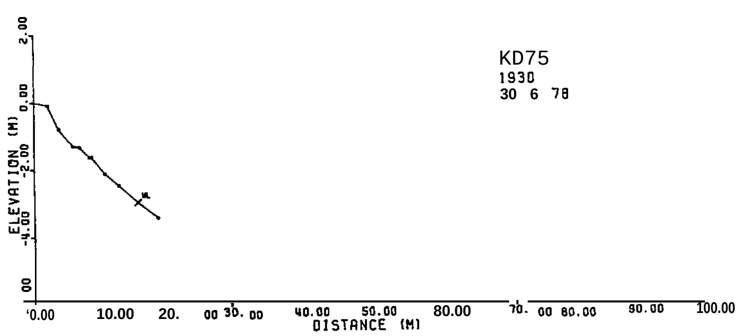
80.00
90.00
100.00


KD75
1930
30 6 78
ELEVATION (M)
DISTANCE (M)
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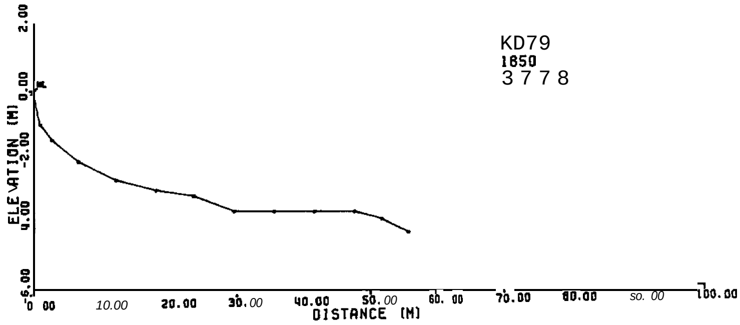
10.00
20.
30.00
40.00
50.00
80.00
70.00
80.00
90.00
100.00


KD77
1815
ELEVATION (M)
DISTANCE (M)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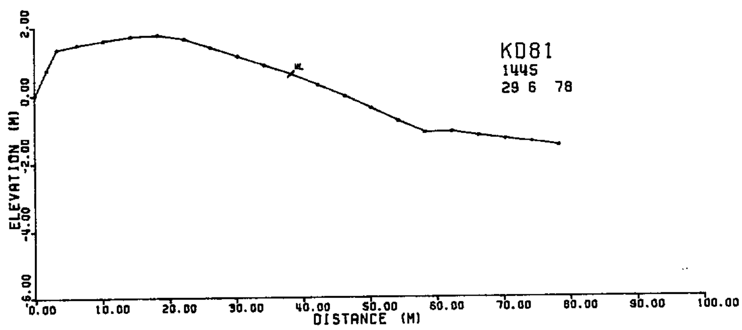
DISTANCE (M)


KD81
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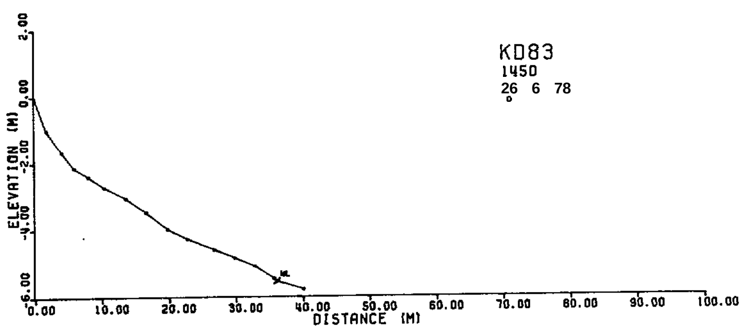
DISTANCE (M)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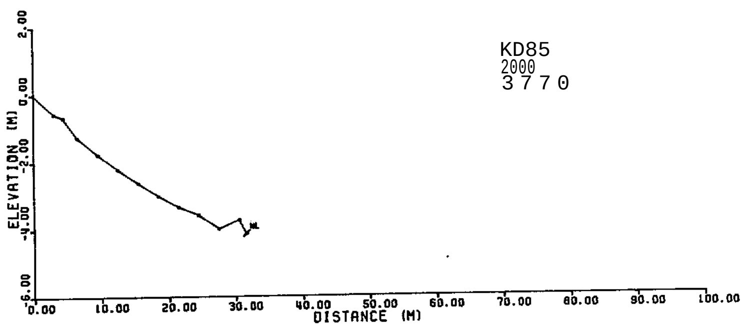
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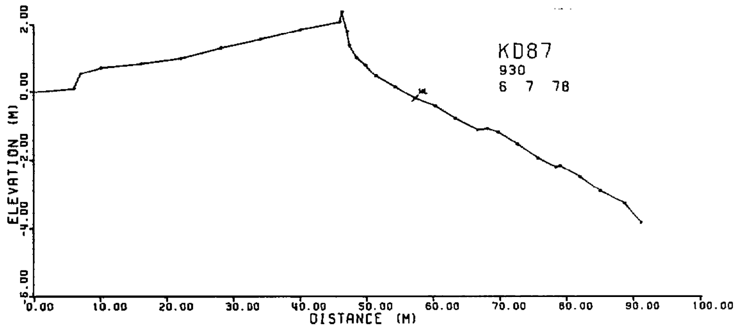
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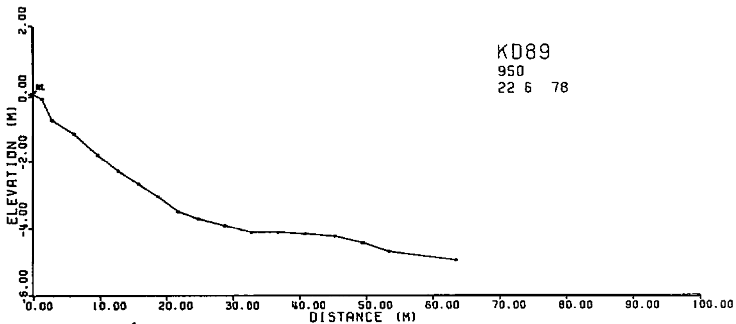
DISTANCE (M)


KD89
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22 6 78
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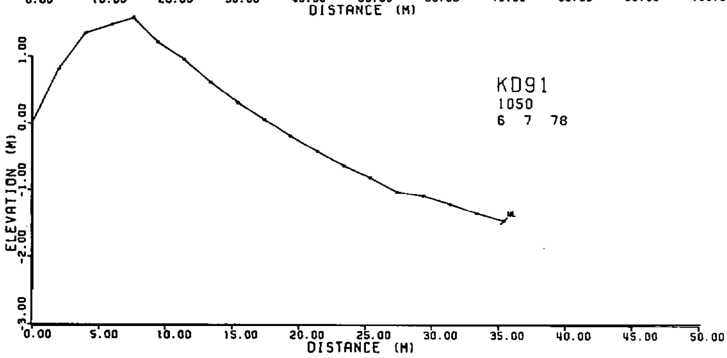
DISTANCE (M)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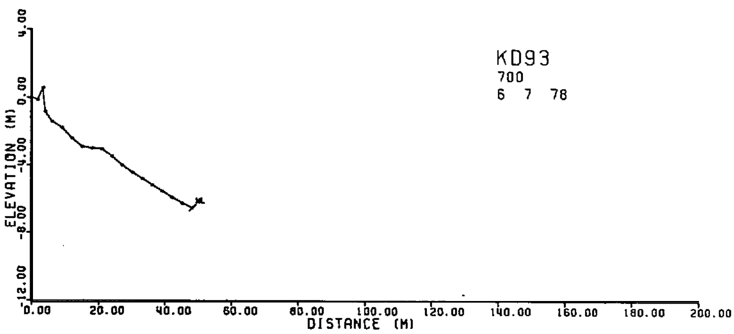
DISTANCE (M)


KD93
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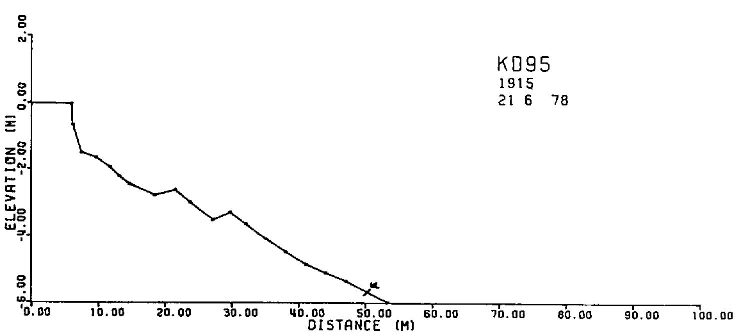
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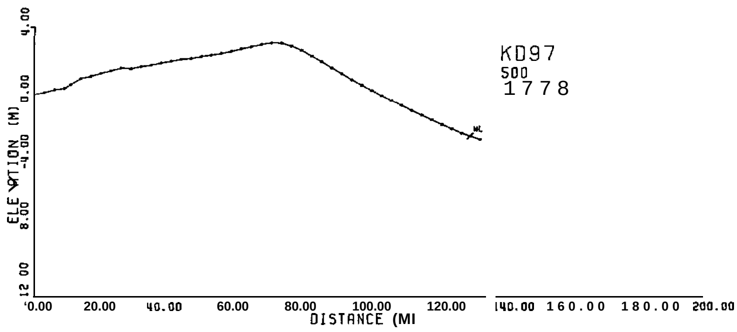
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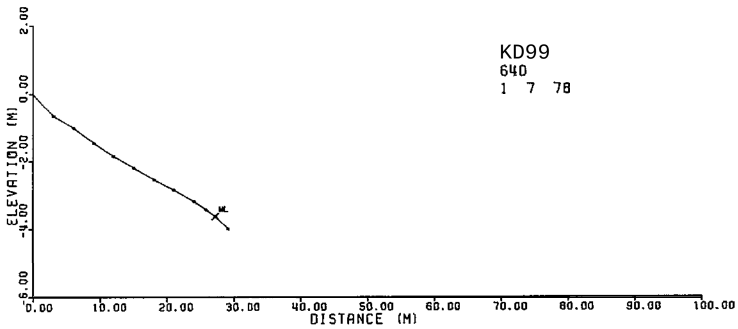
DISTANCE (M)


KD99
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1 7 78
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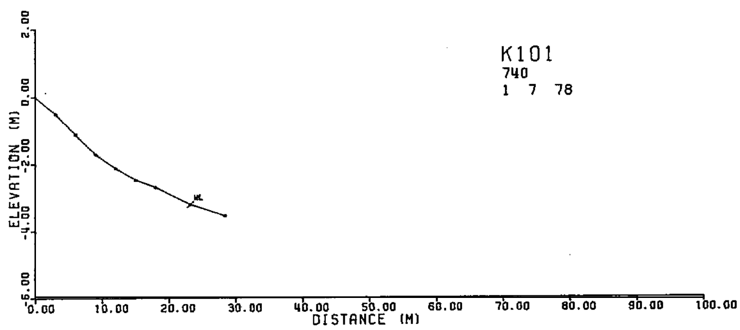
DISTANCE (M)


K101
740
1 7 78
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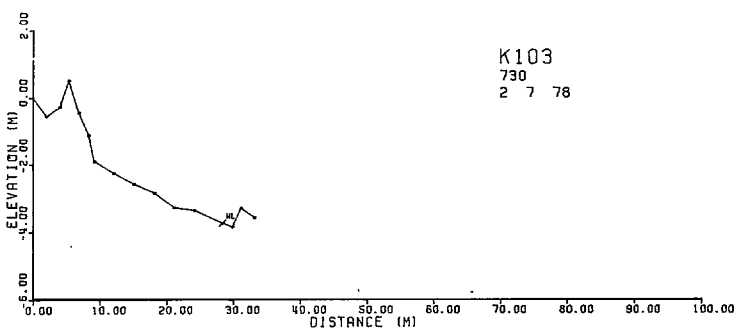
DISTANCE (M)


K103
730
2 7 78
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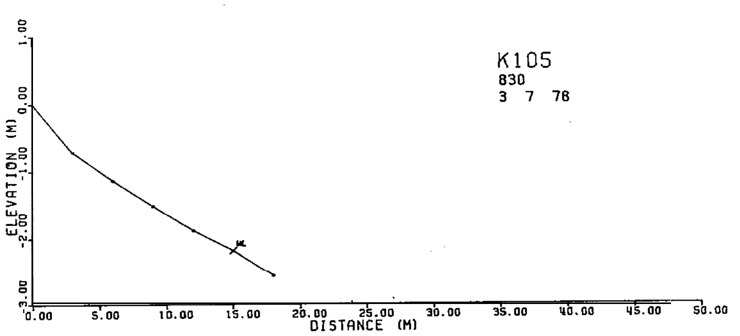
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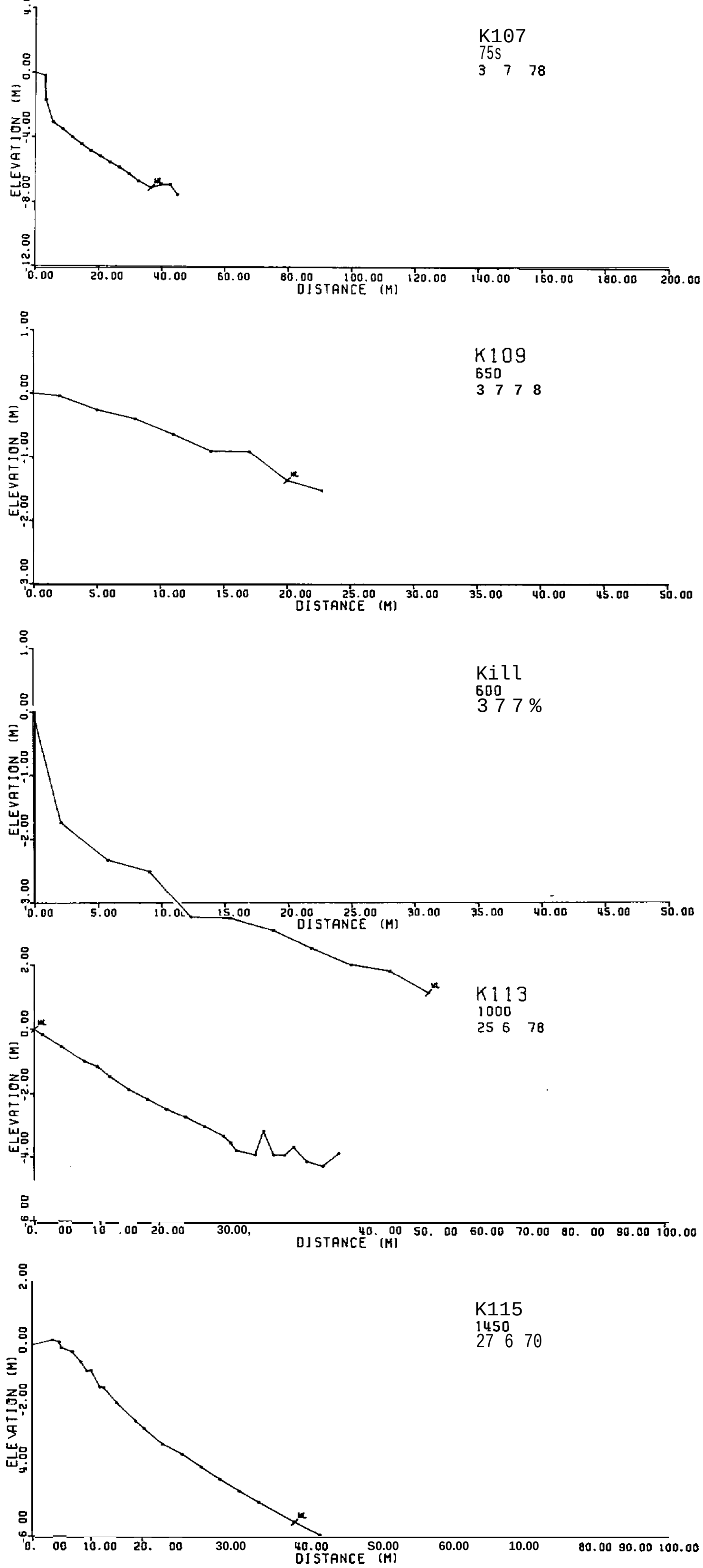
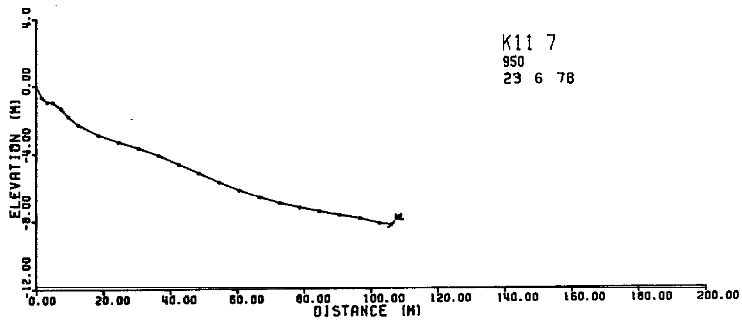
830
3 7 78
ELEVATION (M)
DISTANCE (M)


ELEVATION (M)
DISTANCE (M)
K107
75S
3 7 78
K109
650
3 7 7 8
Kill
600
3 7 7%
K113
1000
25 6 78
K115
1450
27 6 70


K11 7
950
23 6 78
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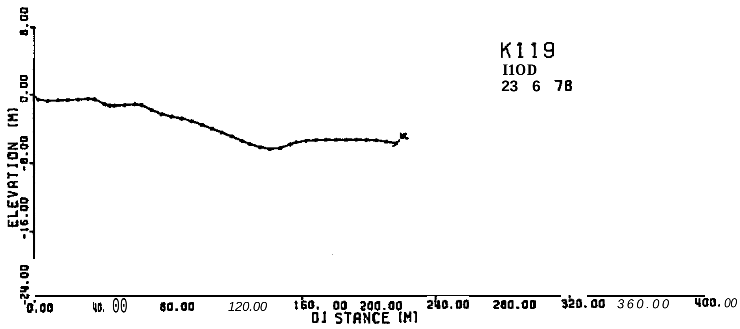
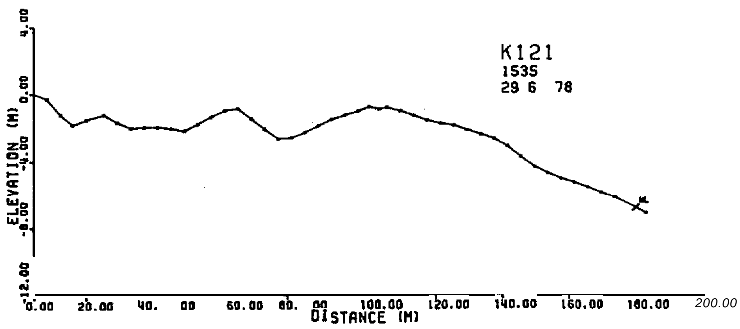
DISTANCE (M)


K119
11OD
23 6 78
ELEVATION (M)
DISTANCE (M)


K121
1535
29 6 78
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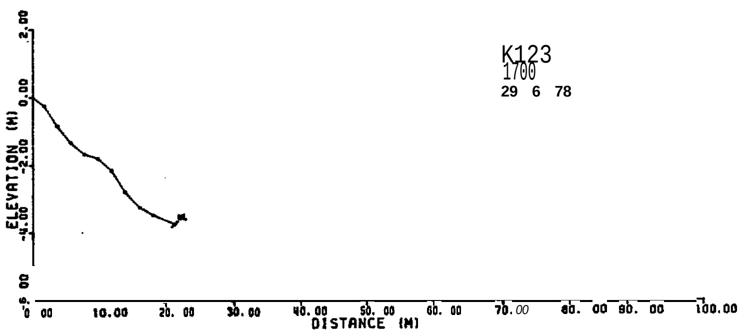
DISTANCE (M)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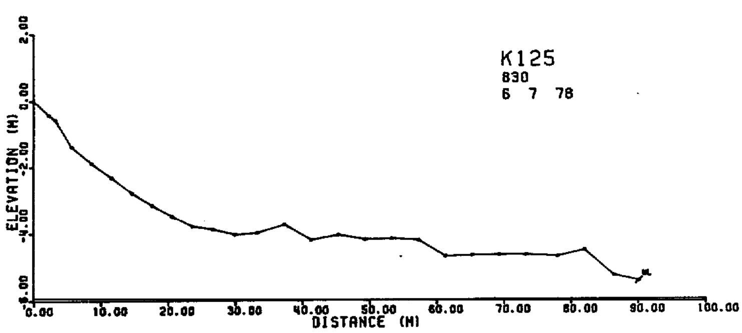
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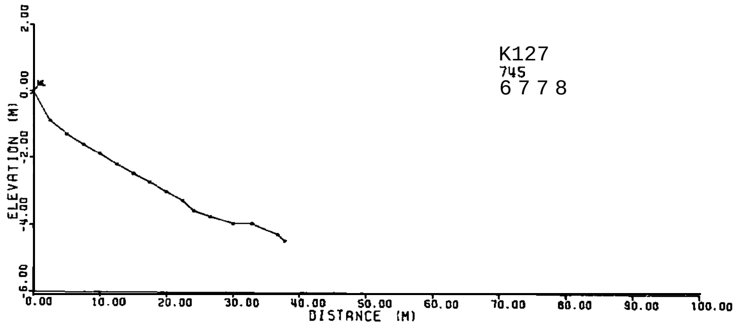
DISTANCE (M)


K127
745
6 7 7 8
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-2.00
-4.00
-6.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
DISTANCE (M)