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APPENDIX C
GEOTECHNICAL ANALYSIS
NAVIGATION IMPROVEMENTS
AKUTAN, ALASKA

Geotechnical Report
Akutan Small Boat Harbor
Akutan, Alaska

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1.0 INTRODUCTION

This report presents the results of literature review, field explorations, laboratory testing and geotechnical engineering studies conducted for a proposed small boat harbor to be located in Akutan Bay on Akutan Island, Alaska. In June 1998, Shannon & Wilson, Inc. was contracted to review existing geotechnical information that had been compiled from studies around Akutan Bay. As part of this work, five locations were selected as possible harbor locations. Literature was gathered from the United Stated Geological Society (USGS), the State of Alaska Division of Geological and Geophysical Surveys (DGGS), the Corps of Engineers (COE), Tryck Nyman Hayes (TNH), and our own library. In this first effort, we found very little published geological information about Akutan Island.

In this 1998 study, five sites, listed below, were being considered for the new harbor facility:

- Site 1 North Creek
- Site 2 Akutan Point (at east end of Akutan Bay)
- Site 3 Akutan Village (Salthouse Cove)
- Site 4 Head of Akutan Bay (at west end of Akutan Bay), and
- Site 5 Old Whaling Station.

Based on the results of this initial literature search, two of the sites were selected for further study. These were the North Creek and the Head of Akutan Bay (HAB) sites.

In October 1998, Shannon & Wilson, Inc. contracted with Tryck Nyman Hayes to conduct offshore geotechnical explorations at the two sites in Akutan Bay. As part of this effort, Arctic Geosciences, Inc. was subcontracted to perform a geophysical investigation at each proposed harbor site. This work provided subbottom profile data to show relative soil layering and bedrock contact depths across each site to complement the geotechnical explorations. Appendix A contains project specific site plans and boring logs for this project phase.

Ten borings were drilled for this study, eight in the North Creek site, and two in the HAB site. Select samples from the borings were transported to a chemical analysis laboratory for environmental testing. Geotechnical studies based on these explorations indicated that pile supported structures would be feasible due to very dense soil conditions relatively close to the mudline in the North Creek site. Initial efforts toward designing the appropriate harbor structures for the North Creek site were thwarted because the bottom topography sloped steeply so near shore that sufficient harbor area could not be provided to accommodate the expected boat volume.

The last exploratory effort was conducted onshore at the HAB site at the west end of Akutan Bay. Ten borings for geotechnical information and 31 test pits for environmental information were advanced across the proposed harbor site. The geotechnical and environmental exploratory work was performed simultaneously from March 21 to March 27, 2001. The purpose of this exploration program was to determine the onshore surface and subsurface soil conditions, develop preliminary design recommendations for the proposed small boat harbor development, and give guidance concerning environmental conditions at the site. The environmental concerns were addressed in a separate report. For the geotechnical report, engineering recommendations were given concerning earthquake risks and liquefaction potential, foundation requirements for rubble mound jetties, pile capacities to support docking floats, viable slopes for the onshore dredged harbor, and construction of upland facilities and an access road. Appendix B contains boring logs from this 2001 effort.

2.0 SITE AND PROJECT DESCRIPTION

As stated previously, two of the five sites were considered for potential harbor sites. Initially, both sited were considered in terms of offshore harbor facilities. After the 1998 studies, the project was further refined to consider a dredged harbor facility in the inland area of the HAB site. Following are descriptions of the sites that were considered.

2.1 North Creek

The North Creek Site is located on the north shore of Akutan Bay at the base of a steep hillside that extends to the water line. Water depths at this site increase rapidly toward the bay. The proposed harbor was planned approximately 1,000 feet west of the Trident facility. The harbor plan consisted of a 2.3-acre constructed upland area to make up the eastern portion of the harbor facility with approximate 8.76-acres of mooring basin enclosed by a pile supported 1,200-foot long wave barrier and dock structure some 320 feet from shore.

Two creeks fall out of the mountains on either side of the harbor. Approximately 1,300 feet to the east of the proposed site a creek drains a mountain valley. This creek supplies the Trident facilities with fresh water via four underwater HDPE pipes that are situated along this site. The creek to the west was included in the planned development area. Sediment from this creek has created an alluvial fan that was to support the planned upland construction. The upland area fill was to be enclosed on the seaward side by a sheet pile bulkhead.

2.2 Head of Akutan Bay

The HAB site is located at the western terminus of Akutan Bay and consists of a gently sloping beach that is adjacent to low-lying wetlands from which two primary streams enter the bay. One of the streams is directly north of the project area and the other is south of the project area. The water depths in this portion of the bay are shallower due to sediment deposition. Limited offshore explorations at this site encountered loose sand soils that extended to depths that indicated that an offshore facility should be ruled out in this location.

The proposed onshore harbor location is in the currently undeveloped onshore area at the head of the Bay. The site specific topography consists of a gently sloping beach and a narrow, sharply elevated beach berm, with slightly sloping headlands reaching back to mountain slopes approximately 1,300 feet behind the beach berm. This berm and the gradual rise in elevation are reflected in the contours in the site plan of Fig. 2. The ground surface across the site is covered with tidal grasses. At the north end of the beach, a narrow valley extends in a northwesterly direction to Akutan Mountain. The larger of two significant streams that enter the bay from the upland area drains this narrow valley along the toe of the mountains and dumps into the bay at the north end of the beach. The smaller of these two streams carries melt and runoff water out of the mountains at the south end of the beach and directly west of the beach. During times when snow melt and heavy rains cause seasonal high water, several minor surface rivulets traverse the beach uplands from out of the mountain to the west.

The vegetative cover of the island is sparse of trees. Land cover consists of several varieties of short shrubs, brush and grasses. Grasses, sedges and mosses grow thick on the hillsides within Akutan Bay. The relatively flat lying ground at the head of the bay is covered with a thick matte of grasses and interspersed brush.

The offshore water depths in this western portion of the bay are shallower than the north and south portions due to sediment deposition of streams and wave action. The current harbor plan consists of a dredged harbor area located behind the beach in the upland area, level storage/parking areas, and a road to the City of Akutan. These proposed features are shown in yellow on Fig. 2. The storage areas and road will be built up using dredged material from the basin as fill. The mooring basin will be an estimated 12 acres. The marine (offshore) entrance to the harbor will be a channel constructed across the beach and enclosed by the rubble mound breakwaters shown in Fig. 2. At the time that our crew arrived at the site, the snow had melted and caused the near surface soils to be saturated. The rivulets mentioned earlier were running full. Within two days, the temperature dropped below freezing, a light snow covered the ground, and the level of the water in the rivulets had diminished considerably.

3.0 FIELD EXPLORATIONS

Exploratory trips were made to Akutan Bay in 1998 and 2001 to determine subsurface soil conditions and to provide information for design of the proposed harbor. During both trips our explorations included drilling work. For the 2001 work test pits were dug throughout the proposed dredge site for environmental purposes. The soil data from the test pits was included in our studies for geotechnical considerations. Sampling from the borings was typically conducted using Modified Penetration Test procedures. In the Modified Penetration Test, samples are recovered by driving a 3-inch outside diameter (O.D.) split spoon sampler into the bottom of the advancing hole with blows of a 340-lb hammer free-falling 30 inches onto the drill rod. The number of blows required to advance the sampler the final 12 inches of a total 18-inch penetration in the test is termed the Modified Penetration Resistance, which was recorded for each sample. These values are shown graphically on the boring logs adjacent to the sample depth. The values give a measure of the relative density (compactness) or consistency (stiffness) of cohesionless or cohesive soils, respectively.

3.1 1998 Explorations

A total of 10 off-shore borings, designated BH-A, BH-1 through BH-7, BH-10 and BH-11, were advanced at two sites within Akutan Bay between October 14 and October 24, 1998. Borings BH-A and BH-1 through BH-7 were advanced at the North Creek Site. Borings BH-10 and BH-11 were located at the HAB site. Borings were drilled to variable depths, depending on conditions encountered in the borings. The exact depths reached in each boring are recorded on the 1998 boring logs in Appendix A. Boring locations are shown on the site plans presented as Figures 2 and 3 of that Appendix.

Drilling services were provided by Tester Drilling Services of Anchorage, Alaska. The drill rig was a Nodwell-mounted Mobile B-61 drill rig parked with the drill apparatus over water on a barge operated by Fairweather Marine. A temporary deck was attached behind the barge in such a way that the driller, helper, and engineer could work behind the rig, over the water. The borings were advanced using 8-inch outside diameter, 3-1/4 inch inside diameter, continuous flight, hollow-stem auger.

The barge was stabilized by a four point anchor system and was guided to each drilling location by a tug boat which remained tied to the barge while drilling was accomplished, standing by as emergency transport. An experienced engineer from our firm was present continuously during drilling to locate the borings, observe drill action, collect samples and log subsurface conditions.

Borings ranged in depths of between 25 feet to 77 feet past the mud line in water depths of between 5 and 56 feet. Sample depths depicted on the boring logs are referenced to mud line. The elevation of the mud line in each boring is shown at the top of the boring log and is referenced to mean lower low water (MLLW) elevation. As the borings were advanced, samples were generally recovered at 5-foot depth intervals.

3.1.1 Geophysics

Arctic Geoscience, Inc (AGSI) conducted a geophysical investigation of each potential harbor site. The purpose of this program was to provide subbottom data in support of the geotechnical information collected during Shannon & Wilson's field program. AGSI provided 4,500 lineal feet of subbottom profile data at the North Creek Site and 1,000 lineal feet from the HAB site. In collecting this data AGSI mobilized a three-person team to Akutan. AGSI survey was completed using a Bubble Pulser, Chirp II subbottom profiler and CHIRP Technology Side Scan Sonar. A description of these instruments is included in the geophysical report in Appendix A. Upon completion of data reduction a draft copy of our boring logs was provided to AGSI as lithologic control. AGSI integrated our boring data with interpreted cross-sections of track lines at each location. The location of these track lines is presented in Figure 1 of AGSI's report in Appendix A.

3.2 2001 Explorations

A total of 10 borings, designated B-1-01 through B-3-01, B-5-01 through B-10-01, and B-12-01, were advanced at the site between March 21 to 27, 2001. Their locations are shown in Fig. 2. Borings were drilled to depths of between 25 and 51.5 feet. The exact depth of each boring can be found on the boring logs in Appendix B. At the same time that the borings were being drilled, a second Shannon & Wilson crew was digging 31 shallow test pits around the site for environmental sampling purposes. The test pits generally only advanced through the upper 4 to 6 feet of silty soil with intermixed organics due to the shallow ground water elevation. These data were considered mostly for their usefulness in determining the thickness of this unsuitable soil throughout the site.

Denali Drilling, of Anchorage, Alaska provided drilling services for this project, using a skid–mounted, Mobile B-61 drill rig. The borings were advanced with an 8-inch O.D. continuous flight hollow-stem auger. An experienced engineer from our firm was present continuously during drilling to locate the borings, observe drill action, collect samples and log subsurface conditions.

The locations of most of the borings and some of the test pits were determined using a differential GPS locating system. These boring and test pits are shown on the site plan of Figure 2. The lack of accurate locations by GPS for the rest of the test pits and borings was due to satellite inadequacy (ie: the GPS would not register repeatable results at some locations). The boring locations not determined by GPS were approximated relative to surface features at the site. Test pit locations that could not be determined either by the GPS system or approximated were marked in the field but are not shown. The GPS located borings are differentiated in the figure from those located relative to surface features by symbol color.

As the borings were advanced, samples were typically recovered at 5-foot depth intervals. All sampling was conducted using Modified Penetration Test procedures.

When the crew was preparing to leave Akutan, we found that approximately two thirds of the soil samples that had been collected were not where they had been stored in the Aleut Corporation warehouse. When we inquired about the samples with Corporation employees, we found out that someone had mistaken the bags for garbage, had removed and burned them. The samples that were returned to our Anchorage laboratory were recovered from the last three holes that were drilled, namely Borings B-10-01, B-1-01 and B-2-01.

4.0 LABORATORY TESTING

Soil samples were tested to develop index and physical parameters for use in evaluating subsurface conditions, determining material quality for reuse as backfill, conducting stability analyses, and preparing foundation recommendations for the proposed project. The laboratory testing program included visual identification, moisture content determination and grain size analyses of select samples. All tests were performed in the Shannon & Wilson, Inc. Anchorage laboratory and in general accordance with the American Society of Testing and Materials (ASTM) standard test procedures. Laboratory testing results are not included in this summary report, but were incorporated into the boring logs in Appendix B.

Grainsize classification tests consisted of mechanical sieve analyses and selectively, hydrometer analyses. These tests are used to confirm the field classification, evaluate permeability, drainage, and frost characteristics, to establish liquefaction potential, and finally, suitability for reuse as backfill for constructing roads and upland staging areas.

Grainsize classification tests for the 1998 project consisted of 24 mechanical sieve analyses and hydrometer analyses. These tests were conducted according to procedures described in ASTM D-422. Hydrometer analyses were performed on 10 samples that were observed to contain more than 10 percent fine material (passing #200 sieve). The remaining fourteen samples underwent mechanical sieve analysis only due to their obviously low fine content.

Grainsize classification tests for the 2001 project consisted of 4 mechanical sieve analyses. One of the grainsize analyses was performed on a combination of several samples. This combined sample was put together to make a Modified Proctor Analysis (ASTM D-1557) sample, from which one compaction test point was performed. This test was used as a simple method to estimate how much the soil grains will break down when the material is compacted into place as backfill. The compaction results from the combined sample indicated little breakdown of the soil particles. The specific gravity of this material was found to be about 2.7.

Twenty-one moisture content tests were performed on samples recovered from the 2001 borings. These tests were conducted in accordance with procedures described in ASTM D-2216-92. Results of moisture content tests are presented in the boring logs of Appendix B.

Two Atterberg tests were performed on samples from the 2001 program, from Boring B-1-01, Sample S-10 and from Boring B-10-01, Sample S-7. These tests were generally conducted according to procedures described in ASTM D-4318 to refine the visual classification of the cohesive soils and provide quantitative information about the engineering parameters of this soil. Test results indicate that the soil represented by both samples are non-plastic. The results of these tests are summarized on the boring logs in Appendix B.

5.0 REGIONAL GEOLOGY

Akutan Island is located at latitude 54°05' N, longitude 165°55' W, which is about 27 miles northeast of Unalaska Island. The island is about 17 miles long, 13 miles wide and is oriented roughly east to west along the longer axis. Akutan Volcano dominates the island. Most of the island is rugged and steeply sloping with shorelines consisting of steep cliffs and rocky headlands. Evidence of past glaciation is seen on the portions of the island not covered by recent volcanic flows. Glaciation has changed landforms in the area to produce serrated ridges, cirques (steep sided bowl shape depressions), hanging valleys, and broad U shaped valleys. The lower elevations have developed a soil profile overlying volcanic ash deposits. The vegetation generally consists of tundra and low-lying brush, except in the lowlands of the head of the bay, which is covered with tidal marsh type grasses. Akutan Harbor is a fjord or a U-shaped valley formed by glaciers that subsequent to the disappearance of the glaciers was filled in with seawater.

Mt. Akutan is a volcano that is at approximately 4,275 ft. elevation at its summit and is located about 6 miles west of Akutan Bay. It is one of the most active volcanoes in the Aleutian Arc, having erupted at least ten times since 1848. The most recent ash eruption occurred in 1979 and the most recent lava flow in 1929. Recently, the volcano has been seismically active.

The rock type is intermediate in composition (basalt/andesite) and the flanks of the volcano consist of alternating layers of pyroclastic debris and solidified lava flows. The volcano, like much of the Aleutian Islands, was formed by the convergence of the North American and Pacific lithospheric plates. This convergence produced a seismically active belt where the Pacific Plate is being subducted under the North American Plate. The eruption of the magmas and the seismic activity throughout the Aleutians, including Akutan Island, are intimately related to this process. The potential for seismically induced ground failures such as submarine landsliding, surface cracking, and liquefaction is moderate to high.

The typical surficial geology of the island is volcanic rock overlain with a relatively thin soil layer, generally consisting of volcanic ash, with rock outcrops and limited accumulations of organic silts. At this site, this soil unit was mostly sand of volcanic origin and at least 50 feet thick. The rock generally has an irregular surface in contact with the overlying sediments due to varying degrees of erosion and irregularity of deposition. Rocks on the island consist of andesite, basalts, welded and nonwelded tuffs. Rocks created by volcanoes generally range from granite to andesite to basalts. The granites typically have a higher percentage of quartz and are generally very durable for construction processes. The andesite is typically gray, brown, or reddish color and consists of a variety of minerals similar to granite. It is less durable than granite, due to limited amount of quartz within the rock. Basalt is usually black or dark brown and is enriched in iron and magnesium. Of the three types of rocks (granite, andesite and basalt) basalt is the least durable. The basalt flows generally have a moderate dip of about 20 to 30 degrees and are typically 20 to 40 feet thick. The welded and nonwelded tuffs are rocks created from the debris produced during a volcanic eruption. Welded tuffs are formed during the heat of the explosion actually welding the rock and ash particles together. Welded tuffs generally are durable and strong. Nonwelded tuffs are formed from compaction and solidification of the rock and ash particles after the eruption. Nonwelded tuffs generally weather easily, similar to sandstone or other sedimentary rocks.

6.0 SUBSURFACE CONDITIONS

6.1 1998 Explorations

6.1.1 North Creek Site Subsurface Conditions

The subsurface soils encountered at the North Creek Site were consistent with anticipated conditions in that loose to medium dense sands were encountered down to variable depths followed by denser material. In general the borings advanced in common tidal zones encountered similar soil conditions. The borings placed near shore (Borings BH-1, BH-A, BH-3 and BH-4), those advanced further out from shore (Borings BH-2 and BH-5) and those placed in front of the creek outlet along the eastern edge of the site encountered similar conditions.

Borings BH-1, BH-A, BH-3 and BH-4 were drilled near shore in water depths between 5 and 18 feet. These borings all encountered loose to medium dense sands underlain by very dense or hard layers. Borings BH-A and BH-3 were placed very near the shoreline in 6 and 5 feet of water, respectfully. In each of these borings very dense layers were encountered at or very near the surface, attempted sampling of these units resulted in refusal in most cases. These very dense layers consisted of gravel containing cobbles and boulders. Similar soils were discovered at greater depths in Borings BH-1 and BH-4. In these borings loose to medium dense sands and gravels extended down to approximately 20 feet below mud line (bml), sampling attempts past this point resulted in minimal sampler penetration. All of these near shore borings were finished in very dense materials that varied in lithology and description but yielded consistent blow counts.

Borings BH-2 and BH-5 were advanced further from the shore, in approximately 50 feet of water. Loose to medium dense sand was encountered down to about 15 feet bml in these borings where medium dense gravel was found. The last sampling attempt in Boring BH-2, at about 34 feet bml, was refused in gravelly boulders. Boring BH-5 hit a hard, silt layer at about 24 feet bml. In this case the silt unit extended to approximately 31 feet bml where solid rock was discovered. The core sample recovered from this unit was a brecciated conglomerate that exhibited little to no weathering and had a rock quality index of 72. Due to the limited length of the coring run (approximately 1.2 feet) this rock could not be confirmed as bedrock. Boring BH-5 was the only boring that encountered such solid competent rock material.

Borings BH-6 and BH-7 were located in the eastern portion of the development where the proposed constructed upland will be located as shown in the site plans of Appendix A. These borings encountered loose sediments down to approximately 40 feet bml. In Boring BH-6, medium dense gravel and sand was discovered at approximately 42 feet bml, these units increased in density with depth to the bottom of the boring. Boring BH-7 was advanced to 77 feet past mud line and like Boring B-6 found medium dense sands and gravels at approximately 40 feet bml. At about 70 feet bml the sands and gravels became denser and contained cobbles that resulted in refusal of the last two sample attempts.

AGSI's geophysical survey findings were fit with our boring data with geophysical boundaries correlating fairly well with the geotechnical information. The interpreted cross-sections provided by AGSI, with our boring data superimposed on them, are presented as Figures 13 through 15 of their report in Appendix A. Figure 14 illustrates the correlation between the thickness of the initial loose sediments encountered in Borings BH-2, BH-5, BH-6 and BH-7 and interpreted soil sections. Small discrepancies exist in the underlying denser material. The likely cause for these differences is the material retrieved from the split spoon sampler during our geotechnical investigation. Due to the regularity of cobbles and boulders in this soil, we often retrieved rock fragments in our sampler. The draft bore logs provided to AGSI had these sections classified as weathered rock units or possibly bedrock. It is more likely these rock encountered during exploration were cobbles and boulders suspended in the gravelly soil section. Overall the correlation of geotechnical field data and the resultant cross-section provided by AGSI was good.

6.1.2 Head of Akutan Bay Subsurface Conditions

The subsurface soil conditions at the HAB site were consistent between Borings BH-10 and BH-11. Water depths were 11 and 10 feet, respectfully for these borings. As expected, the soils we encountered during drilling were consistent with those of a depositional environment. Both borings discovered loose sands down to approximately 30 feet blm. The sand encountered throughout Boring BH-11 yielded consistent blow counts ranging between 4 and 10 blows per foot. The sand unit in Boring BH-10 was very loose from about 16 to 35 feet bml. A silty sand unit was encountered at the bottom of Boring BH-11. Boring BH-10 encountered similar silty sand at approximately 30 feet bml. This unit contained seashell fragments, gravel and was underlain by silty, sandy gravel with cobbles at approximately 40 feet. Blow counts within in these two units were slightly higher than in the overlying clean to slightly silty sand, as shown in the boring logs, Appendix A.

The geophysical survey conducted at the head of the bay by AGSI used the soil boring data to verify their results in comparison with the conditions encountered in our borings. The geophysical data, as interpreted by AGSI, exhibits soil conditions consistent with those found in our borings. Interpreting the sandy gravel encountered in bottom of Boring BH-10 in relation to the AGSI data, the loose sediment layer appears to thin out as one progresses shoreward. At depths below where our borings advanced, an interpreted layer from the AGSI data appears to contain boulders, and exists below a relatively thin layer of interpreted sandy gravel. If this strata sequence is consistent moving shoreward, it is possible the sandy gravel encountered in Boring BH-10 could be relatively thin and underlain by a denser unit with gravel and boulders.

6.2 2001 Explorations

The borings for this effort encountered similar soil conditions across the proposed (onshore) harbor site. We found 4 to 6 feet of silty sand or sandy silt with grassy organics over medium dense, clean to slightly silty sand. Based on Fig. 3, the grain size curves depict the sand as a well graded material with small amounts of gravel and silt fines. These same conditions of a thin silt/sand cap over native sand were verified throughout the site by the 31 environmental test pits, which were basically dug to depths that were at or just below the water table. Soil descriptions from the test pits are presented in Shannon & Wilson's companion environmental report titled "Environmental Site Investigation, Proposed Harbor Location, Akutan, Alaska".

The subsurface conditions at the site were better than anticipated in that the sands that were encountered were not consistently loose, as feared, but were in fact generally medium dense. The density is generally reflected in the uncorrected blow count summary in Fig. 4. This plot shows N values between 5 and 30 blows per foot (b/ft) with the average being 13 b/ft. In the program we planned to use the Standard Penetration Test method (SPT) to measure soil density but were forced to use modified procedures because the equipment could not be flown to Akutan with the time constraints. The inability to use the SPT means the N-values taken by the modified method needs to be corrected to more closely reflect equivalent SPT values and density conditions. Based on our experience at numerous other sites, SPT values normally exceed Modified Penetration Resistance values by 100 percent or more. This would increase the density from 13 blows per foot to an equivalent SPT 26 blows per foot. Recognizing that some conservatism is appropriate when using empirical correlations, we have based our follow-on recommendations on the assumption that the design N value (which is used to indicate the density of the sand) is 50 percent rather than 100 percent greater than our Modified Penetration results. This results in average N values of 19 to 20 blows per foot.

Borings B-1-01 and B-2-01 were drilled near shore within the beach environment so that the upper silty sand layer was not present. Beyond this difference, all of the borings encountered similar conditions and medium dense sands. Note that heaving sands were a hindrance in every boring, from about 10 feet below the ground surface (bgs) in virtually every boring. We did not encounter bedrock in our borings.

As noted in the boring logs, water was encountered at about 3 feet bgs in every boring except Borings B-1-01 and B-2-01, in which the ground water level was at 8 feet bgs. The ground water elevation in the vicinity of these two borings is more than likely dependent on the tidal influence of Akutan Bay. The water in soil samples taken from borings in the upland area seemed to be somewhat saline. No measurements were taken to verify this observation, or to measure salinity.

7.0 RECOMMENDATIONS

7.1 Seismic Considerations

Seismic mapping by the Alaska Department of Transportation & Public Facilities (ADOT) recorded one large (Richter Magnitude 7.1 to 8) earthquake with an epicenter within 25 miles radius of the City of Akutan and two earthquakes of Magnitude 6.1 to 7. The ADOT estimated that a peak acceleration force of 0.35g will have a 90% probability of not being exceeded in 50 years and could be used as a design earthquake force for this site. Tsunamis (earthquake generated waves) are also a potential for any of the sites within the bay.

For this design study, the geometry of slopes that were studied included 1 vertical to 2 horizontal (1V:2H) and 1V:3H, including both basin slopes and above ground slopes of berms to be used around parking/storage area the geometry of slopes that were studied included 1 vertical to 2 horizontal (1V:2H) and 1V:3H, including both basin slopes and above ground slopes of berms to be used around parking/storage areas.

We analyzed the stability of slopes using a seismic coefficient of 0.15g, which is between 1/3 and 1/2 of the maximum acceleration force estimated by the ADOT. This reduction is determined by factoring based on landform, slope height and length, and amplifications that are typical in slopes. Structures generally experience accelerations that are less than maximum values for much of the event. The following authors recommend this reduction in the peak acceleration: Marcuson, W.F. III "Moderator's report for the session on 'Earth dams and stability of slopes under dynamic loading'," Proceedings, International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Missouri (1981); and Hynes-Griffin, M.E. and Franklin, A.G. "Rationalizing the seismic coefficient method," Misc. Paper GL 84-13, US Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi (1984).

As a point of comparison, 0.15g corresponds to the magnitude of shaking that occurred in the 1964 Good Friday earthquake. The acceleration of the ground during an event can only be estimated based on observed damage, displacement of buildings or other structures or from an evaluation of compiled data from other earthquakes. Estimates of the Good Friday ground acceleration were made by diverse individuals such as William Cloud, past chief of the Seismological Field Survey, USGS (0.18g), Woodward Clyde Consultants (0.15 to 0.2g) and others whose estimates ranged from 0.14 to 0.17g. In a 1964 study of the Turnagain Landslide in Anchorage, Alaska, performed for the US Army Corps of Engineers, and several subsequent studies for development in the Turnagain area, Shannon & Wilson, Inc., used the value of 0.15g as the reasonable estimate for the Good Friday earthquake.

7.2 Breakwater Foundation

The bearing soils in the planned breakwater zone appeared to be typical of the site everywhere, and are medium dense, clean to slightly silty sand. The maximum breakwater height will be around 33 feet, at the leading edge (offshore) of the structure. The portion of the breakwater fill that will be founded near the existing ground surface at the onshore end of the structure will not reach a maximum height of more than about 15 feet, with a maximum bearing pressure of about 1 tsf. The maximum bearing pressure that the breakwater embankment is expected to exert on the soil is about 2 tons per square foot (tsf). The allowable bearing pressure that can be exerted on the soil will vary from about 1.5 tsf near the surface to 3 tsf depending on the amount of burial of the breakwater foundation. In our opinion, therefore, the medium dense sand at the site will provide sufficient bearing capacity for the breakwater. We understand that the breakwater will be constructed of rock riprap.

Slope stability studies for the breakwater embankment indicate that the medium dense native sands are not sufficiently compact to resist slope failure below the embankment under design seismic conditions. If the breakwater is constructed without treating the foundation soil, the amount of damage that will occur during a design earthquake event is variable, depending on the amount of compacted material that is used. In order to achieve a factor of safety of greater than 1.0, we recommend that the native sands in the offshore portions of the breakwater foundation area be over-excavated to 20 feet below the lowest adjacent ground surface elevation to the breakwater and replaced with compacted granular material to act as a buttress. The buttress material should be extended to a point where the proposed breakwater base reaches elevation 0.0 feet (MLLW), at which point the buttress excavation can transition to the surface at a 3:1 (3 horizontal to 1 vertical) slope.

Figure 6 gives the general geometry of the breakwater, and shows the estimated mass of soil requiring reconstruction. Using the failure envelopes from our analyses relative to the geometry of 12 versions of the proposed breakwater, the following table presents reconstruction requirements geometric configuration. The table presents the expected percentage of breakwater material needing reconstruction. This value is tabulated in relation to the length of bottom of embankment (a), and Factor of Safety (FS). The Figures in Appendix C relate to the tabulated results from A1 to A12 and from the left down and to the right. The reconstruction requirements that are indicated are extreme amounts expected for a large magnitude (design) earthquake. During the normal life of the project the likelihood of an earthquake of design magnitude is relatively small. Percentage of reconstruction under most seismic events expected at the site will be smaller than shown in this table.

Percentage of Reconstruction by Configuration											
Breakwater with Buttress						Breakwater w/out Buttress					
Slope						Slope					
2H:1V			3H:1V			2H:1V			3H:1V		
a (ft)	FS	Amt.	a (ft)	FS	Amt.	a (ft)	FS	Amt.	a (ft)	FS	Amt.
30	.95	25%	30	1.11	0%	30	.79	30%	30	.80	40%
50	1.0	12%	50	1.14	0%	50	.80	30%	50	.80	33%
70	1.0	10%	70	1.22	0%	70	.81	20%	70	.80	28%

The stability analysis results presented in the table are presented graphically in the figures in Appendix A.

7.3 Breakwater Settlements

The magnitude of settlements that can be expected within the breakwater fill is dependent on the applied loads, the density of the foundation soil, and the care with which the breakwater materials are placed and compacted. For loads not exceeding the expected loads above, we estimate that the total maximum settlements will be on the order of 4 inches. Most of this settlement should occur as the fill is being placed. Differential settlements will be gradual due to the anticipated load distribution, and should be highest near the center of the fill, where the load is greatest. Total and differential settlements within the embankment may be substantially higher if the fill is poorly placed. Because of the nature of the deposition of the sand (by volcanism) the consistency is comparable throughout the site and with depth. The settlements that would occur if no treatment of the foundation soils were conducted would depend on the net amount of material that is added to construct the breakwater. If this amount is considerable, the estimated amount of settlement could be as much as 6 inches overall.

7.4 Dredge Slopes

Interior harbor slopes will be formed by dredging the cap of silty sands and deeper clean sand to the basin elevation of –17.0 feet (MLLW) or roughly 25 feet bgs. Stability analyses were performed in order to determine the appropriate slope geometry, with particular emphasis on providing seismically stable slopes. The analyses were performed using the two-dimensional, limit equilibrium program, PCSTABL5M. This is a two-dimensional, limit equilibrium slope stability program that is used to model a slope and determine the factor of safety against sliding by the simplified Janbu, simplified Bishop, and Spencer method of slices, depending upon the routine selected. The program features random techniques for generating potential failure surfaces and identifies the ten most critical failure surfaces and their respective factors of safety. Techniques include generating circular, sliding block, or irregular failure surfaces. The program allows for heterogeneous soils systems, anisotropic soil strength properties, excess pore water pressure due to shear, static ground water and surface water, pseudo-static earthquake loading, and surcharge boundary loading.

In general our studies indicate that slopes that extend below water level need to be constructed on 1V:3H in order to have a factor of safety against failure in seismic conditions of at least 1.1. Slopes above the water table can be constructed on 1V:2H and based on our calculations, will have at least a 1.1 factor of safety. Under static loading, the factors of safety are much higher, on the order of 1.5 to 2.

7.5 Dredge Slope Protection

Slopes that will be subject to tidal and wave action need to be protected from raveling and material loss from negative pore pressures caused by rapid draw down. The most effective protection against wave action is rock riprap. The effects of rapid draw down (tidal influences) are managed by having a filter material between the native soil and rock rip rap. Riprap design requirements are variable depending on the design wave height, which is not known at this time. In general, filter material needs to be well graded such that the D_{85} (85 percent of the particles are smaller than this size) particle size is at least 1 inch. The native soil we encountered in our borings do not meet this standard (the particle sizes are considerably smaller by percentage). Since the native soils are generally porous, but are smaller gravel to sand sizes, we recommend that some method be used below the filter soil to decrease the porosity of the near surface soil below the riprap. This can be accomplished by constructing a minimum 1 foot thick layer of low permeability silt or clay layer beneath the filter material, or else by installing a low permeability geofabric in this zone.

7.6 Liquefaction Considerations

It is generally considered that sand soils that are prone to liquefaction are uniform (poorly graded) fine to medium sands with a mean grain size (D_{50}) that is around 0.25 millimeters (mm). This is illustrated in Fig. 5 which shows the gradations characteristics of soil from published case histories and laboratory tests that were prone to failure under strong earthquake shaking. The grain size analyses for this project, also shown in Fig. 5, indicate that although the soil is predominantly sand, it is slightly gravelly to gravelly, well graded (non-uniform) and the mean grain size is much greater than 0.25 mm (about 1 mm). This indicates that the sand soil at the Akutan Harbor site is at worst only moderately prone to liquefaction. Sustained ground movements will be necessary in order for these soils to liquefy. These coarser soils and gravelly sands are considered less likely to liquefy, because they possess a higher coefficient of permeability. More pervious soils tend to discourage the rapid build up of pressure and liquefaction because these pressures bleed off almost as fast as they build up during the earthquake.

The medium dense consistency of the clean sands also tend to make the soil be more resistance to a rapid build up of pore pressures and liquefaction than would occur in a looser deposit. Based on our analyses, if the sand lost strength locally as a result of liquefaction, the factor of safety of the submerged slopes would be less than 1.0, meaning the slope would fail. The potential area of strength loss, and failure, should be at the toe of the submerged slope, where confining pressures are minimal. The failure in this area would likely occur as bulging of the toe soils in a generally shallow slumping failure envelope. This undermining of the below water portion of the slopes would cause the soil and rock riprap in the upper region of the slope to slump and fall. In our opinion the riprap planned for the slope surface should be carried down to the toe of the slope to increase the confining pressure, discourage slumping and help minimize slope movement.

If, in the future, additional structures will be considered as improvements on the land around the harbor, it will be important to provide engineered foundations for these structures.

7.7 Dredging

The slightly gravelly to gravelly, well-graded sand encountered below the unusable, silty sand with organics in our borings is medium dense. This material will be relatively easy to excavate, however, it is mostly clean sand and when mixed with water may run as it is brought to the surface if clam buckets or drag lines are used for dredging. Probably the most efficient method to remove this material is to use a suction dredge, if the gravel is not too coarse, or a closed clam bucket. In either case, the dredge material will appear soupy because of excess water and will remain so until this water has a chance to drain out of the sand. If the dredge spoils are to be brought on land and reused, it may have to be contained for a short time or spread out to facilitate down slope drainage and solidification. Because the high water table will make slope development difficult in the inner harbor area, dredging should occur in the driest part of the year if possible. If used as structural backfill, this sand material would likely be free draining, and once excess water is drained from the soil matrix it should compact well.

The upper 4 to 6 feet of surface soil is silty sand with organics throughout. This surface material should be stockpiled so that a large face is produced, much like snow disposal berms are constructed. The large face will provide surface area for moisture to seep and evaporate out of the material. Once dried out, this material can be used at the base of proposed fill areas. As long as the filled surfaces will not be paved, the thickness of structural fill over this silty soil can be limited to a minimum of about 24 inches. If paving is planned, the structural cover should be at least 36 inches.

7.8 Staging Area

Along with the dredged harbor, there will be elevated uplands fills to be used as staging areas for fishing equipment and storage. These fills will be constructed with dredge material from the harbor excavation. As stated in the previous section, the material that will be dredged from the harbor area should be suitable for construction of the fills. The dredge spoils, including the upper 4 to 6 feet of native soil that has tideland grasses and small brush, should be stockpiled in such a way that the excess moisture can be drained out of the soil before the pads are constructed. We recommend that the upper silty soil with organics be used only in the very bottom portions if the fill.

The clean sand dredge spoils may be used above the siltier material as structural fill placed to level the site. All fill material should be placed in lifts not to exceed 10 to 12-inches loose thickness, and compacted to a density of at least 95 percent of the maximum density as determined by the Modified Proctor compaction procedure (ASTM D-1557).

7.9 Site Drainage

Drainage control will be most critical due to the large amount of dredged material that will be produced. The area used to store this excess dredge material will be substantial, so that normal runoff routes from the mountains will be cut off. Ditches and regularly spaced culverts will provide the most efficient way to direct runoff under and around the fill areas. If the ground water in the upland area truly exhibits salinity, the excess dredge fill material will be draining this water into the bottom of the fill. Culverts used to direct runoff water from the mountains into streams should be solid wall pipe so that saline water draining from the fill soils cannot mix with the fresh, surface runoff water. Perforated culverts should be used to help drain the fill soils, but should be directed into flat areas where the water can infiltrate into the native soil, or into the harbor.

8.0 LIMITATIONS

The analyses, conclusions, and recommendations contained in this report are based on site conditions as they presently exist and further assume that the exploratory borings are representative of the subsurface conditions throughout the site, i.e., the subsurface conditions everywhere are not significantly different from those disclosed by the explorations. A copy of "Important Information about your Geotechnical/Environmental Report" is attached in Appendix D for a clarification of the expectations that can be realized from this document.

If, during construction, subsurface conditions different from those encountered in these and prior explorations are observed or appear to be present, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submittal of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, it is recommended that this report be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

Unanticipated soil conditions are commonly encountered and cannot fully be determined by merely taking soil samples or making test borings, particularly when attempting to develop in or near a slide mass. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs.

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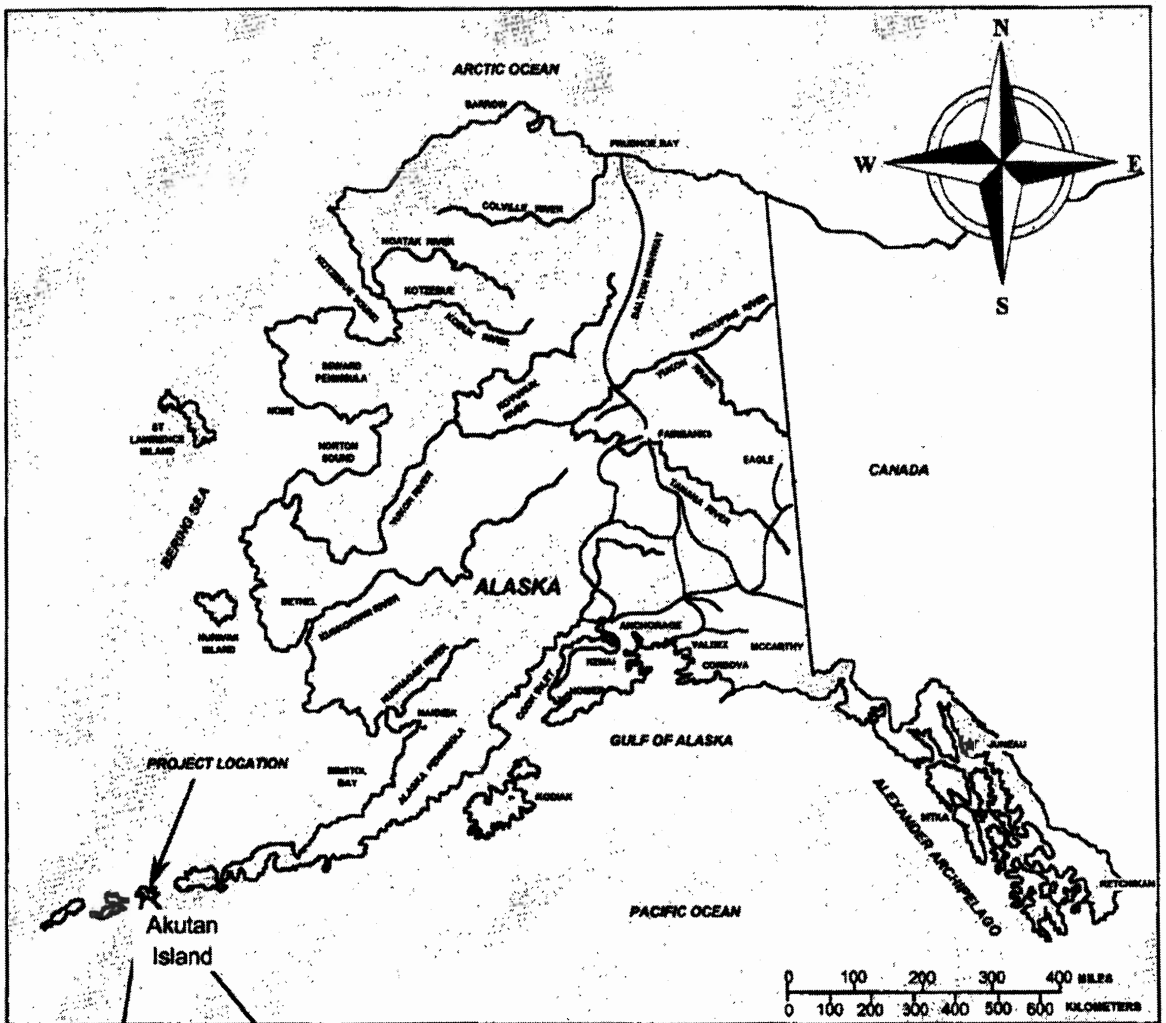
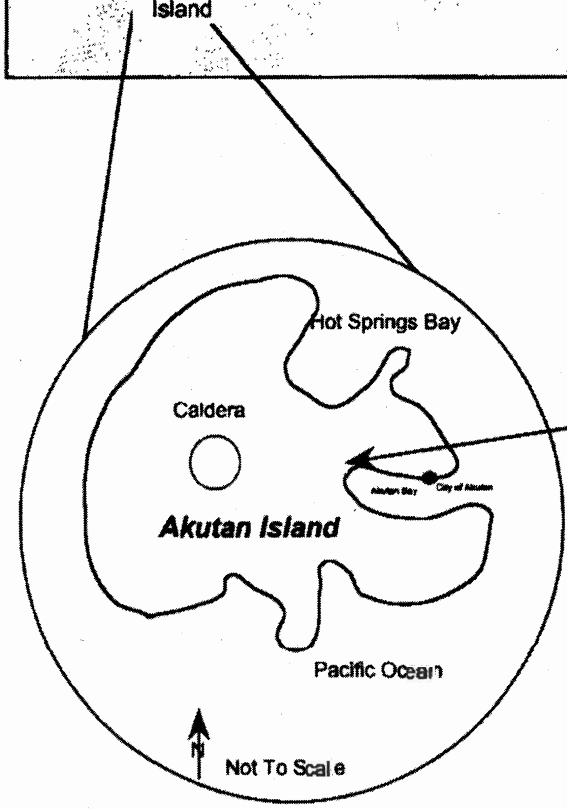
Prepared By:	Reviewed By:
Grover L. Johnson, P.E. Principal Engineer	William S. Burgess, P.E. Associate





Akutan Small Boat Harbor
Akutan, Alaska

VICINITY MAP

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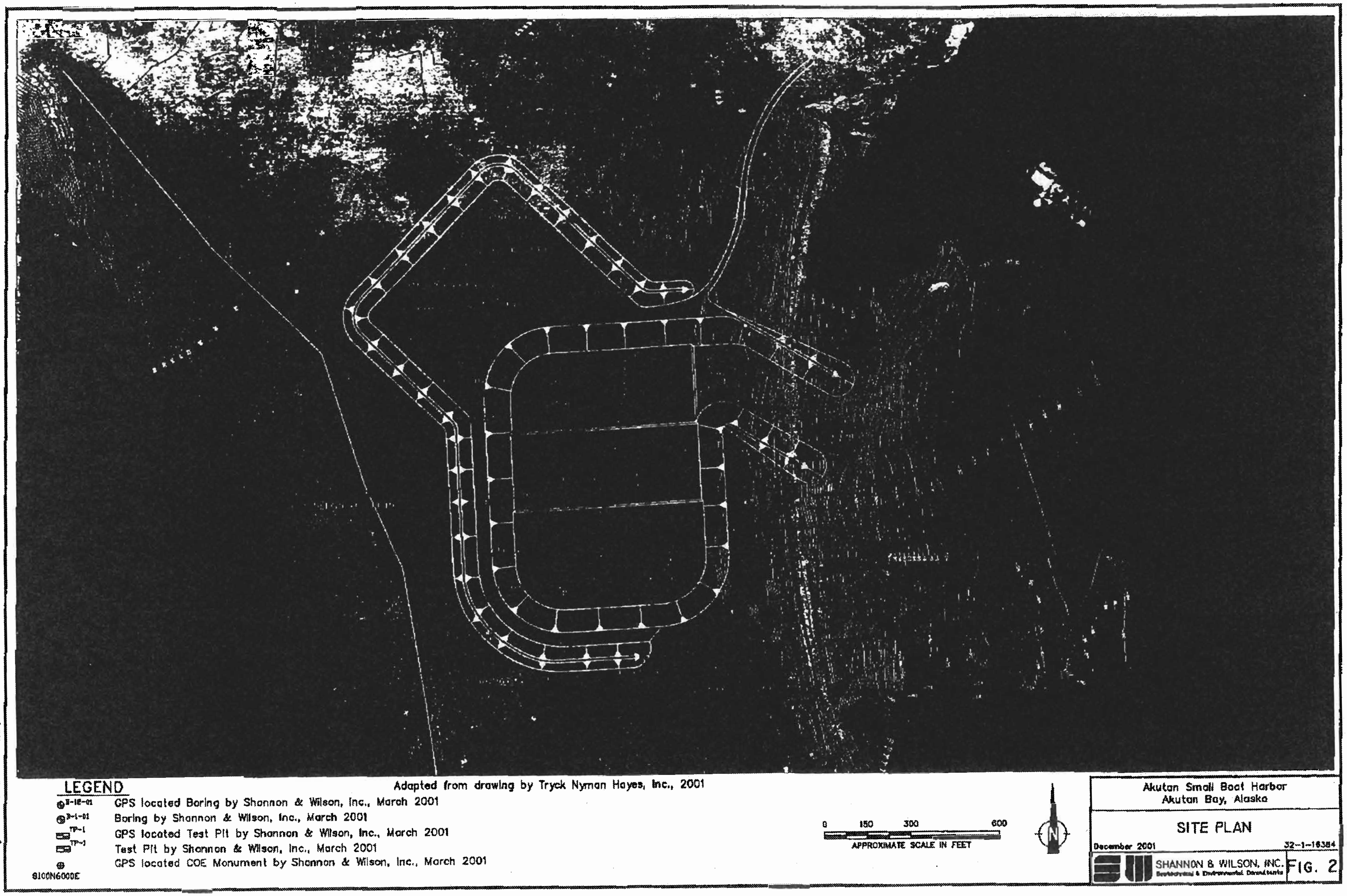
Fig. 1



Akutan Small Boat Harbor
Akutan Bay, Alaska

SITE PLAN

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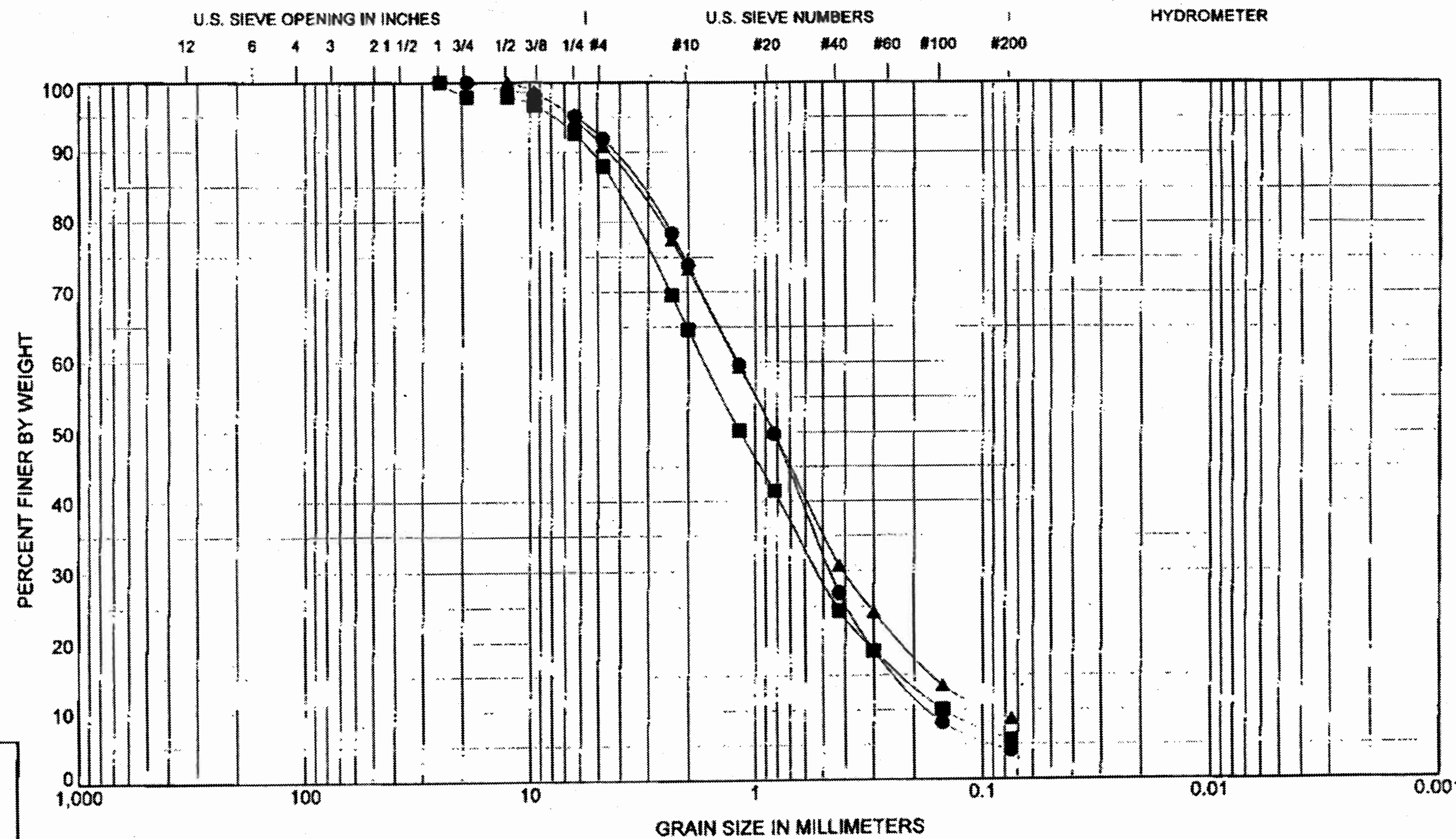
FIG. 2

6384site.dwg 1:1 Shannon & Wilson, Inc



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Sample	Depth, Ft	Classification	LL	PL	PI	Cc	Cu
● B-1-01	15.0 - 16.5	Slightly gravelly SAND (SW)				1.1	7.0
■ B-1-01	25.0 - 26.5	Slightly silty, slightly gravelly SAND (SW-SM)				1.1	11.3
▲ B-10-01	10.0 - 11.5	Slightly silty, slightly gravelly SAND (SW-SM)				1.5	13.4

Sample	Depth, Ft	D100	D60	D30	D10	%Cobble	%Gravel	%Sand	%Silt	%Clay
● B-1-01	15.0 - 16.5	19	1.2	0.46	0.17	0	8	88	4	
■ B-1-01	25.0 - 26.5	25	1.69	0.53	0.15	0	12	82	6	
▲ B-10-01	10.0 - 11.5	12.5	1.21	0.41	0.09	0	9	82	9	

Akutan Small Boat Harbor
Akutan, Alaska

GRAIN SIZE CLASSIFICATION

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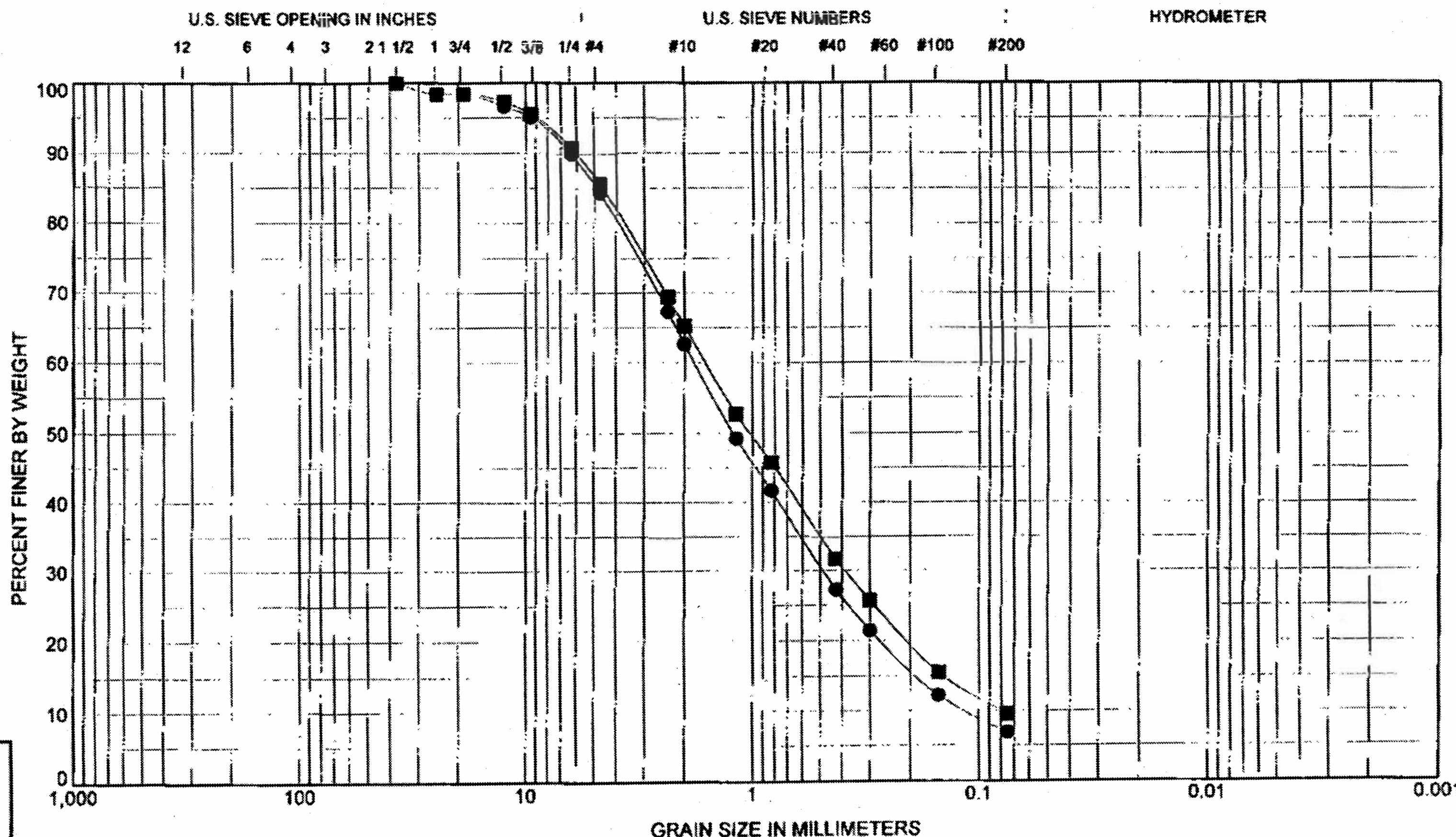
Fig. 3
Sheet 1 of 2



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Sample	Depth, Ft	Classification	LL	PL	PI	Cc	Cu
● B-9-01	5.0					1.1	16.0
■ B-9-01	5.5					1.2	20.3

Sample	Depth, Ft	D100	D60	D30	D10	%Cobble	%Gravel	%Sand	%Silt	%Clay
● B-9-01	5.0	37.5	1.8	0.48	0.11	0	16	78	7	
■ B-9-01	5.5	37.5	1.61	0.39	0.08	0	14	76	10	

Akutan Small Boat Harbor
Akutan, Alaska

GRAIN SIZE CLASSIFICATION

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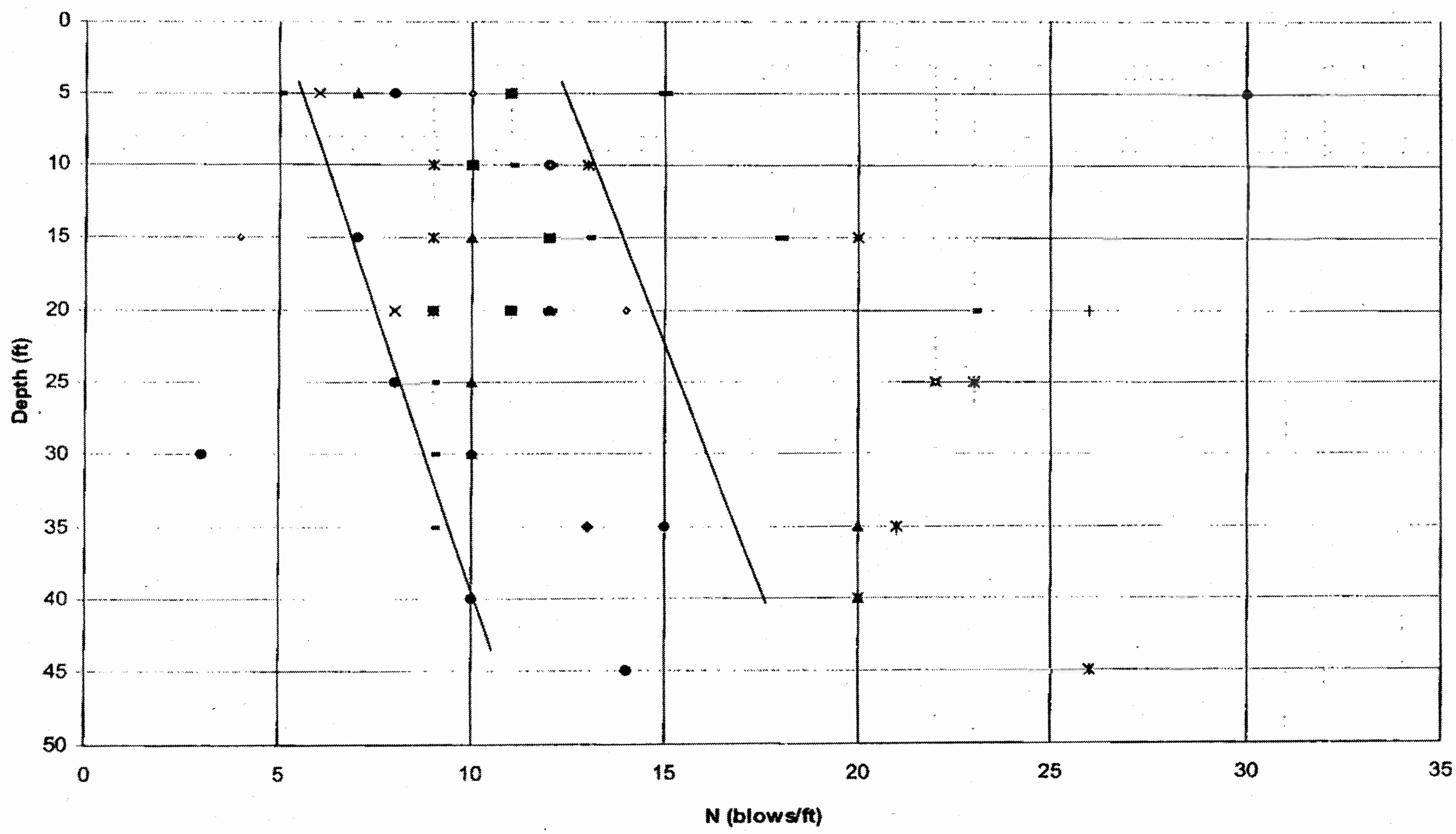
Fig. 3
Sheet 2 of 2



Legend

- ● Blow Count for Samples from Boring B-1

Akutan Small Boat Harbor
Akutan Bay, Alaska

PENETRATION RESISTANCE vs. DEPTH

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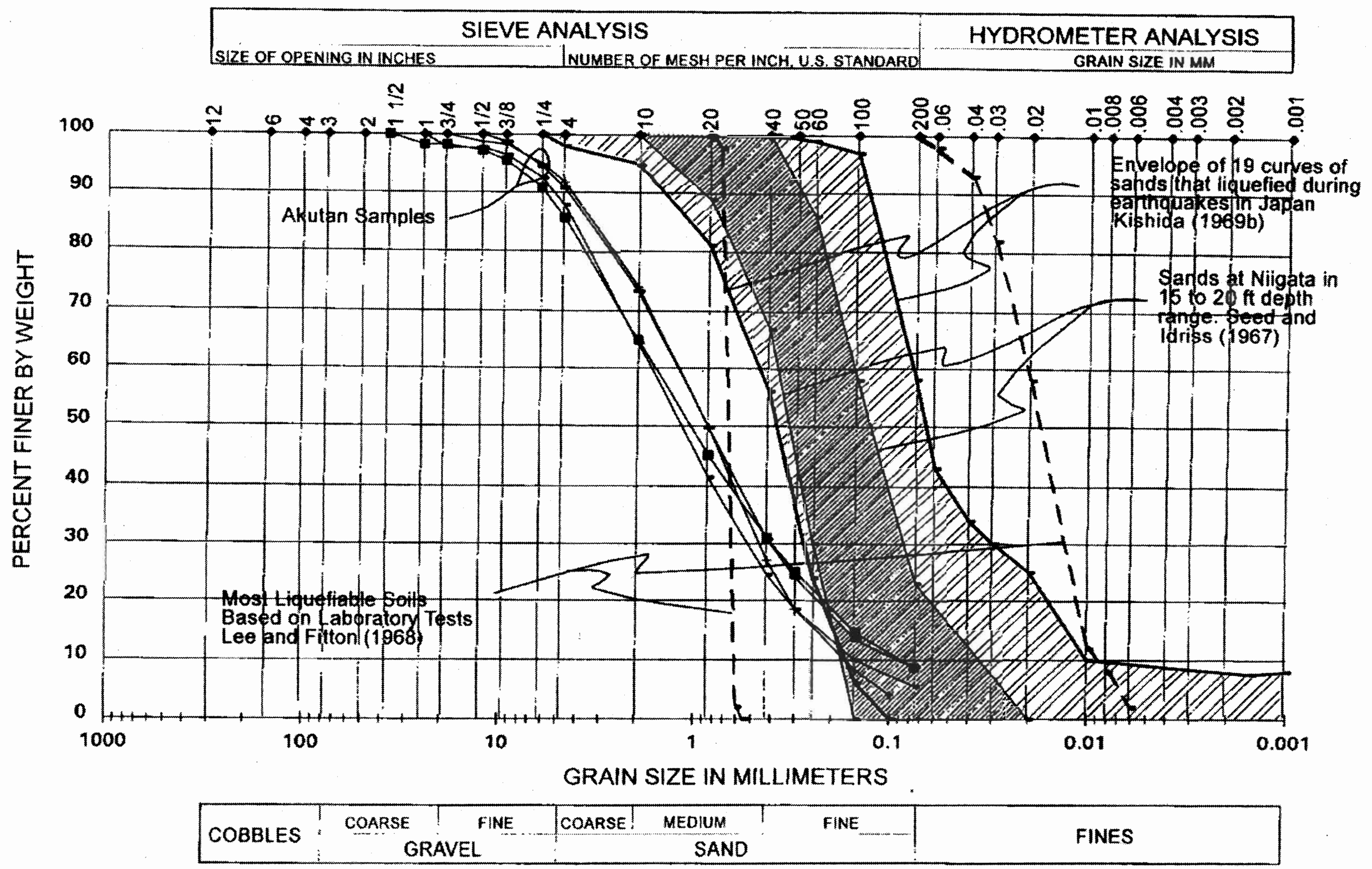
Fig. 4



Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAIN SIZES SUSCEPTIBLE TO LIQUEFACTION

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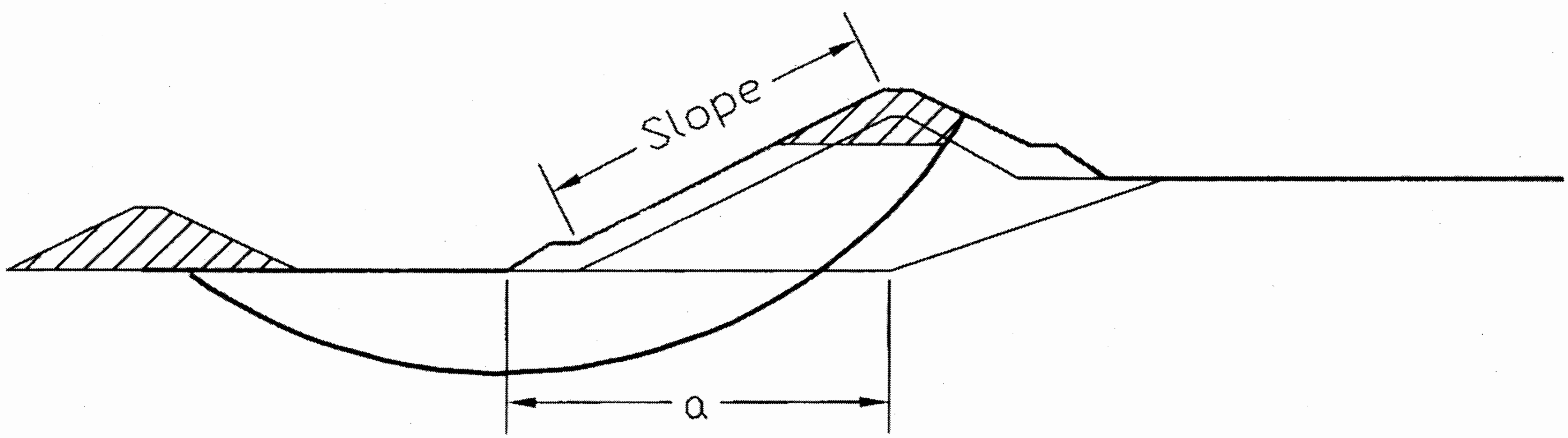
Fig. 5



Breakwater Geometry for Reconstruction Evaluation

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

BREAKWATER GEOMETRY

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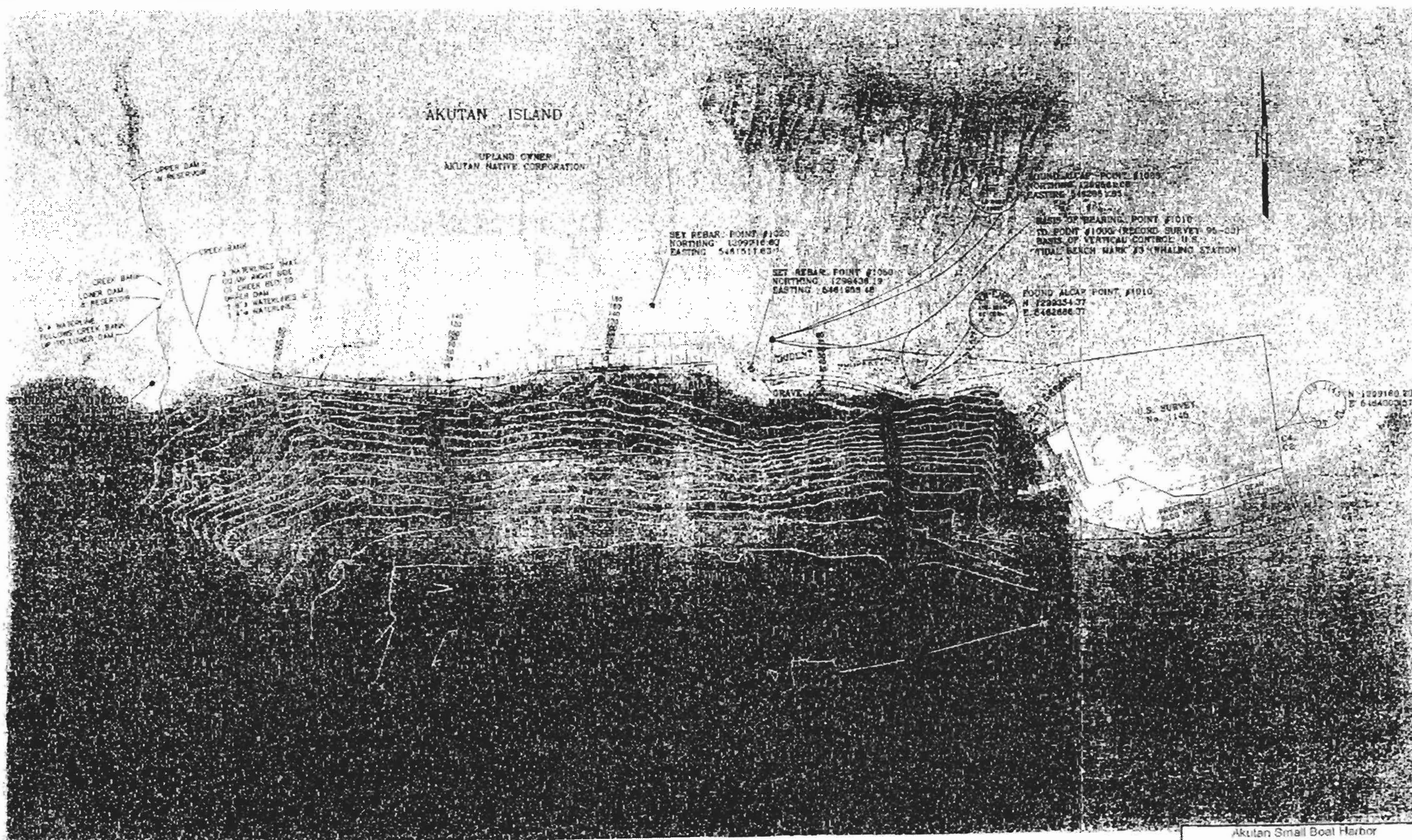
FIG. 6

APPENDIX A

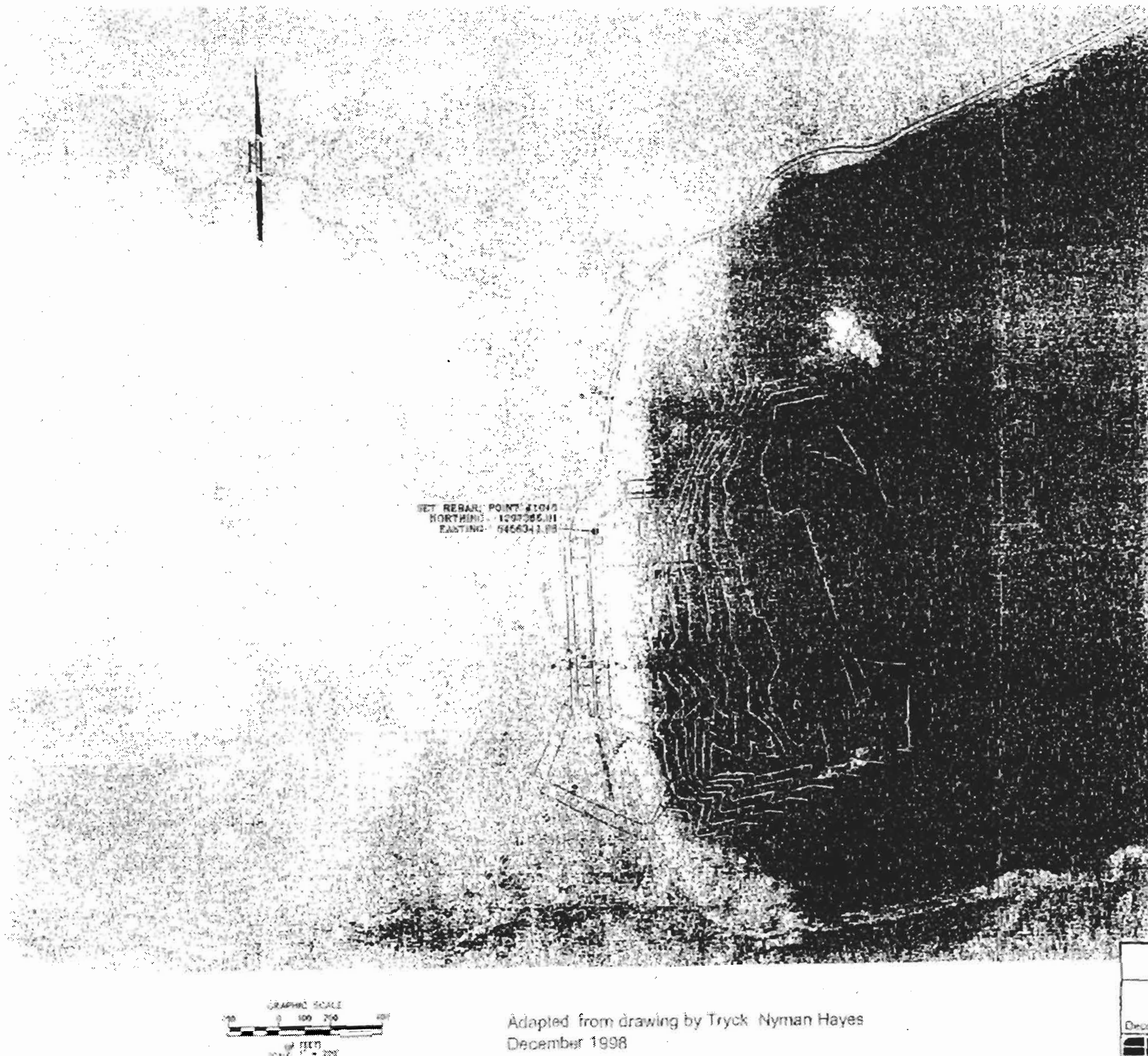
1998 Exploratory Data
Site Plans
Boring Logs
Arctic Geosciences, Inc. Report



GRAPHIC SCALE (IN FEET) SCALE: 1" = 200'

Adapted from drawing by Tryck, Nyman Hayes
December 1998

Akutan Small Boat Harbor Akutan, Alaska	
NORTH CREEK SITE	
December 1998	
SHANNON & WILSON, INC.	Fig. 2



Adapted from drawing by Tryck Nyman Hayes
December 1998

Akutan Small Boat Harbor
Akutan, Alaska

HEAD OF AKUTAN BAY SITE

December 1998 | A-994

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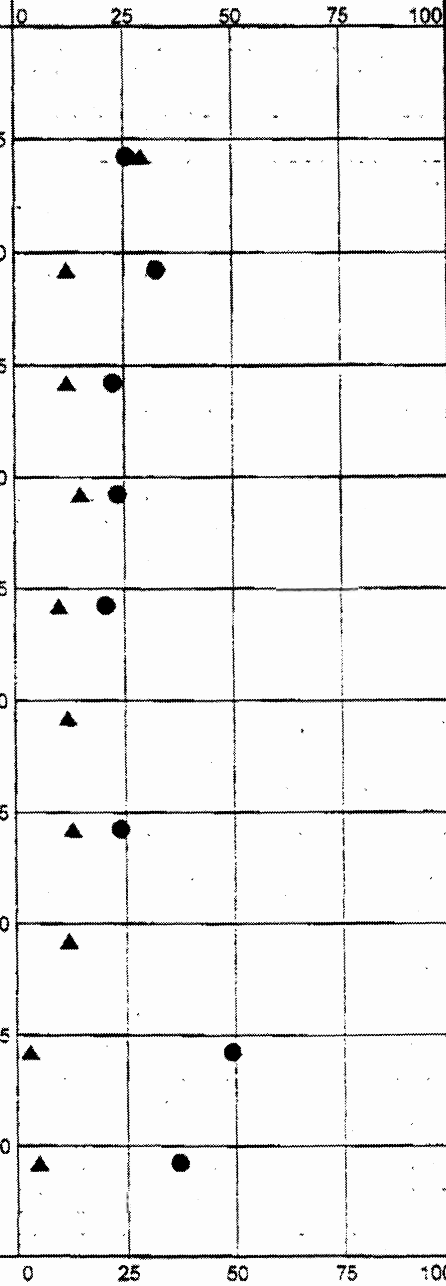
Fig. 3

MATERIAL DESCRIPTION Approx. Surface Elevation 2 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Well graded SAND with silt (SW-SM), medium dense, brown, wet to saturated					
			S-1		5
Increased gravel from 9 to 11.25 ft. Heaving sands during sampling efforts from 10 ft.	11.3		S-2	3/27/01	10
Well graded SAND with silt and gravel (SW-SM), medium dense, black, wet to saturated S-3; Gravel 8%, Sand 88%, Silt 4%			S-3		15
			S-4		20
S-5; Gravel 12%, Sand 82%, Silt 6%			S-5		25
			S-6		30
			S-7		35
			S-8		40
	46.0		S-9		45
SILT with sand (ML), soft to medium stiff, black, wet to saturated Sample S-10, Non-Plastic	51.5		S-10		50
Bottom of Boring Boring Completed 3/27/2001					

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



● % Water Content

Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND

- Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Ground Water Level ATD
- Perched Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-1-01

December 2001 32-1-16384

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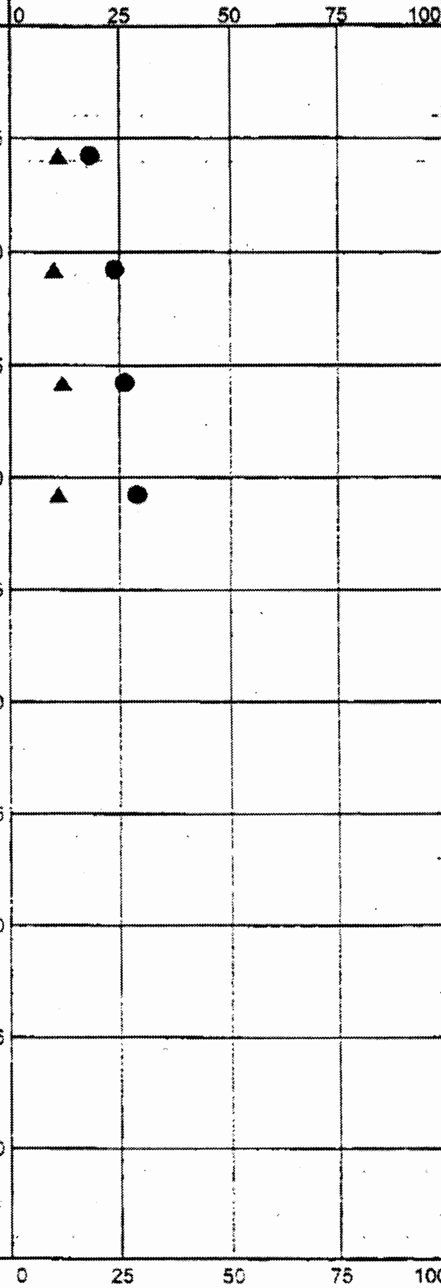
Geotechnical and Environmental Consultants

Fig. A-1

MATERIAL DESCRIPTION Approx. Surface Elevation 5 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Well graded SAND with silt (SW-SM), medium dense, black, wet to saturated Beach location Heaving sands during sampling efforts from 15 ft.			S-1 S-2 S-3 S-4	3/26/01	5 10 15 20
Bottom of Boring Boring Completed 3/26/2001	25.0				25 30 35 40 45 50

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Ground Water Level ATD
- Perched Water Level

● % Water Content

Plastic Limit ⊢—●—⊣ Liquid Limit
Natural Water Content

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-2-01

December 2001 | 32-1-16384

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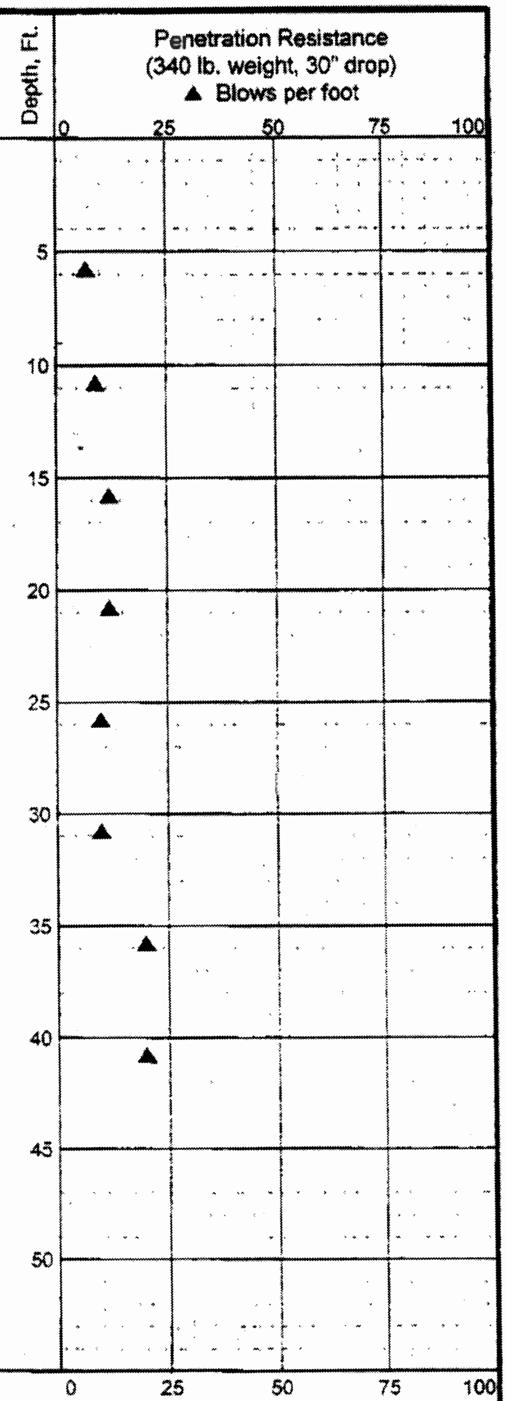
Fig. A-2

S&WGEO1 LOG ENGL.GPJ S&W GEO1.GDT 4/5/02

MATERIAL DESCRIPTION Approx. Surface Elevation 4 Ft.	Depth, Ft.	Symbol	Samples	Ground Water
Silty SAND or sandy SILT (SM or ML) with numerous organics throughout, loose to medium dense, brown, wet	3.5			3/25/01
Well graded SAND with silt (SW-SM), medium dense, brown, wet to saturated Heaving sands during sampling efforts from 10 ft.	17.0		S-1 S-2 S-3	
Well graded SAND (SW), medium dense, black, wet to saturated, with occasional layers of silt Layer of SILT (ML) from 29 to 32.8 ft., stiff, black, wet to saturated	41.5		S-4 S-5 S-6 S-7 S-8	
Bottom of Boring Boring Completed 3/25/2001				



LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Ground Water Level ATD
- Perched Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-3-01

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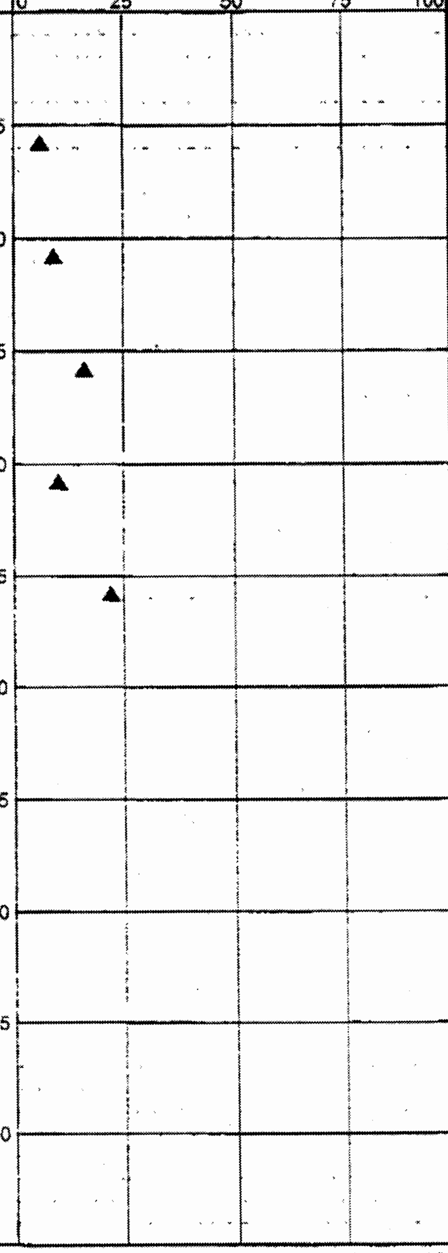
Fig. A-3

S&WGEO1 LOG ENGL.GPJ S&W GEO1.GDT 4/5/02

MATERIAL DESCRIPTION Approx. Surface Elevation 13 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Silty SAND or sandy SILT (SM or ML) with numerous organics, loose to medium dense, brown, wet				3/24/01 ∇	
Well graded SAND with silt and gravel (SW-SM), loose to medium dense, brown, wet to saturated	4.0		S-1, S-2, S-3, S-4		5, 10, 15, 20
Well graded silty SAND with gravel (SW-SM), grading to silty SAND, medium dense, gray, wet to saturated Fine silty SAND with depth	21.1		S-5		25
Bottom of Boring Boring Completed 3/24/2001	26.5				30, 35, 40, 45, 50

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



● % Water Content

Plastic Limit |—●—| Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- ∇ Ground Water Level ATD
- ▼ Perched Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-5-01

December 2001 | 32-1-16384

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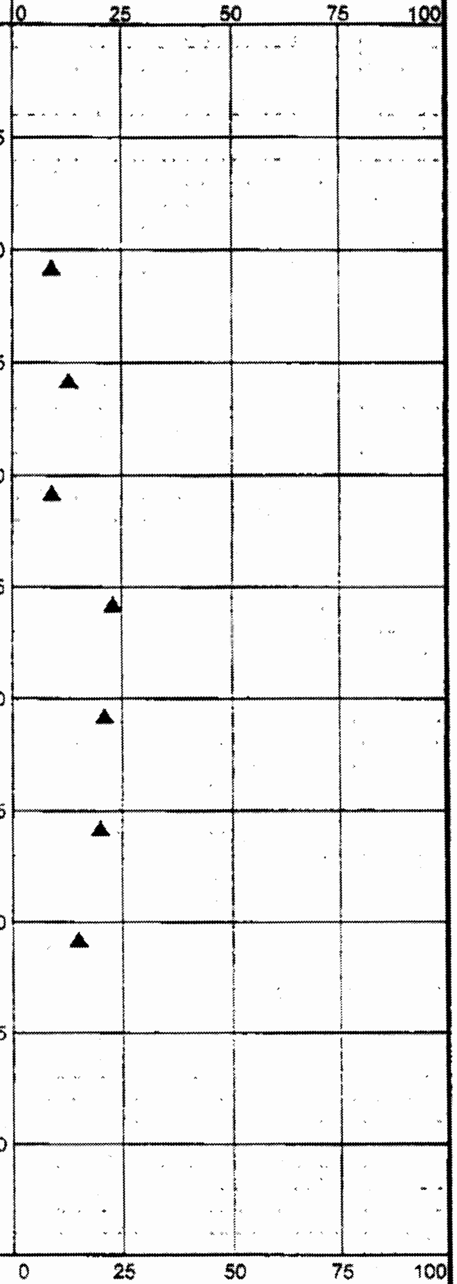
Fig. A-4

S&WGEO1 LOG ENGL.GPJ S&W GEO1.GDT 4/5/02

MATERIAL DESCRIPTION Approx. Surface Elevation 12 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Silty SAND or sandy SILT (SM or ML) with numerous organics, loose to medium dense, brown, wet				3/23/01	
Well graded silty SAND (SW-SM), medium dense, black, wet to saturated	4.5				5
Heaving sands during sampling efforts from 10 ft.			S-1		10
			S-2		15
			S-3		20
			S-4		25
			S-5		30
			S-6		35
			S-7		40
					45
Bottom of Boring Boring Completed 3/23/2001	46.5				50

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Ground Water Level ATD
- Perched Water Level

● % Water Content

Plastic Limit ├─●─┤ Liquid Limit
Natural Water Content

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-6-01

December 2001 32-1-16384

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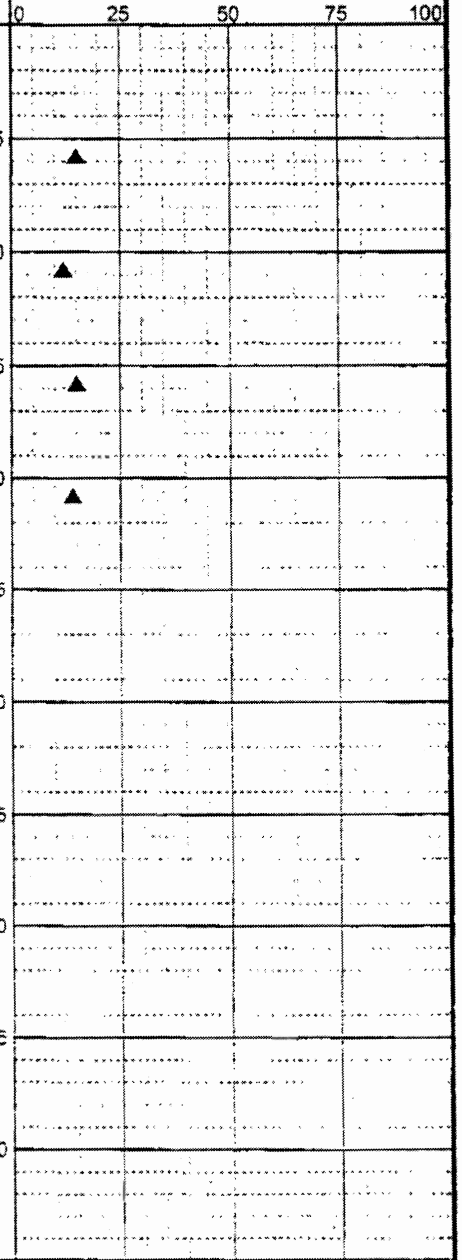
Fig. A-5

S&WGEO1 LOG ENGL.GPJ S&W GEO1.GDT 4/5/02

MATERIAL DESCRIPTION Approx. Surface Elevation 11 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Silty SAND or sandy SILT (SM or ML) numerous organics, medium dense, brown, wet	4.0			3/25/01	
Well graded SAND with silt (SW), medium dense, brown, wet to saturated	10.0		S-1		5
Poorly graded, silty SAND (SM-SM), medium dense, gray, wet to saturated, fine sand	25.0		S-2, S-3, S-4		10, 15, 20
Bottom of Boring Boring Completed 3/25/2001					25

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



0 25 50 75 100

● % Water Content

Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Ground Water Level ATD
- Perched Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-7-01

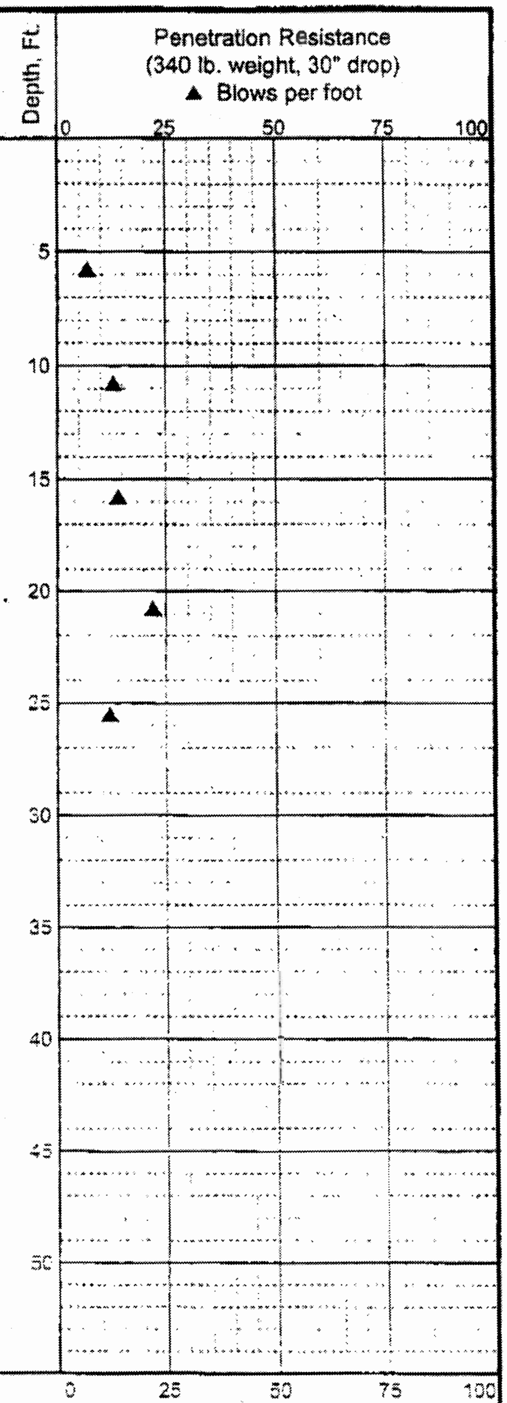
December 2001 32-1-16384

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Fig. A-6

S&WGEO1 LOG ENGL.GPJ S&W GEO1.GDT 4/5/02

MATERIAL DESCRIPTION Approx. Surface Elevation 12 Ft.	Depth, Ft.	Symbol	Samples	Ground Water
Silty SAND or sandy SILT (SM or ML) with numerous organics, loose to medium dense, brown, wet				3/22/01
Well graded SAND with silt (SW), medium dense, gray, wet to saturated	5.5		S-1, S-2	
Heaving sands during sampling efforts from 15 ft.			S-3, S-4	
Well graded SAND with silt (SW-SM), medium dense, black, wet to saturated	23.0		S-5	
Bottom of Boring Boring Completed 3/22/2001	26.0			



LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Ground Water Level ATD
- Perched Water Level

● % Water Content

Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-8-01

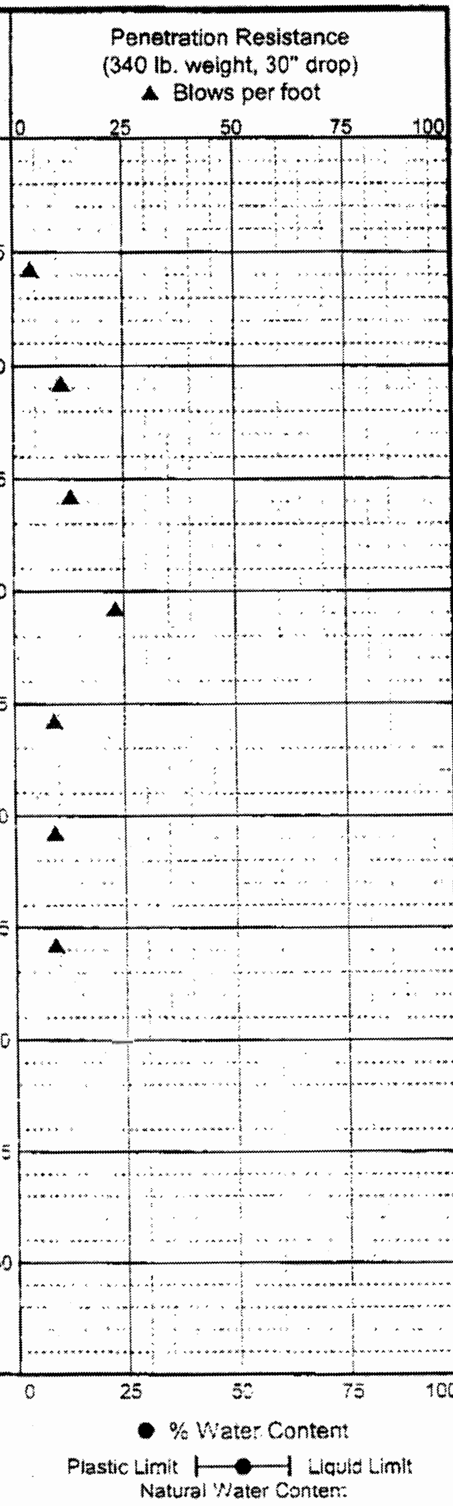
December 2001 32-1-16384

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Fig. A-7

S&WGEO1 LOG ENGL.GPJ S&W GEO1.GDT 4/5/02

MATERIAL DESCRIPTION Approx. Surface Elevation 13 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Silty SAND or sandy SILT (SM or ML) with numerous organics, medium dense, brown, wet				3/21/01	
Well graded SAND with silt (SW-SM), medium dense, brown or gray, wet to saturated Heaving sands during sampling efforts from 10 ft.	6.0		S-1, S-2, S-3, S-4, S-5		5, 10, 15, 20, 25
Silty SAND (SM) with shell fragments, medium dense, black, wet to saturated	30.8		S-6		30
Well graded SAND with silt (SW-SM), medium dense, gray, wet to saturated	33.0		S-7		35
Bottom of Boring Boring Completed 3/21/2001	40.0				40, 45, 50



LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Ground Water Level ATD
- Perched Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by IPP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-9-01

December 2001 32-1-16384

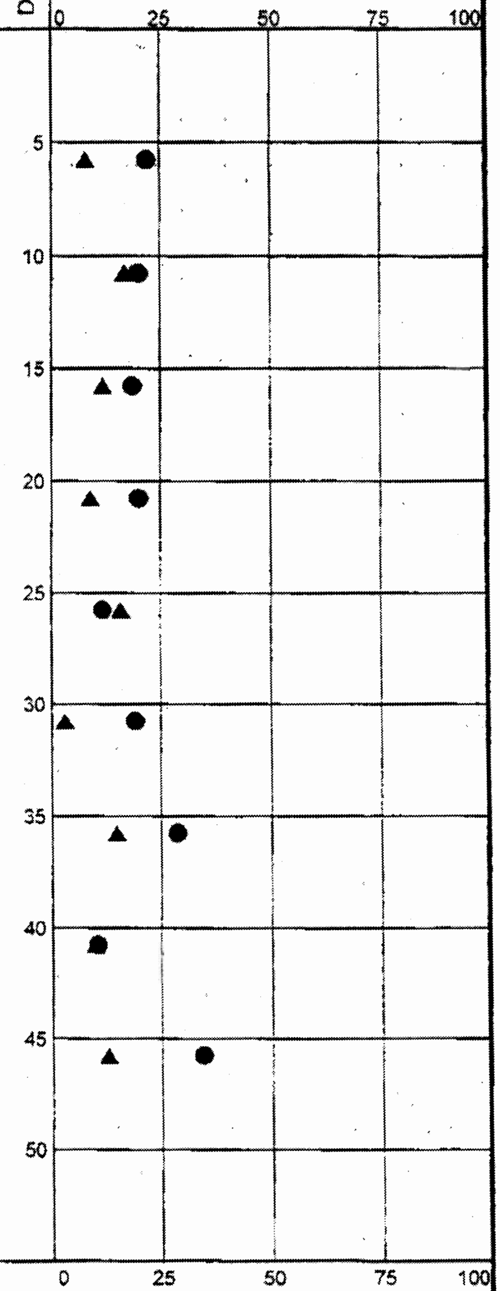
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Fig. A-8

S&WGEO1 LOG ENGL.GPJ S&W GEO1.GDT 4/5/02

MATERIAL DESCRIPTION Approx. Surface Elevation 10 Ft.	Depth, Ft.	Symbol	Samples	Ground Water
Silty SAND or sandy SILT (SM or ML) with numerous organics throughout, loose to medium dense, brown, wet				3/26/01
Well graded SAND with silt and gravel (SW-SM), medium dense, brown, wet to saturated S-2; Gravel 9%, Sand 82%, Silt 9% Heaving sands during sampling efforts from 10 ft.	5.0		S-1 S-2 S-3	
Well graded SAND (SW), medium dense, black, wet to saturated, occasional layers of silt Layer of SILT (ML) from 34 to 36.5 ft., stiff, black Sample S-7, Non-Plastic	19.0		S-4 S-5 S-6 S-7 S-8 S-9	
Bottom of Boring Boring Completed 3/26/2001	50.0			

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



● % Water Content

Plastic Limit ├──●──┤ Liquid Limit
Natural Water Content

LEGEND

- • Sample Not Recovered
- ⌶ 2" O.D. Split Spoon Sample
- Ⅲ 3" O.D. Split Spoon Sample
- Ground Water Level ATD
- Perched Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-10-01

December 2001 | 32-1-16384

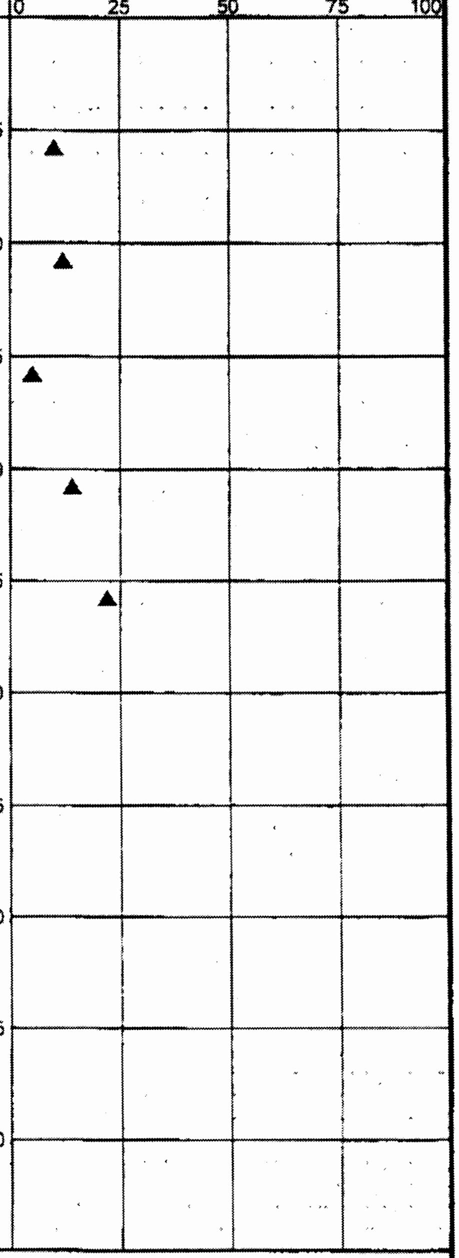
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Fig. A-9

SAWGEO1 LOG ENGL.GPJ S&W GEO1.GDT 4/5/02

MATERIAL DESCRIPTION Approx. Surface Elevation 14 Ft.	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Silty SAND or sandy SILT (SM or ML) with numerous organics throughout, loose to medium dense, brown, wet	4.0			▽ 3/24/01	
Well graded SAND with variable zones of silty SAND (SW-SM), medium dense, black, wet to saturated Heaving sands during sampling efforts from 10 ft.	26.5		S-1, S-2, S-3, S-4, S-5		5, 10, 15, 20, 25
Bottom of Boring Boring Completed 3/24/2001					30, 35, 40, 45, 50

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



0 25 50 75 100

● % Water Content

Plastic Limit |—●—| Liquid Limit
Natural Water Content

LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- ▽ Ground Water Level ATD
- ▼ Perched Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. Pocket pen values are represented by PP. Torsional force vane values are represented by TV. Percent passing the number 200 sieve is represented by P200.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING B-12-01

December 2001 32-1-16384

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Fig. A-10

ARCTIC GEOSCIENCE, INC.
1000 O'MALLEY DRIVE, SUITE 205 • ANCHORAGE, ALASKA 99515-3069

December 9, 1998
98-0401

Shannon & Wilson, Inc.
5430 Fairbanks Street, Suite 3
Anchorage, Alaska 99518

Attention: Ms. Lorie Dilley, Project Manager

Final Report
Akutan Harbor Study
Geophysical Survey Services
Akutan, Alaska

Transmitted herewith are three copies of Arctic GeoScience Inc.'s final report for the Akutan Harbor geophysical survey. Arctic GeoScience, Inc. (AGSI) was retained to provide geophysical services in support of Shannon & Wilson, Inc.'s (SWI) U.S. Corps of Engineers Alaska District harbor study at Akutan Bay, Alaska. The purpose of this geophysical survey was to provide subbottom data in support of the geotechnical information sought for the design of a new small boat harbor in Akutan Bay, Alaska. During the execution of our services, AGSI's representatives consulted with Mr. Keith Mobley, Ms. Lori Dilly, and Mr. Mitch Miller of Shannon and Wilson Inc., and Mr. Mel Saunders, with Tryck Nyman Hayes, Inc. 's. This transmittal completes our scope of services.

Arctic GeoScience Inc. appreciates this opportunity to assist Shannon and Wilson Inc. We remain available to assist you in the future. Should you have any questions or require any additional information, please do not hesitate to contact the undersigned or Michael Schlegel at (907) 522-4300.

Sincerely,
Arctic GeoScience Inc.

Stephen F. Davies, MSc
Vice President

Phone (907) 522-4300 FAX (907) 522-4301

Akutan Harbor Study
Geophysical Survey Services
Akutan Bay, Alaska

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Akutan Harbor Study
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1.0 INTRODUCTION

Arctic GeoScience, Inc. (AGSI) was retained to provide geophysical services in support of Shannon & Wilson, Inc.'s (SWI) U.S. Corps of Engineers Alaska District harbor study at Akutan Bay, Alaska. Our geophysical services were authorized verbally by Mr. Keith Mobley of SWI, on August 14,1998. Arctic GeoScience Inc. executed our services in their entirety under this verbal agreement with Shannon and Wilson Inc. The purpose of this geophysical survey was to provide subbottom data in support of the geotechnical information sought for the design of a new small boat harbor in Akutan Bay, Alaska. During the execution of our services, AGSI's representatives consulted with Mr. Keith Mobley, Ms. Lori Dilly, and Mr. Mitch Miller of Shannon and Wilson Inc., and Mr. Mel Saunders, whom was Tryck Nyman Hayes, Inc. 's (TN&H) onsite representative during AGSI's geophysical survey, as well as, providing positioning services.

This transmittal completes AGSI's scope of services in support of SWI's harbor study at Akutan Bay, Alaska.

2.0 PROJECT OBJECTIVE AND SCOPE OF SERVICES

AGSI's geophysical services were directed at investigating proposed Harbor Sites 1 and 4, which are located at North Creek and the head of Akutan Bay, respectively (Figure 1). AGSI's scope of services were developed as a result of SWI's negotiations and program planning with TN&H and the US Corps of Engineers. AGSI did not participate nor provide consultation in support of developing the geophyiscal field program. The primary objective of the geophysical survey was to obtain subbottom data which could be used to interpret the acoustic base of sediments, which could approximate the depth to bedrock along the new dock face alignments. AGSI's geophyscial services were limited to providing 4500 lineal feet (1373 meters) of subbottom profile data at Site 1, and 1000 lineal feet (305 meters) of subbottom profile data from Site 4. Our geophysical services were to be logistically supported by SWI, which was inclusive of transportation for our personnel and equipment, accommodations for our personnel while on location, and navigation/positioning services to control our geophysical survey. As a result, AGSI provided all logistical support to accomplish our geophysical services, as well as, providing logistical support inclusive of transportation and accommodations to TN&H's positioning specialist and his field equipment. AGSI provided vessel support to TN&H's hydrographic survey.

3.0 GEOPHYSICAL PROGRAM SUMMARY

3.1 Field Operations Summary

AGSI mobilized a three-person field team and geophysical support equipment to Sand Point, Alaska via commercial airliner on September 23,1998. Upon arrival at Sand Point, Alaska, our field team and TN&H's onsite representative traveled to Akutan aboard AGSI's chartered 110-ft vessel, F/V Lady Simpson. During transit, AGSI and TN&H representatives coordinated project activities and conducted a health and safety review.

AGSI's geophysical survey lines were pre-plotted and oriented by TN&H's positioning specialist, such that they intercepted SWI's proposed drill hole locations. Navigational control for this survey was provided to AGSI in real-time latitude/longitude through TN&H's Ashtech Global Positioning System (GPS) instruments. Post-plot coordinates of the tracklines and fix points were provided in Alaska State Plane Coordinates to AGSI by TN&H upon completion and our return to Anchorage.

The F/V Lady Simpson and our field crew arrived onsite in Akutan Bay at 2330 hours, September 26, 1998. Upon our arrival, our field team immediately began assembling and calibrating AGSI's high-resolution geophysical equipment. An operations summary is presented in Table 1, a time and events summary is presented in Table 2, and a detailed time and events listing can be found in Appendix A. All geophysical survey operations were conducted aboard the F/V Lady Simpson. AGSI's 20-ft inflatable boat was available, but it was only enlisted to set up topographic survey control on the beach and deployment of oceanographic recorders. The S-4 Oceanographic Recorders began collection of tide data September 27, 1998 at approximately 1400 hrs, and completed the data collection at 0900 hrs on the 28th of September. A tide staff established at the coastline by TN&H's positioning specialist was used to monitor sea level change during survey activities on the 28th and the 29th of September.

Table 1

Summary of Survey Operations
Akutan Harbor Survey

DATE	FROM	TO	TASK/EQUIPMENT	SITES
September 27 1998	09:00 hours	18:00 hours	Establish survey control Deploy current meters	Site 1
September 28 1998	11:30 hours	15:30 hours	Sidescan, Chirpll	Site 1
September 28, 1998	16:00 hours	17:30 hours	Bubble Pulser	Site 1
September 28, 1998	20:45 hours	21:15 hours	Bubble Pulser	Site 4
September 29, 1998	11:30 hours	13:00 hours	Sidescan, Chirpll Retrieve current meters	Site 4

Table 2

Summary of Time and Events
Akutan Harbor Survey

Travel Summary	
Anchorage to Akutan	85 hours
Akutan to Anchorage	46.5 hours
Survey and Stand-By Summary	
Time surveying	8
Tide gauging	1
Onsite stand-by	12.5

Once survey control was established, the data acquisition program commenced. The geophysical survey lines originally pre-plotted in our Anchorage office were revised in the field to accommodate the site conditions present at the time of our survey. Because of the steep southerly dipping geologic structure and the resulting out-of-plane noise at Site 1, a survey grid for the Bubble Pulser data was developed onsite. A series of 13 tracklines were surveyed with AGSI's Bubble Pulser parallel to shore on 15-meter spacing (Figure 1). AGSI also surveyed 6, north south oriented, tie-lines spaced at 50-meter intervals.

The original survey plan for Site 4 was to shoot a total of 5 tracklines; 2 lines parallel to shore (north-south), 25 meters apart and 3 lines perpendicular to shore (east-west), 100 meters apart (Figure 1). AGSI's Bubble Pulser survey was reduced onsite to 3 tracklines, two primary lines with north-south orientation that were spaced 50 meters apart and one east-west bisecting cross line. The reduction in AGSI's planned coverage was due to the shallow water encountered with respect to the pre-plot location of SWI boreholes. The location of SWI's Site 4 boreholes originally plotted offshore on the pre-plot project site map were determined by TN&H surveyor in the field to be located on the beach based on coordinate relationship to the study area. The geophysical survey lines were run as close to the beach as logistically possible.

Sidescan sonar and subbottom data were collected simultaneously. Side Scan Sonar and subbottom data were collected along 20 tracklines based on the revised Site 1 survey plan. Seventeen primary lines were run perpendicular to shore, spaced approximately 25 meters apart, while the tie-lines were parallel to shore at 70-meter spacing (Figure 1). At Site 4, AGSI's survey consisted of 9 tracklines, three primary north-south lines spaced 50 meters apart, and six east-west tie-lines spaced 50 meters apart.

AGSI's geophysical team completed its field services September 29, 1998 at approximately 1430 hours. The field crew demobilized our equipment and traveled to Sand Point. From Sand Point, our crew returned to Anchorage via commercial airline.

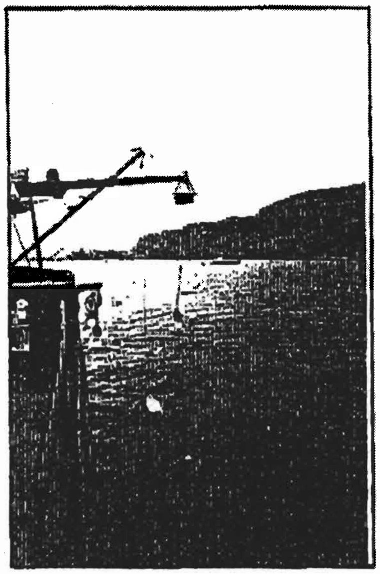
AGSI collected approximately 22,967 lineal feet (7000 lineal meters) of Bubble Pulser data and 17,061 lineal feet (5200 lineal meters) of sidescan and Chirp II subbottom profiler data at Site 1. Approximately 2625 lineal feet (800 lineal meters) of Bubble Pulser data and 6890 lineal feet (2100 lineal meters) of sidescan and Chirp II subbottom data were collected at Site 4. AGSI attended a post survey briefing with SWI in their Anchorage offices at which time SWI's representatives selected three Bubble Pulser lines, lines 1+05, 1+120, and 1+35. The three bubble pulser lines at Site 1 total 4500 lineal feet. One bubble pulser line was selected for Site 4, line S4-2, to total 1000 lineal feet. This selected data set is presented and transmitted in this report, and this data set completes AGSI's scope of geophysical services. The additional Side Scan Sonar, Chirp II subbottom profiler, and Bubble Pulser data is available and in AGSI's files should SWI or its client require additional supporting information

3.2 Geophysical Data Acquisition

AGSI mobilized a suite of high resolution geophysical tools in order to support our capabilities to accomplish the objectives of this geophysical survey. AGSI deployed these geophysical systems at the two proposed harbor locations in Akutan Bay. AGSI's geophysical survey in Akutan Bay included the use of our Bubble Pulser, Chirp II subbottom profiler, and CHIRP Technology Side Scan Sonar. These geophysical tools are briefly described in the following text. A schematic illustrating the deployment location of AGSI's geophysical tools off the survey vessel is presented on Figure 2.

3.2.1 SPR 1200 Bubble-Pulser Seismic Profiler

AGSI utilized our Data Sonics SPR-1200 Bubble Pulser System as the primary geophysical tool to collect subbottom profile data during this program. This system is manufactured by Datasonics Inc., and it is designed to penetrate to bedrock through a variety of sediment types, 50 to 150 meters of penetration. Its light-weight, electromagnetic transducer generates a narrow band 400 Hz acoustic pulse, and its power supply provides an acoustic source level of +200 dB ref 1μPa at 1 meter. This instrument was designed for towing in adverse sea conditions, while collecting data with a range resolution of ±2 meters.



Bubble Pulser data was collected for the purpose of determining the acoustic base of the sediments presented in Akutan Bay. The depth to base of sediments approximates the depth to bedrock. The bubble pulser acoustic source and hydrophone streamer were deployed on the starboard side of the charter vessel during the Akutan geophysical surveys. Prior to immersing the acoustic source, a series of pre-deployment checks were performed on deck. The source was positioned approximately 2 meters starboard of the boat and the hydrophone streamer was positioned about 1 meters aft of the acoustic source.

A 4 milliseconds time delay was used to correct for the distance between the tool and the navigation antenna (8 meters), Figure 2.

Bandpass filtering was the only processing performed for this program. A filter setting with frequency range from 300 Hz to 10,000 Hz was passed without attenuation. The upper 25-40 meters of subbottom data collected from the Bubble Pulser was readily interpreted without further signal processing.

3.2.2 Side Scan Sonar Data Acquisition

Side Scan Sonar imagery was not included in AGSI's scope of services. AGSI mobilized our side scan sonar system to collected seafloor imagery to identify seafloor geohazards and debris that may interfere with future construction of a new harbor. The side scan data is available if in the future this proves beneficial to the dock/harbor designer. One representative trackline was selected and presented on Figure 3.

The side scan towfish was mounted on the starboard crane and deployed off the starboard side during both site surveys. Prior to immersing the towfish, a series of pre-deployment checks were performed on deck. The towfish was deployed with enough cable so that it hung approximately 2 meters below the water surface, below the hull of the vessel, and approximately 2 meters to starboard. The towfish was located approximately 11.5 meters forward of the navigation antenna, Figure 2. Weather conditions were favorable during data acquisition. Tide fluctuations were minimal. Survey vessel speed ranged from 1.5 - 3 knots during the acquisition of side scan sonar data.

3.2.3 Chirp II Subbottom Profile Data Acquisition

High-resolution Chirp II subbottom profiles were acquired to improve the interpretation of sedimentary layering in the upper 15 meters of seafloor. The Chirp II subbottom profiler data would provide high resolution records within the depth of investigation of SWI's planned soil borings. AGSI mobilized our Chirp II subbottom system to collect high-resolution subsurface data to identify seafloor geohazards and to improve interpretation of the near surface stratigraphy. The Chirp II subbottom profiler data is available if in the future this proves beneficial to the dock/harbor designer. One representative trackline was selected and presented on Figure 4.

The Chirp II subbottom towfish was mounted to the port crane of the survey vessel. Prior to immersing the Chirp II towfish, the field crew performed pre-deployment checks on deck. The towfish was deployed so that it hung approximately 1 meter below the water surface and about 5 meters to port. The towfish was located approximately 11 meters forward of the navigation antenna, Figure 2.

4.0 FINDINGS FROM THE GEOPHYSICAL SURVEY

4.1 Geologic Setting

Akutan Island is located in the eastern Aleutian Islands at latitude 54°05' N, longitude 165°55' W. The Aleutian Island Chain is a volcanic arc resulting from the subduction of the northern-moving Pacific Plate under the North American Plate. This subduction zone includes the Aleutian Trench, where the two plates converge, and the Aleutian Volcanic Arc. Magma resulting from the melting of the Pacific Plate at depth rises to the surface, creating islands dominated by volcanoes. Most of the major Aleutian Islands have active volcanoes, including Akutan Island. Akutan Volcano (1300 meters) lies on the west side of Akutan Island. The volcano is active and has had recorded eruptions more than thirty times in the last 200 years. Eruptions have included smoking, lava flows, release of ash, and full explosives.

Akutan Island is rugged and mountainous. The shorelines are mainly steep cliffs and rocky headlands. The central and eastern parts of the island consist of steep ridges separating valleys formed from glacial scouring. These valleys predate the formation of the Akutan Volcano. The drainage pattern of the island radiates from the volcano, suggesting that an old topographic high was located in the area now occupied by the Akutan Volcano. The western side of Akutan Island is gently sloped and drained by streams flowing off of the west flank of the volcano.

4.1.1 General Geology of Akutan Island

Akutan Island consists of volcanoclastic debris flows interbedded with lava flows. The debris flows are overlain with volcanic deposits associated with the Akutan Volcano. The volcanic units as defined by Motyka and Nye (Motyka, Nye, 1998) include the Hot Springs Bay volcanics, the Akutan volcanics, and general Holocene volcanics.

The Hot Springs Bay volcanics underlie most of Akutan Island, and have been found to be at least 700 meters thick. Exposures are seen on about half of the island. The dominant lithology is a poorly sorted and stratified volcanic breccia composed of fragments of basalt and andesite. No distinct internal bedding is apparent, but layers are marked by slight breaks in the slope of the deposit. Angular to rounded blocks of up to 3 meters in diameter are contained in a clay sized matrix. Porphyritic basalt and andesite dikes are also found in the Hot Springs Bay volcanic. The dikes range in thickness from 0.3 to 10 meters. The breccia outcrops are limited to the sea cliffs; inland the breccia forms the rounded grassy slopes. The more resistant dikes form the visible inland outcrops. The Hot Springs Bay volcanics have been interpreted to be Miocene to Pliocene in age.

The Akutan Volcanics unconformably overlie the Hot Springs Bay volcanics. The Akutan Volcanics consists of resistant ridge-capping lava flows ranging in thickness from 2 to 31 meters. The flows either lie directly atop another flow or are separated by thin layers of volcanic breccia. The flows consist of porphyritic basalt and andesite with up to 10%

phenocrysts in a holocrystalline groundmass. These lava flows form steep slopes and make good exposures. Potassium-Argon aging done on the Akutan Volcanics ranges from 1.1 +/- 0.2 to 1.5 +/- 0.1 m.y.

The Holocene Volcanic deposits consist mostly of blocky (aa) lava flows. Both the Akutan Volcano and a small cinder cone that developed around 1852 just northeast of Lava Peak have produced the deposits that make up this group.

4.1.2 Surficial Geology of Akutan Island

Late Wisconsonian-stage glaciation of Akutan Island has resulted in landforms such as cirques and aretes on the higher slopes and u-shaped valleys radiating from the west central region of the island. The u-shaped valleys have been modified by stream erosion cutting channels up to 150 meters deep and volcaniclastic deposition in the lower portions of the major valleys. Morphology of the major valleys and the fjord like features suggest that the glaciers terminated offshore of the present coastlines. Therefore, terminal moraines are not seen. Most lateral moraines have been covered with volcaniclastic debris.

Volcaniclastic deposits are widespread on the island. These deposits consist of layers of volcanic ash and lapilli with occasional bombs. The deposits range in thickness from 0 meters on steep slopes to 30 meters in valley bottoms. Some deposits suggest fluvial and mudflow reworking. This ash has been identified as poor foundation material because it is not dense and tends to liquefy when vibrated.

4.1.3 Geology of Akutan Bay

Akutan Bay is an 8 km long, east-west trending, deep, fjord-like structure that bisects the east end of the island. This fjord interpretation is supported by the data taken in the AGSI survey, where u-shaped structure is apparent, Figure 5. 1980 seismic studies, taken over a stream delta in the harbor, interpreted with a program developed by the U.S. Bureau of Mines, show a two layer model. Layer 1 is interpreted to be loose volcaniclastic ash deposited by the stream in a 3 meter thick layer. Layer 2 is interpreted to be a loose, saturated volcanic ash mixed with loose beach gravels in a layer that extends to a least 10 meters depth. These layers overlay volcanic bedrock.

Beach deposits in Akutan Harbor range from boulders to sand. The steep cliffs that surround the shoreline promote boulder beaches exposed at low tide. As distance increases from the cliffs, deposits range from cobbles to sand, grain size decreasing with distance from the cliffs. This interpretation is supported by the boreholes provided to AGSI by Shannon and Wilson. The three main lithologies consist of sand, gravels, and boulders. The sands correspond to volcanic ashes and reworked beach sands. The gravels correspond to cobbles and gravel located at intermediate distances seaward from the sea cliffs. The intermediate distances indicate some beach reworking causing the break down of larger boulders into the gravels and cobbles. The boulders correspond to sea cliff deposits caused by erosion of the steep surfaces. Because of the irregularity of the sea cliff surfaces, deposition of the sands, gravels and boulders (coarse clastics), will vary depending on the proximity to sources of deposition and stability of the submarine slopes, Figure 6 and 7. This causes the wedge structures and phasing in and out of lithologies seen in the boreholes and the Bubble Pulser's records at Site 1. It is also prudent tc be aware of the potential slope instabilities when designing and implementing coastal structures and facilities.

The head of Akutan Bay trends in a straight line north-south, with stream deltas marking the north and south corners, and a third delta in the northern third of the head. The slope of the head dips gently to the east compared to the steep slope of the north and south facing harbor walls. This supports a glacial carving interpretation of the formation of Akutan Bay. The deposits at the head of the harbor consist of loosely packed volcaniclastics ash, sand, gravel, and cobbles. These deposits are up to at least 12 meters thick, as supported by SWI logs of the boreholes drilled and Bubble Pulser records at Site 4. These sediments most likely have been transported and reworked by the local streams.

4.2 Site Soil Conditions

SWI performed a geotechnical soil boring program at both potential harbor locations. The borehole logs compiled from SWI's geotechnical investigation were transmitted to AGSI in order to facilitate and support geologic interpretations. SWI's geotechnical program was performed after AGSI's field geophysical survey was completed and demobilized from Akutan.

A generalized lithologic summary has been prepared from SWI's soil boring logs. The generalized soil units and log sections are illustrated on Figure 8. The primary USC (Unified Soil Classification) soil units identified in SWI's logs consist of:

- silt,
- sand and silty sand,
- sandy gravel,
- gravel,
- gravelly boulders,
- weathered bedrock (undifferentiated bedrock),
- and bedrock (undifferentiated bedrock),

A copy of the borehole logs and supporting geotechnical data provided to AGSI from SWI is presented in Appendix B.

4.3 Geophysical Interpretation

The Bubble Pulser survey consisted of 22,967 lineal feet (7,000 lineal meters) of Bubble Pulser data at Site 1, and 2,625 lineal feet (800 lineal meters) of Bubble Pulser data at Site 4. SWI's three tracklines, selected for Site 1 that support the purpose of this investigation, are presented in Figures 9 through 11. Figure 12 presents S4-2 the representative geophysical survey line from Site 4. The Bubble Pulser subbottom profiling system was able to achieve penetration of approximately 200 feet (70 meters). In general, the quality of the data is good, allowing for the identification of the seafloor reflector (mudline), sedimentary layering, and the interpreted top-of-bedrock reflector used to provide the interpreted depth of sediments annotated on Figure 1, without performing extensive processing of the data record. Multiple reflections (i.e. multiples), which are artifacts created by the acoustic signal reverberating in the water column and between subbottom layers, were observed on most of the records and are annotated as such on the geophysical records presented with annotated interpretations.

AGSI is unable at this time to present a depth to bedrock isopach for the survey area as the bathymetry has not been provided to us at this time. AGSI has obtained copies of SWI's borehole logs from the geotechnical investigation performed at potential Harbor Sites 1 and 4. In lieu of the isopach mapping requested, AGSI has provided sectional interpretations, with SWI's borehole data annotated where applicable, along the selected geophysical records. Three selected bubble pulser records from lines E1+35, E1+20, and E1+05 are presented on Figures 13 through 15. AGSI only has provided our interpretation annotated on the bubble pulser line for Site 4, line S4-2, on Figure 16 as the boreholes identified and drilled by SWI were in shallow water near the beach, and AGSI geophysical survey lines do not pass through these locations at Site 4.

AGSI has also presented an interpreted "base of sediment" (from AGSI's interpreted mudline) along the three selected bubble pulser tracklines at Site 1 and along the selected trackline at Site 4, Figure 1.

4.3.1 Presentation of Findings at Potential Harbor Site 1

Harbor Site 1 is situated near North Creek at the base of a moderately steep to steep slopes, associated with a relic sea cliff. The steep cliffs at Site 1 that encompass and limit the shoreline to boulder beaches are typically exposed at low tide.

Four principle sedimentary intervals characterize the Bubble Pulser records at Site 1:

Interpreted Lithology

- Sand and Fine-Grained Sediment
- Sandy Gravel
- Gravel, Boulders
- Coarse-grained Sediment
- Sedimentary Wedge

The apparent sediment thickness was scaled from the Bubble Pulser data record at each event location and controlled by comparison with boring logs provided by SWI. A smooth and laterally continuously reflector correlates well with the base of a sand unit described on the SWI's boring logs (Appendix B). This sand interval, which is highlighted in light yellow on Figures 13 through 15, is found in SWI borings 2, 5, 6, and 7. It is described as brown to black, loose, wet, medium-grained sand, with some seashells. Boring logs describe the sand unit as being 15 to 50 feet (5 to 16 meters) thick, and it increases in thickness from west to east.

The underlying sedimentary unit appears to be continuous from east to west and maintains a thickness of 13 to 16 feet (4 to 5 meters). This unit, which is highlighted in green, occurs in SWI soil borings 2, 5, 6, and 7. SWI describes this interval as consisting of gray/green to black, sandy gravel of medium density.

Beneath the sandy gravel is a uniform layer, which is highlighted in pink on Figure 13 through 15. This unit maintains a nearly constant unit thickness of 5 feet (1.5 meters). Descriptions of this layer on geologist's logs from SWI borings 2 and 5 indicate that this unit consists of green/gray gravelly boulders or possible bedrock. Bedrock type or consistency is undifferentiated. Bedrock core obtained in SWI borehole 5 presents an RQD of 72 with no description.

AGSI interprets two units underlying the gravelly boulder unit on Lines E1+05 and E1+20. To the east is a wedge-shaped lithologic unit, which is highlighted in yellow. This wedge laps onto and truncates against the lowest interpreted sedimentary unit, which is highlighted in blue. It varies in thickness from 6 to as much as 16 feet (2 to 5 meters). Scattered, discontinuous, subhorizontal reflectors within the wedge-shaped unit suggest that it is composed of clastic sediments, but no soil boring data are available for verification.

The deepest interpreted sediments at Site 1 are highlighted in blue. This interval contains scattered, discontinuous, subhorizontal and occasional onlapping reflectors, which suggest clastic sediments, but no borehole data is available from this interval.

At Site 1, the dashed red line that forms the lower boundary of the blue interval represents the acoustic limit of interpreted sediments. The depth to this limit increases from west to east from 98 to 121 feet (29 to 37 meters). Depths to the acoustic limit of interpreted sediments are presented on Figure 13 and 15.

4.3.2 Presentation of Findings at Potential Harbor Site 4

Site 4 is situated at the head of Akutan Bay. The head of Akutan Bay is a depositional environment which should consist of loosely packed volcaniclastics, ash, sand, gravel and cobbles reworked by fluvial processes. Our interpreted record for Bubble Pulser Line S4-2 is presented on Figure 16. Two soil borings were completed at Site 4 by SWI, but neither of these borings were close enough to Line S4-2 to use as lithologic control for AGSI's interpretation of this record. AGSI has interpreted three sedimentary units on Line S4-2. SWI borehole logs for boring 10 and 11, drilled at Site 4, findings were predominately sand, silty sand with gravel to depth of 40 feet.

Interpreted Lithology

- Sand and Fine-Grained Sediment
- Sandy Gravel
- Gravel, Boulders
- Coarse-grained Sediment
- Sedimentary Wedge

The shallowest interpretive unit is characterized by strong, continuous, subparallel reflectors. This unit, which is highlighted in yellow on Figure 16, is interpreted to be sand. Underlying the sand is a lens-shaped unit characterized by hummocky internal reflectors that occasionally onlap onto the underlying sediments. This unit is interpreted to be coarser grained sediments, possibly sandy gravel. The lowest interpreted sedimentary unit is highlighted in pink. Based on its stratigraphic position, it is interpreted to consist of coarse sediments, likely sandy gravel to boulders. The acoustic base of deepest interpreted sediments is marked with a dashed red line on Figure 16. This surface represents the lower boundary of reflection characteristics (continuous reflectors, onlap, downlap) that can be reasonably interpreted to be of sedimentary origin. Depths to this interpreted lower sediment boundary are presented on Figure 1.

5.0 LIMITATIONS

AGSI performed these services in a manner consistent with that level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. AGSI's geophysical investigations are conducted within the design limitations of the equipment selected for the specific purpose described herein. However, no warranty, expressed or implied is made. This report is intended for the exclusive use of SWI for the purpose described herein.

6.0 CLOSURE

AGSI appreciates this opportunity to support SWI's small boat harbor study of Akutan, Alaska. Should you have any questions or require any additional information, please do not hesitate to contact Mr. Michael Schlegel or the undersigned at (907) 522-4300.

Sincerely,

Arctic GeoScience, Inc.

Stephen F. Davies
Geoscience Consultant
Vice-President

Reviewed by:

Arctic GeoScience, Inc.

Michael G. Schlegel
Geotechnical Consultant
President / CEO

REFERENCES

Selected Bibliography

Motyka, R.J., Nye, C.J., 1988, "A Geological, Geochemical, and Geophysical Survey of the Geothermal Resources at Hot Springs Bay Valley, Akutan Island, Alaska", Alaska: DNR Report of Investigations 88-3, Fairbanks, 115 p.

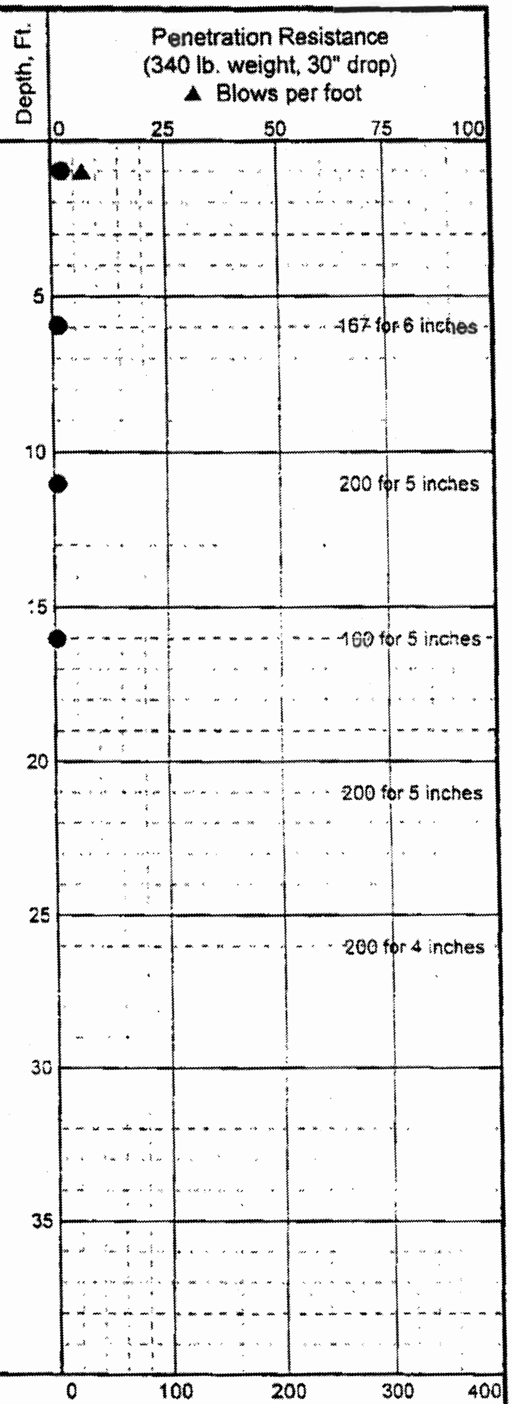
Humphrey, T. D., 1980, "Akutan Hydropower Preliminary Design Report", Ott Water Engineers for The City of Akutan, 115p.

Romick, J.D., 1982, "The Igneous Petrology and geochemistry of Norhtern Akutan Island", Alaska: Master's thesis, University of Alaska, Fairbanks, 151 p.

APPENDIX B

2001 Exploratory Data
Boring Logs

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -3.5 feet	Depth, Ft.	Symbol	Samples	Ground Water
Loose, black, gravelly SAND; wet			S1	Groundwater Not Encountered During Drilling on 10/22/98
Very dense, green/black, silty, sandy GRAVEL, with numerous cobbles; wet	3.5		S2, S3	
Black, soft, moderately weathered, rock	12.5		S4, S5, S6	
Bottom of Boring Boring Completed 10/22/98	26.1			



LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-A

December 1998 A-994

SHANNON & WILSON, INC.
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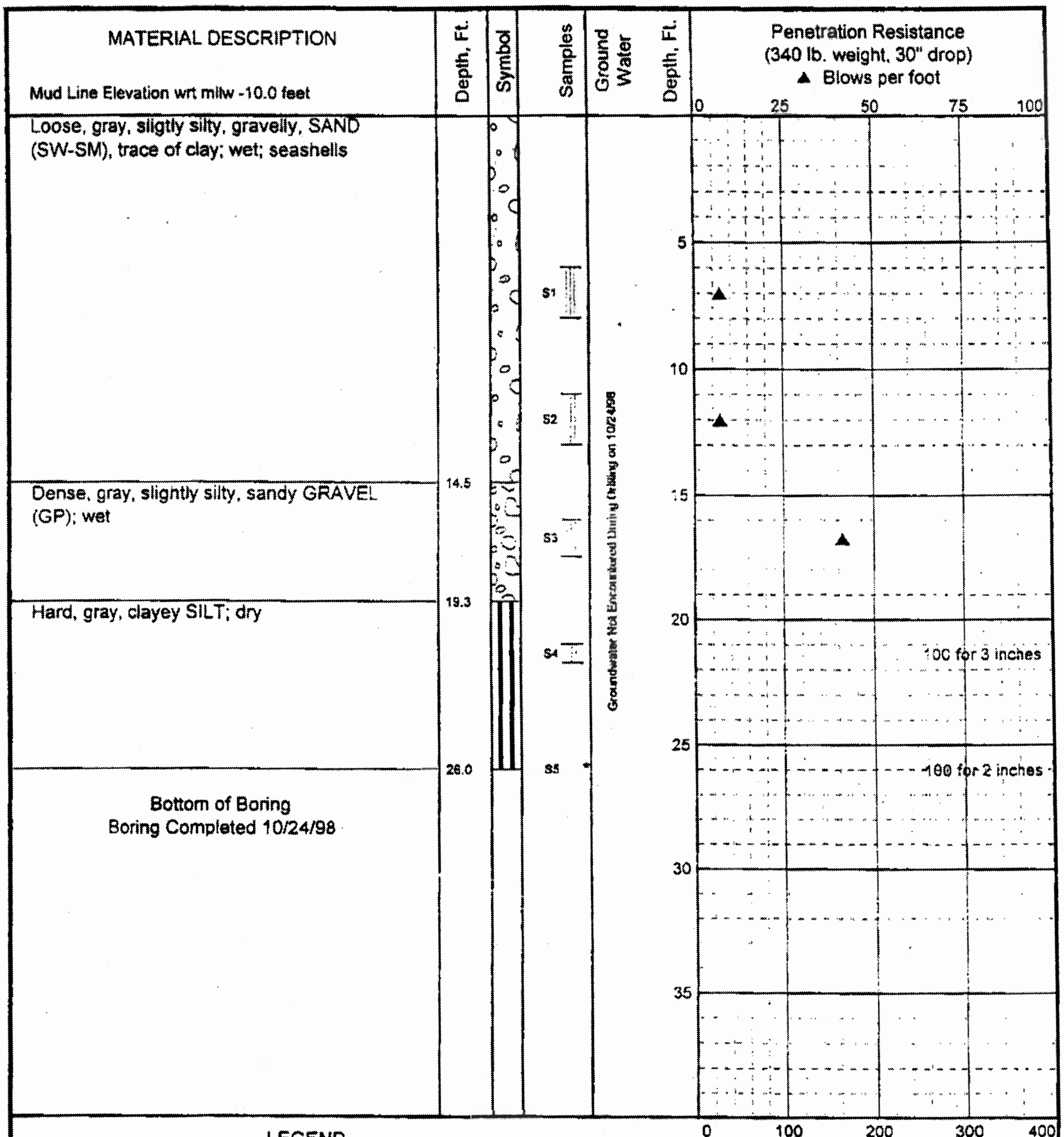
Fig. B-1

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98



LEGEND

*	Sample Not Recovered		Surface Seal
	2" O.D. Split Spoon Sample		Solid Casing and Annular Sealant
	3" O.D. Split Spoon Sample		Well Screen and Filter Sand
	Rock Core		Cuttings Backfill
			Ground Water Level ATD
			Static Ground Water Level

NOTES

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Akutan Small Boat Harbor
Alkutan, Alaska

LOG OF BORING NO. BH-1

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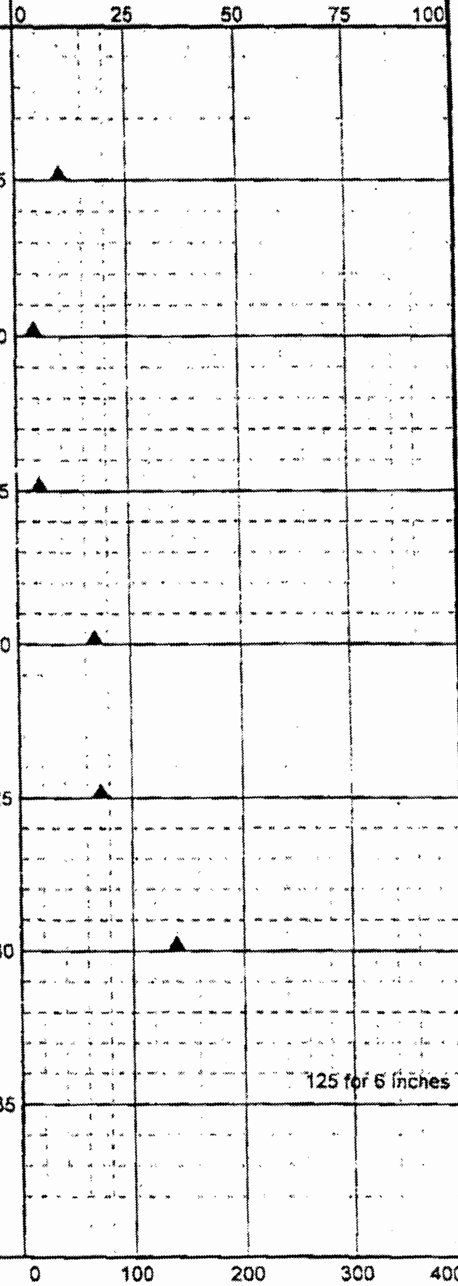
Fig. B-2

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -56.0 feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Loose, gray/black, SAND (SW), with occasional clay lenses and increasing gravel with depth; wet; with seashells			1, 2, 3	Groundwater Not Encountered During Drilling on 10/24/98	5, 10, 15
Medium dense to dense, gray/green, slightly silty, gravelly SAND (SW-SM); wet	17.5		4, 6, 5		20, 25, 30
Very dense, gray/green, gravelly BOULDERS(possibly soft bedrock)	31.0		7		35
Bottom of Boring Boring Completed 10/24/98	34.5				

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



● PID Reading (ppm)

LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
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4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-2

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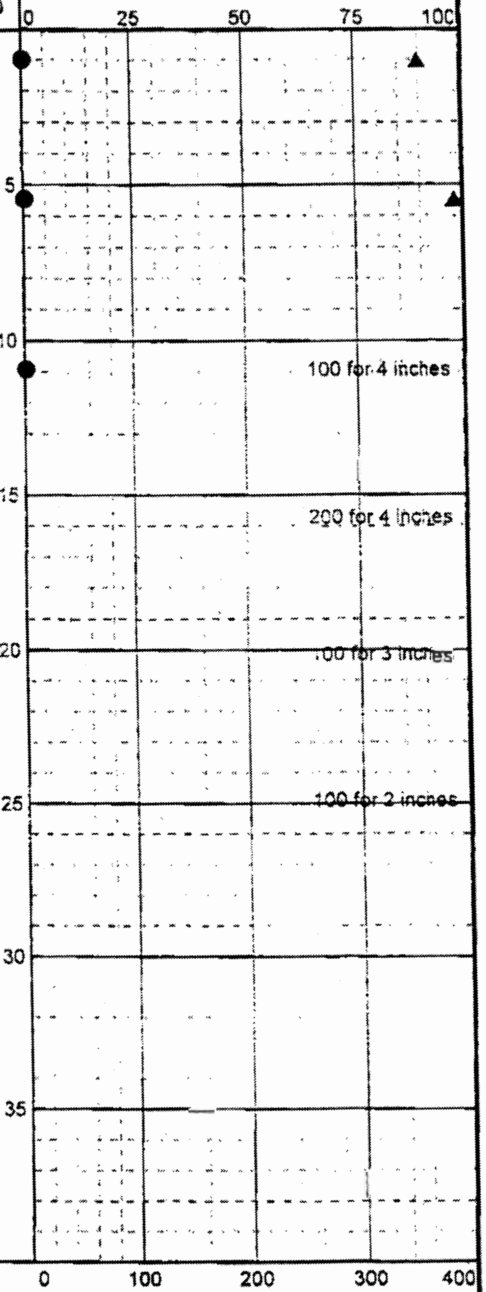
Fig. B-3

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

MATERIAL DESCRIPTION	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Mud Line Elevation wrt mllw -3.1 feet					
Very dense, gray, slightly silty to silty, sandy GRAVEL (GW-GM), with numerous blue/grey weathered cobbles and boulders; dry to moist			S1, S2, S3, S4, S5, S6	Groundwater Not Encountered During Drilling on 10/18/98	
Bottom of Boring	25.0				
Boring Completed 10/18/98	25.0				

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



● PID Reading (ppm)

LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

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4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-3

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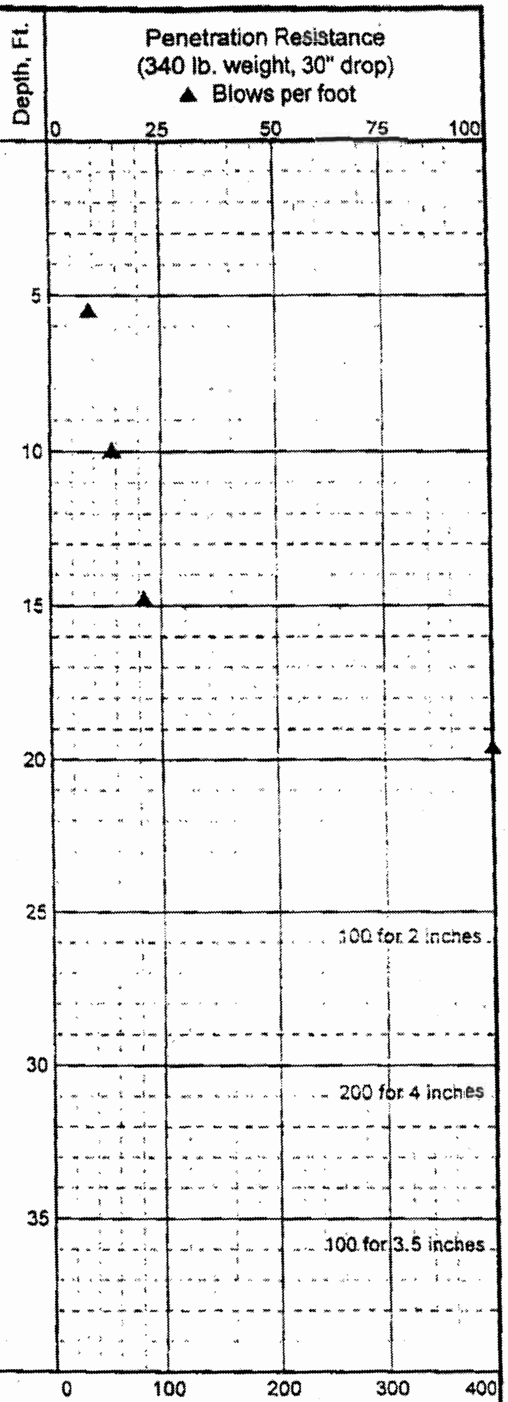
Fig. B-4

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -16.2 feet	Depth, Ft.	Symbol	Samples	Ground Water
Loose to medium dense, black, slightly silty SAND (SW);wet			1, 2	Groundwater Not Encountered During Drilling on 10/17/98
Increased gravel			3	
Medium dense, gray to black, sandy GRAVEL; wet	15.0		4	
Very dense, gray/blue, silty, clayey, sandy GRAVEL, with weathered cobbles and boulders: wet	20.0		5, 6, 7	
Bottom of Boring Boring Completed 10/17/98	36.0			



LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- ▽ Ground Water Level ATD
- ▼ Static Ground Water Level

NOTES

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4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-4

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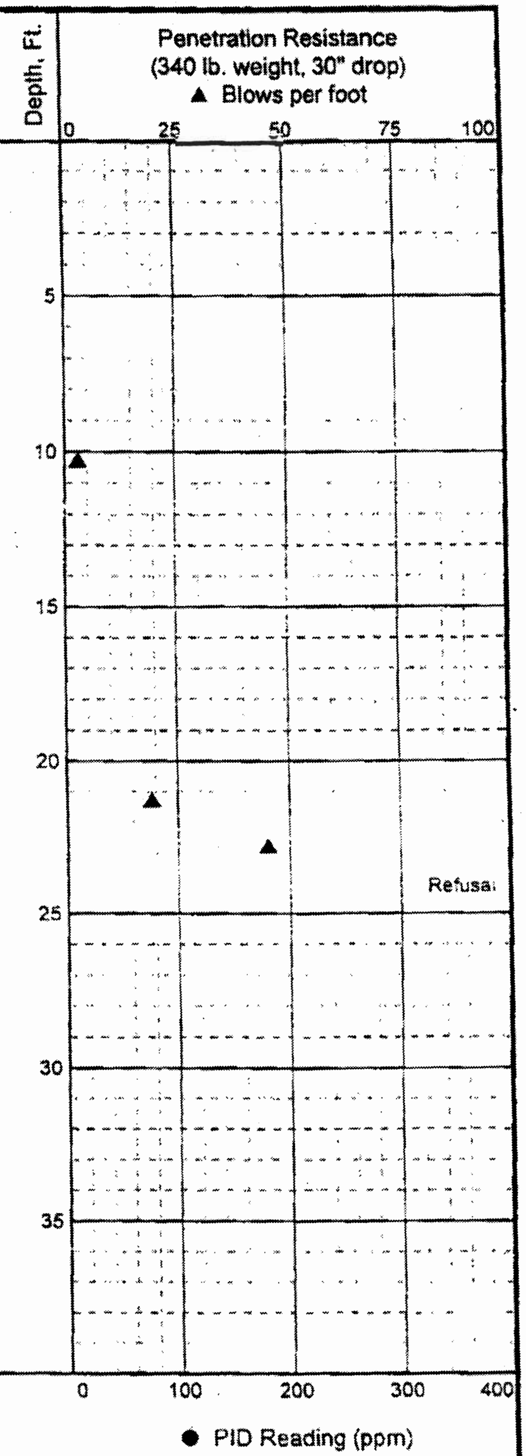
Fig. B-5

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -49.1 feet	Depth, Ft.	Symbol	Samples	Ground Water
Loose to medium dense, gray/black, gravelly, silty SAND (SP); wet; with seashells			1	Groundwater Not Encountered During Drilling on 10/15/98
Medium dense, black, sandy GRAVEL (GP), with weathered cobbles and boulders at approximately 25 feet bml; wet	15.0		2, 3, 4	
Very hard, gray/blue, gravelly, sandy, clayey SILT; moist	25.0			
Hard, fresh, brecciated conglomerate BOULDER	31.0		5	
	32.2			

Bottom of Boring
Boring Completed 10/15/98



LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- ∇ Ground Water Level ATD
- ▼ Static Ground Water Level

NOTES

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4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-5

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Fig. B-6

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -14.7 feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.	Penetration Resistance (340 lb. weight, 30" drop) ▲ Blows per foot
Loose, black, slightly gravelly SAND (SP-SW); wet			1	Groundwater Not Encountered During Drilling on 10/21/98	5	
Increased silt between 10 and 17 feet bml; wet	10.0		2		10	
			3*		15	
	17.0					
			4*		20	
			5		25	
			6*		30	
			7		35	
Increased silt and clay at 37 feet bml						

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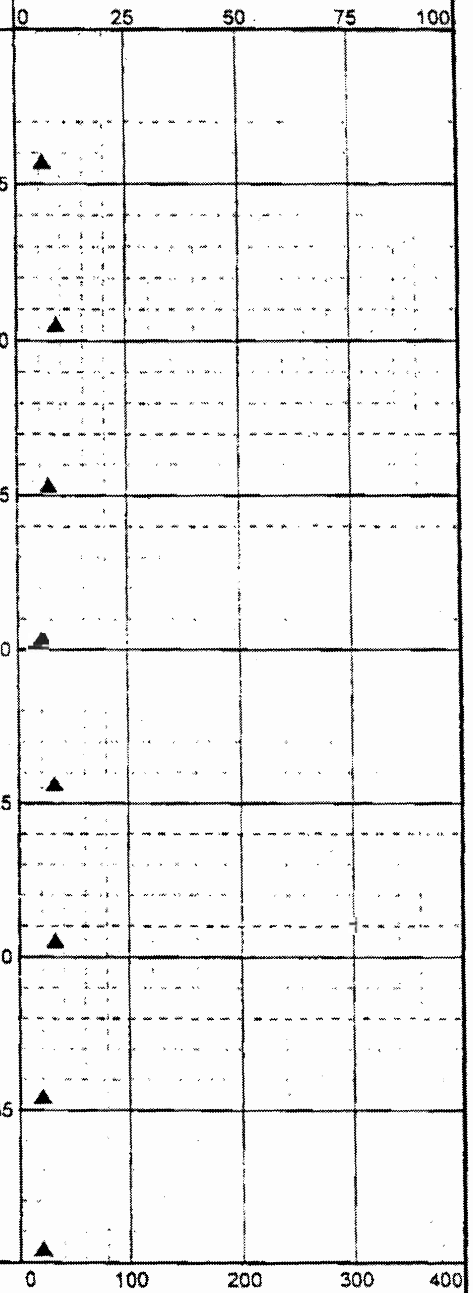

LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

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4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-6

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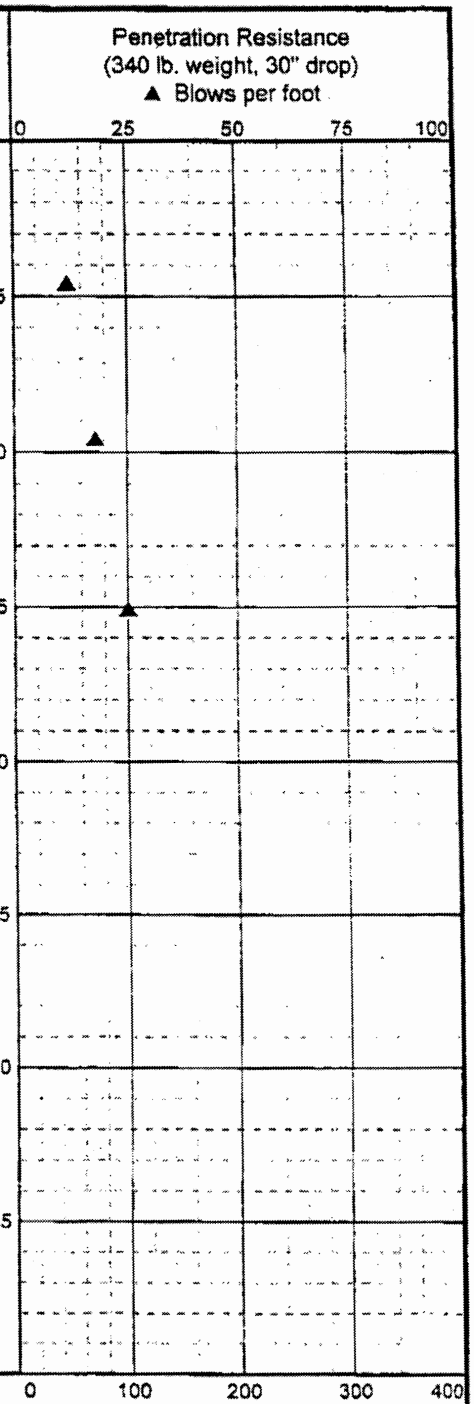
Geotechnical and Environmental Consultants

Fig. B-7
Sheet 1 of 2

MASTER LOG A994.GPJ SHAN_WIL.GDT 12/18/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -14.7 feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
			8		
Medium dense, black, slightly sandy GRAVEL (GP); wet	42.0		9		45
Medium dense, gray, slightly silty, sandy GRAVEL (GP-GM), with cobbles; wet	47.0		10 11	Groundwater Not Encountered During Drilling on 10/21/98	50 55
Bottom of Boring Boring Completed 10/21/98	55.8				60 65 70 75



LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

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4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-6

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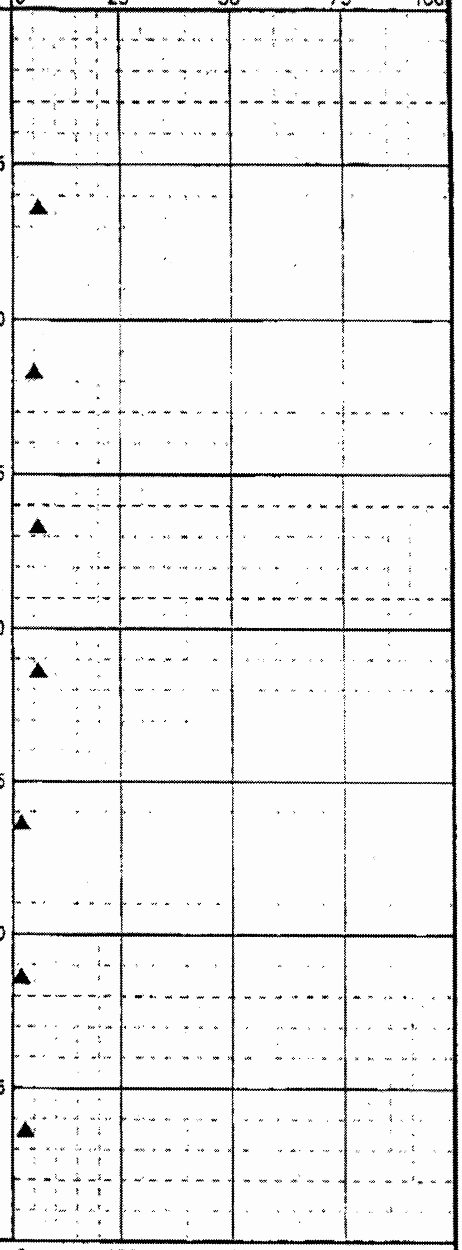
Fig. B-7
Sheet 2 of 2

MASTER LOG A994.GPJ SHAN WIL.GDT 12/16/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -28.6 feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Loose, brown, slightly silty SAND (SW-SM); wet			1, 2, 3, 4	Groundwater Not Encountered During Drilling on 10/23/98	5, 10, 15, 20
Increased silt at 24 feet	24.0		5, 6		25, 30
Soft, gray, sandy SILT (ML); moist to wet	34.0		7		35
CONTINUED NEXT PAGE	39.0				

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



● PID Reading (ppm)

LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

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2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-7

December 1998 A-994

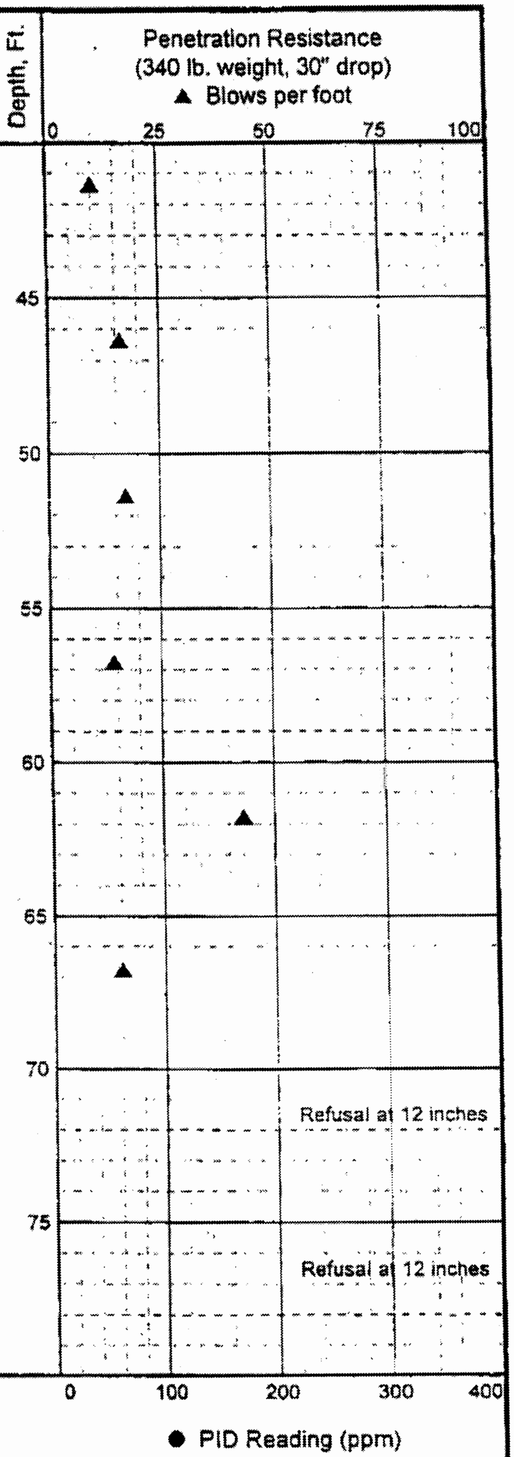
SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Fig. B-8
Sheet 1 of 2

MASTER LOG A994.GPJ SHAN WIL.GDT 12/16/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -28.6 feet	Depth, Ft.	Samples
Loose to medium dense, gray, slightly silty, gravelly SAND (SW); wet		8, 9
Medium dense, gray, silty, sandy GRAVEL; wet	51.5	10, 11, 12
Loose to medium dense, brown, silty SAND (SW-SM); wet	67.0	13
Very dense, gray, silty, sandy GRAVEL, with cobbles; wet	69.0	14, 15
Bottom of Boring Boring Completed 10/23/98	77.0	

Ground Water: Groundwater Not Encountered During Drilling on 10/23/98



LEGEND

- Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

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4. USC letter symbol based on visual classification.

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-7

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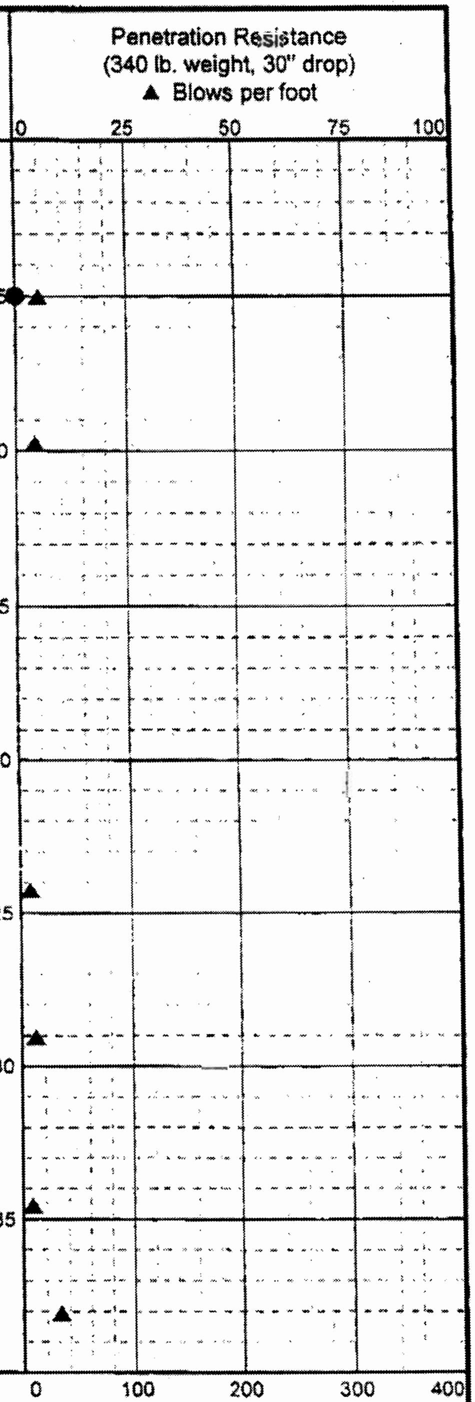
Fig. B-8
Sheet 2 of 2

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -9.9 feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Loose, black, slightly gravelly SAND (SP); wet			1, 2	Groundwater Not Encountered During Drilling on 10/15/98	5, 10, 15
Very loose, black, gravelly, SAND (SP); wet	16.0		3, 4		20, 25
Very loose, black, slightly gravelly to gravelly, silty SAND; wet, with shell fragments	29.5		5, 6		30, 35
CONTINUED NEXT PAGE	39.5				



LEGEND

- Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

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3. Water level, if indicated above, is for the date specified and may vary.
4. LSC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-10

December 1998 A-994

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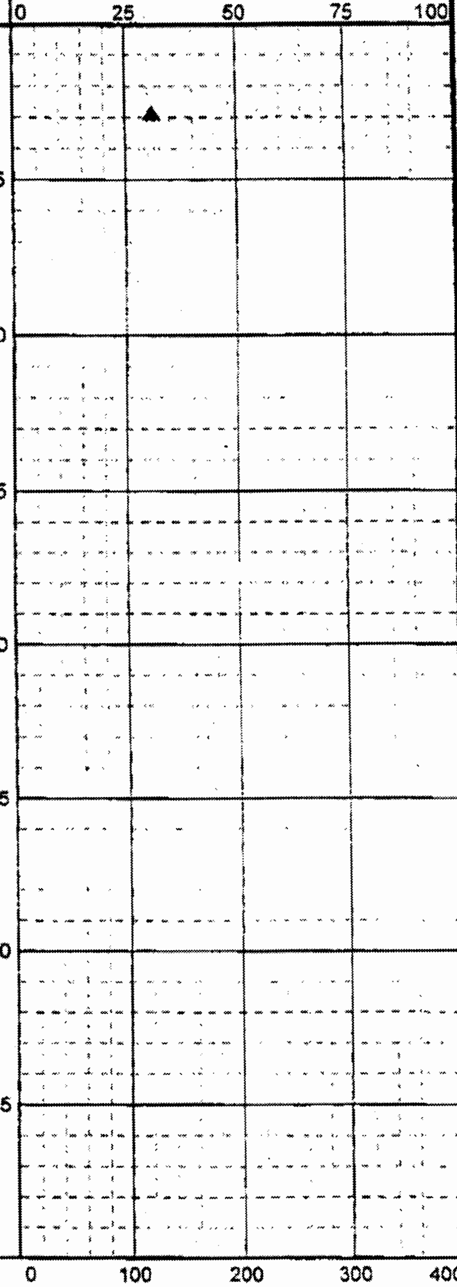
Fig. B-11
Sheet 1 of 2

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -9.9 feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Medium dense to dense, silty, sandy GRAVEL, with cobbles; wet	43.6		7	Groundwater Not Encountered During Drilling on 10/15/98	45 50 55 60 65 70 75
Bottom of Boring Boring Completed 10/15/98					

Penetration Resistance
(340 lb. weight, 30" drop)
▲ Blows per foot



● PID Reading (ppm)

LEGEND

- • Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-10

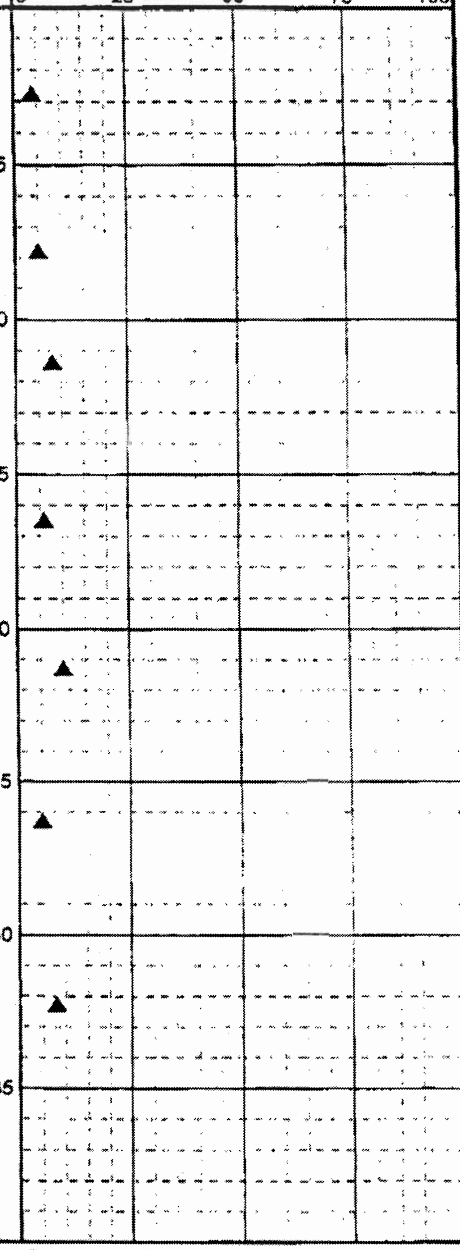
December 1998 A-994

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Fig. B-11
Sheet 2 of 2

MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

MATERIAL DESCRIPTION Mud Line Elevation wrt mllw -7.2 feet	Depth, Ft.	Symbol	Samples	Ground Water	Depth, Ft.
Very loose to loose, black, slightly silty, slightly gravelly SAND (SP); wet			1, 2, 3, 4, 5, 6	Groundwater Not Encountered During Drilling on 10/14/98	5, 10, 15, 20, 25, 30
Increased gravel at 31.5 feet bml	33.0		7		35
Bottom of Boring Boring Completed 10/14/98					



LEGEND

- * Sample Not Recovered
- 2" O.D. Split Spoon Sample
- 3" O.D. Split Spoon Sample
- Rock Core
- Surface Seal
- Solid Casing and Annular Sealant
- Well Screen and Filter Sand
- Cuttings Backfill
- Ground Water Level ATD
- Static Ground Water Level

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of subsurface materials.
3. Water level, if indicated above, is for the date specified and may vary.
4. USC letter symbol based on visual classification.

Akutan Small Boat Harbor
Akutan, Alaska

LOG OF BORING NO. BH-11

December 1998 A-994

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Fig. B-12

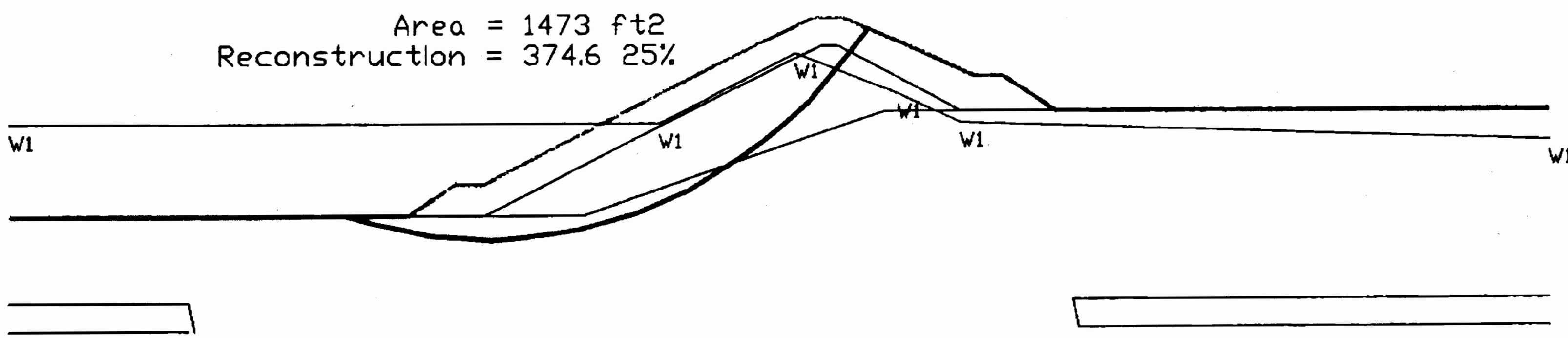
MASTER LOG A994.GPJ SHAN WIL.GDT 12/18/98

APPENDIX C

Stability Analysis Results

Akutan Breakwater, Buttress, a=30', slope 2:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1



GSTABL7 v.2 FSmin=0.95
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

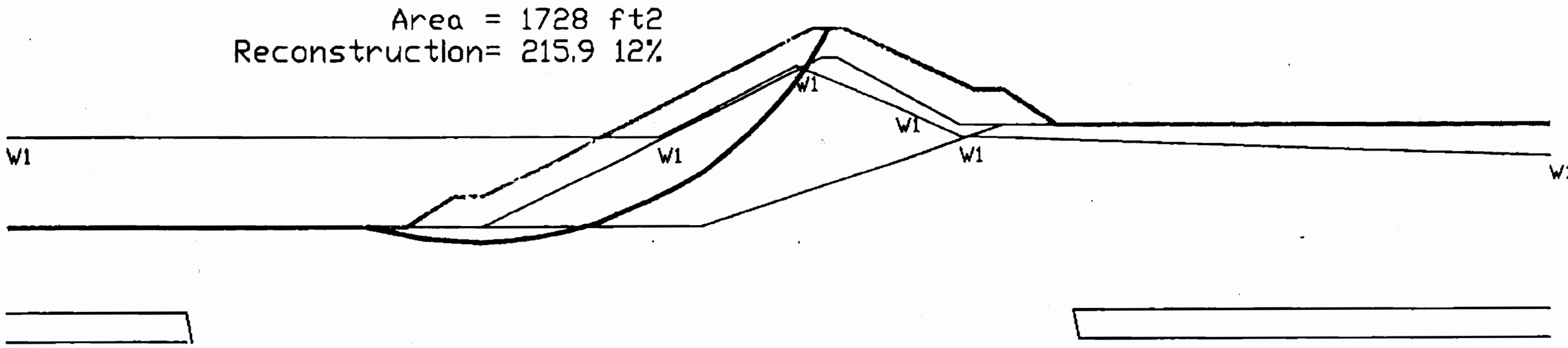
December 2001 32-1-16384

SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

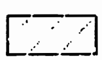
FIG. A1

Akutan Breakwater, Buttress, a=50', slope 2:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1



GSTABL7 v.2 FSmin=1.00
Safety Factors Are Calculated By The Modified Bishop Method



Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

December 2001 32-1-16384

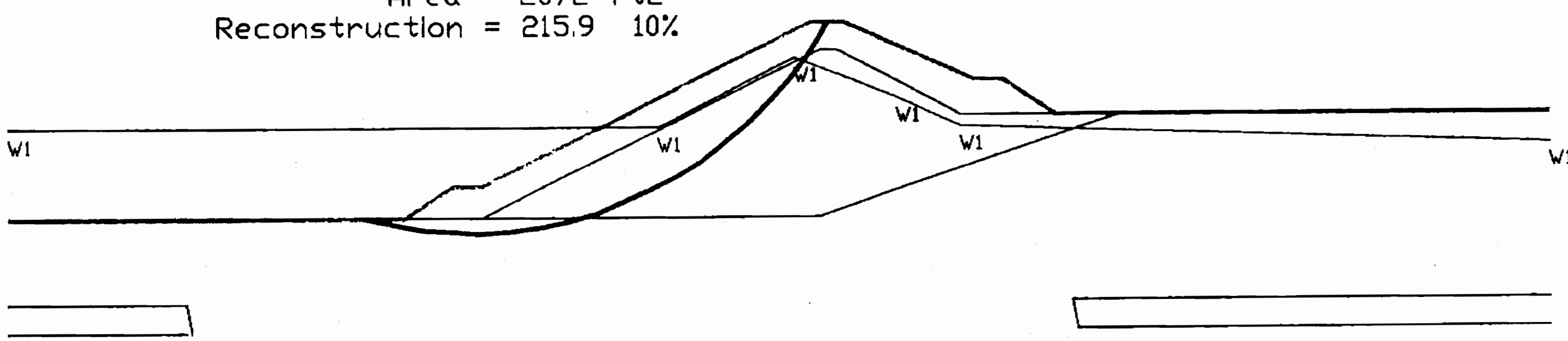
SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

FIG. A2

Akutan Breakwater, Buttress, a=70', slope 2:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 2072 ft2
Reconstruction = 215.9 10%



GSTABL7 v.2 FSmin=1.00
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

December 2001 32-1-16384

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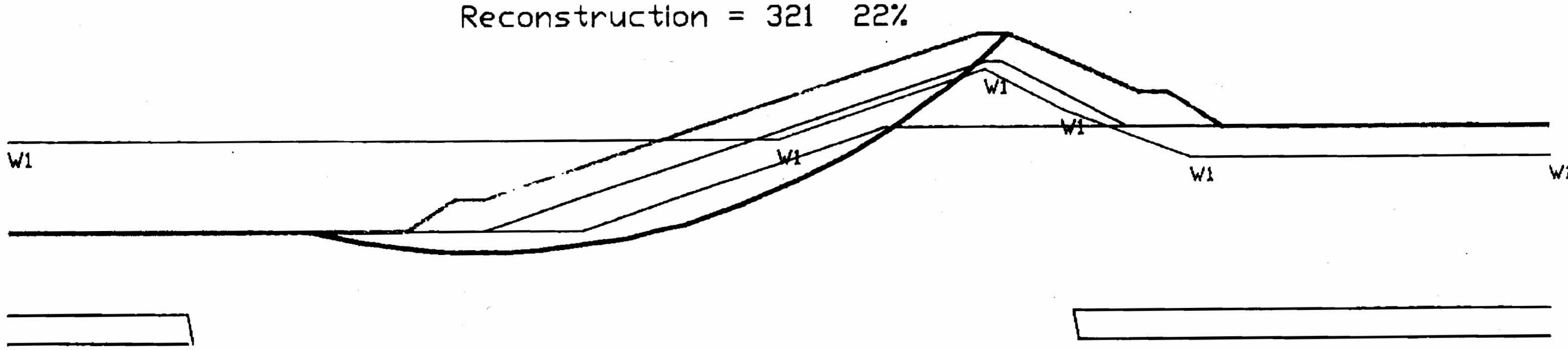
FIG. A3

6384geometry.dwg 1:1 12/4/01 Shannon & Wilson, Inc.

Akutan Breakwater, Buttress, a=30, slope 3:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 1491 ft2
Reconstruction = 321 22%



GSTABL7 v.2 FSmin=1.11
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

December 2001 32-1-16384

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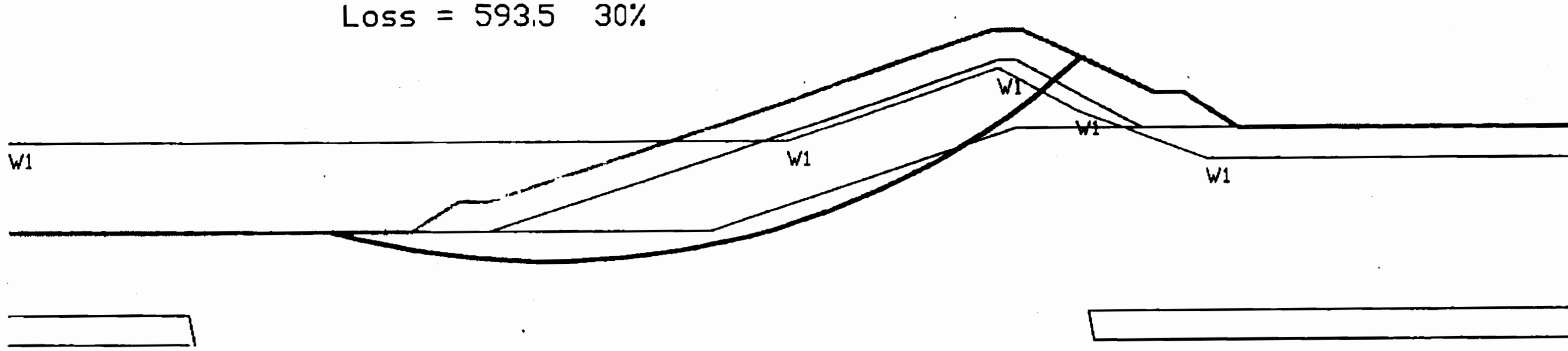
FIG. A4

6384geometry.dwg 1:1 12/4/01 Shannon & Wilson, Inc.

Akutan Breakwater, Buttress, a=50, slope 3:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 1988 ft2
Loss = 593.5 30%



GSTABL7 v.2 FSmin=1.14
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

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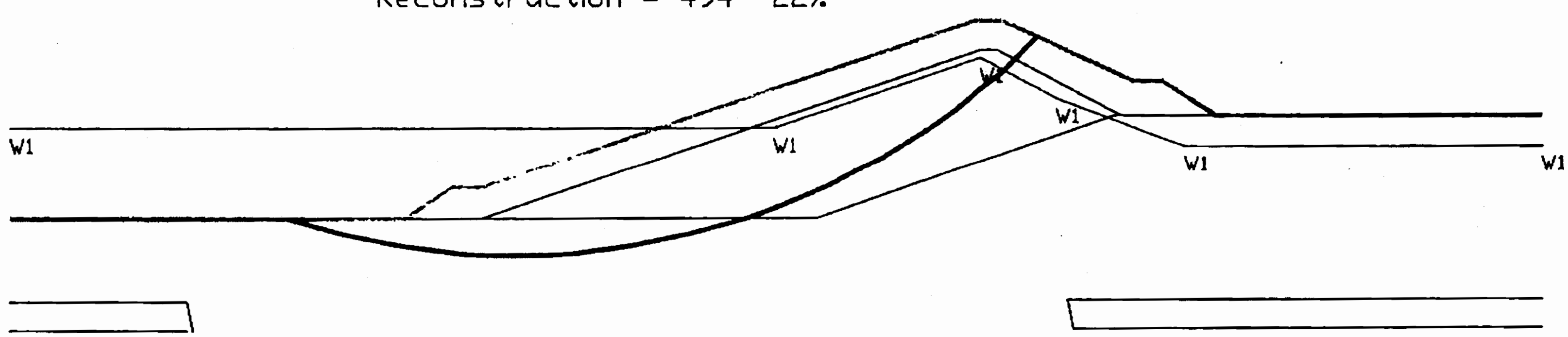
FIG. A5

6384geometry.dwg 1:1 12/4/01 Shannon & Wilson, Inc.

Akutan Breakwater, Buttress, a=70, slope 3:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 2233 ft2
Reconstruction = 494 22%



GSTABL7 v.2 FSmin=1.22
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

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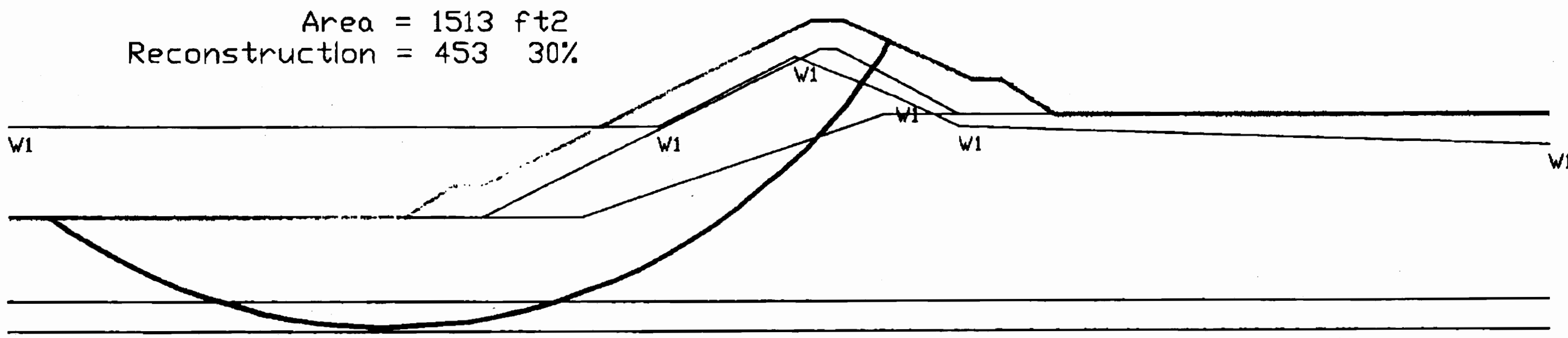
FIG. A6

6384geometry.dwg 1:1 12/4/01 Shannon & Wilson, Inc.

Akutan Breakwater, No Buttress, a=30', slope 2:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1



GSTABL7 v.2 FSmin=0.79

Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60

APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

December 2001 32-1-16384

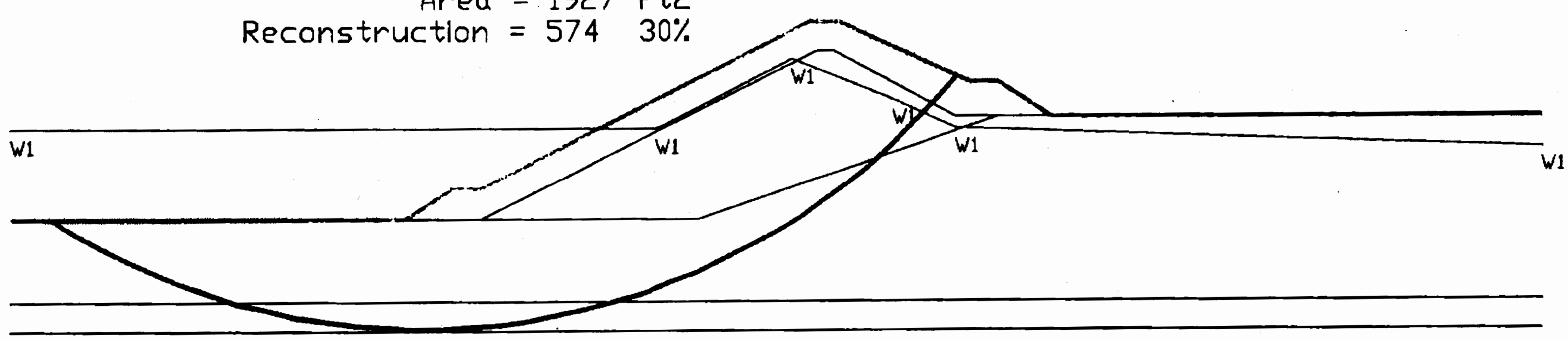
SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

FIG. A7

Akutan Breakwater, No Buttress, a=50', slope 2:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 1927 ft2
Reconstruction = 574 30%



GSTABL7 v.2 FSmin=0.80
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

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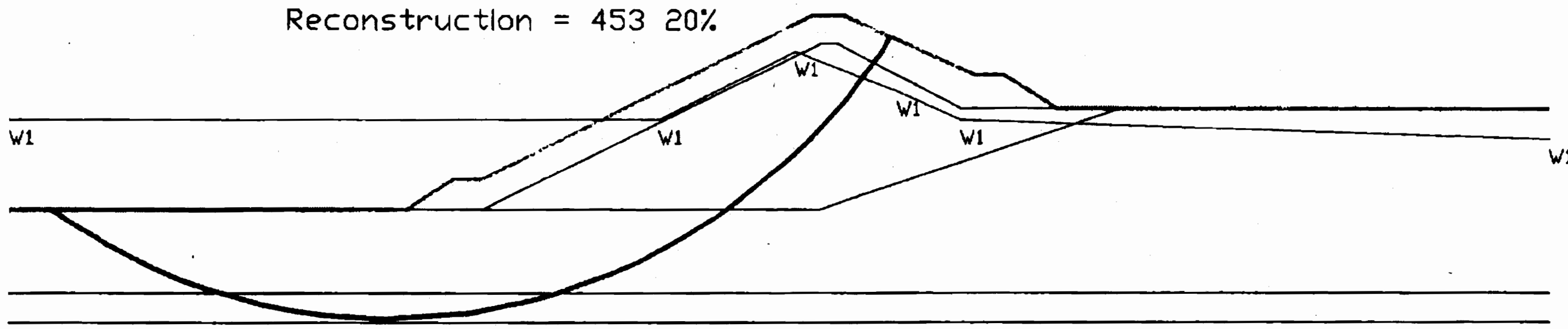
FIG. A8

6384geometry.dwg 1:1 12/4/01 Shannon & Wilson, Inc.

Akutan Breakwater, No Buttress, a=70', slope 3:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 2204 ft2
Reconstruction = 453 20%



GSTABL7 v.2 FSmin=0.81
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

December 2001 32-1-16384

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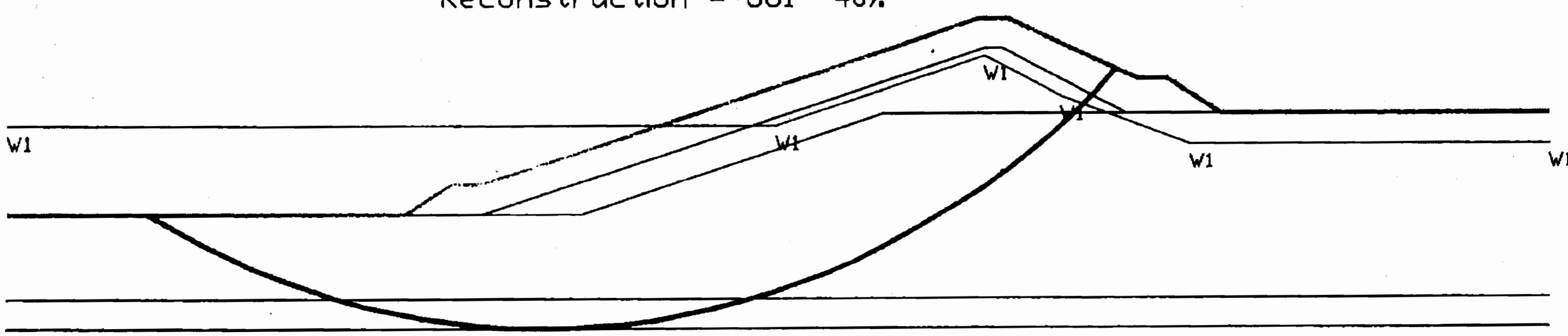
FIG. A9

Akutan Breakwater, No Buttress, a=30, slope 3:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 1690.5 ft2
Reconstruction = 681 40%



GSTABL7 v.2 FSmin=0.80
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

December 2001 32-1-16384

SHANNON & WILSON, INC.
Geotechnical & Environmental Consultants

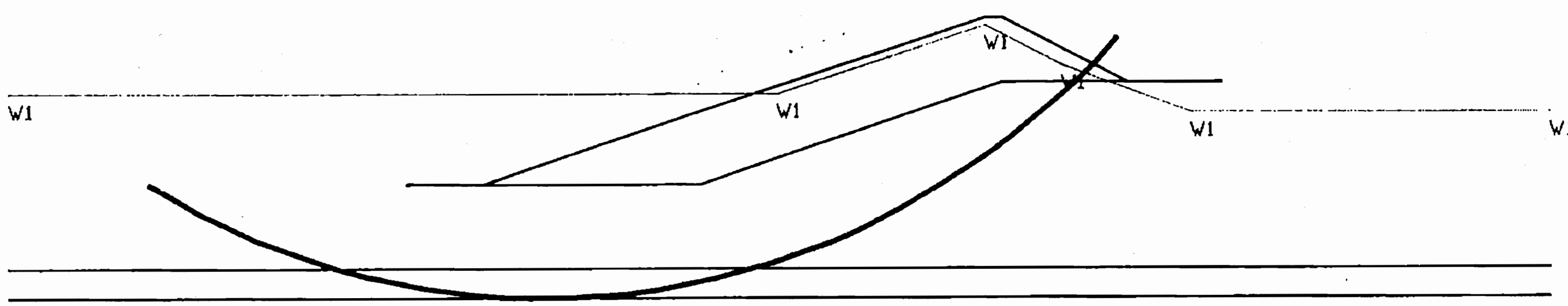
FIG. A10

6384geometry.dwg 1:1 12/4/01 Shannon & Wilson, Inc.

Akutan Breakwater, No Buttress, a=50, slope 3:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 2032 ft2
Reconstruction = 673.7 33%



GSTABL7 v.2 FSmin=0.80
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

December 2001 32-1-16384

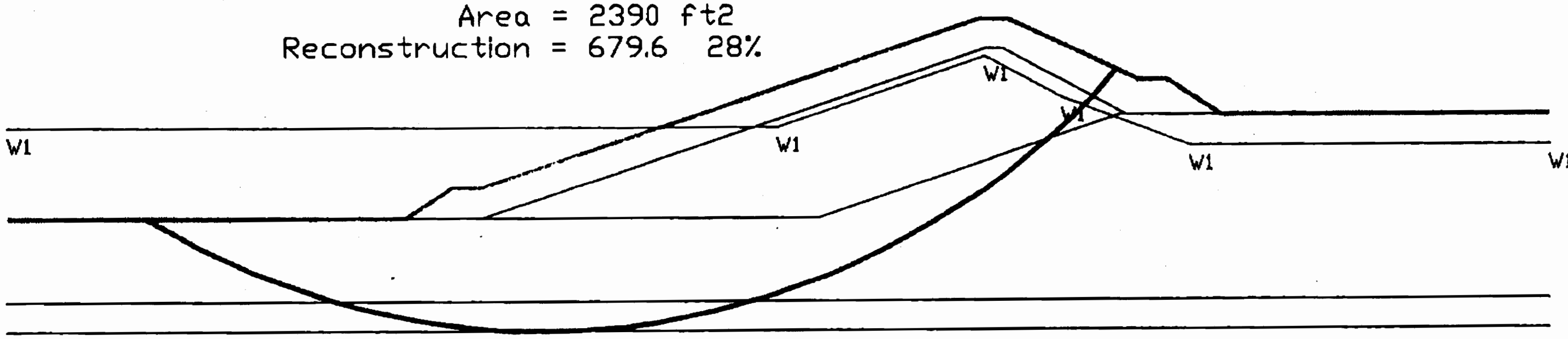
SHANNON & WILSON, INC. Geotechnical & Environmental Consultants

FIG. A11

Akutan Breakwater, No Buttress, a=70, slope 3:1

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Rip Rap	1	150.0	150.0	0.0	40.0	W1
Gravel	2	120.0	140.0	0.0	38.0	W1
Native	3	100.0	115.0	0.0	32.0	W1
Siltzone	4	90.0	105.0	250.0	0.0	W1

Area = 2390 ft2
Reconstruction = 679.6 28%



GSTABL7 v.2 FSmin=0.80
Safety Factors Are Calculated By The Modified Bishop Method

Approximate Reconstruction Requirement

0 15 30 60
APPROXIMATE SCALE IN FEET

Akutan Small Boat Harbor
Akutan Bay, Alaska

GRAPHICAL STABILITY ANALYSIS RESULT

December 2001 32-1-16384

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FIG. A12

6384geometry.dwg 1:1 12/4/01 Shannon & Wilson, Inc.

APPENDIX D

Important Information About Your Geotechnical/Environmental Report

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Attachment to Geotechnical Report
Dated: December 2001
To: John Daley, Tryck Nyman Hayes
Re: Akutan Small Boat Harbor, 32-1-16834

Important Information About Your Geotechnical/Environmental Report

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one; or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland

APPENDIX D
CIRCULATION STUDY
NAVIGATIONAL IMPROVEMENTS AT AKUTAN, ALASKA

1. Introduction

1.0 Akutan Setting

Akutan Harbor is located on Akutan Island in the Fox Island group of the Aleutian Islands (Figure 2.). It is about 40 nautical miles east-northeast of Unalaska. The harbor's longitudinal axis lies almost east-west and the harbor is 3.5 n.m. long and 0.5 n.m. wide at its head, on the west end, and increases to about 2 n.m. wide near its open, eastern end. It is just over 200 feet deep near the central portion of its mouth. There are two small fresh-water streams that enter the harbor near the head of the bay; one on the north side and one on the south.

The only industry is the Trident Seafoods fish processing plant located on the north shore between a half and three-quarters of a mile west of the Community of Akutan (Figure 1).

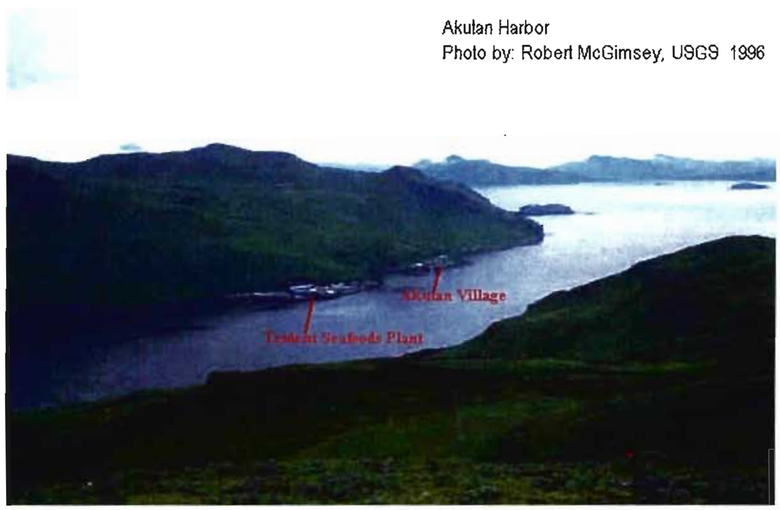

Figure 1. View of Akutan Harbor looking east toward the mouth of the harbor.

Fishing is the principal livelihood for the Akutan locals. Akutan is included in the Aleutian East Borough. It is serviced on a daily basis by floatplane from Unalaska. There are no airport or harbor facilities. Inclement weather routinely causes major delays or cancellations of these flights. There is a community dock where fuels and other materials are offloaded.

The harbor is bordered on both sides by mountain ridges with peaks that are 1,500 to 2,000 feet high. The elevations between these peaks can be on the order of 1,000 feet. These features channel the winds up and down the harbor in an east-west direction. Only close to the shoreline and due to the shoreline orientation is the wind direction likely to vary from this channel wind direction. Occasionally, winds may sweep down from lower portions of the ridges and approach the harbor from the side. These are probably short-lived, localized events that do not contribute much to the harbor circulation.

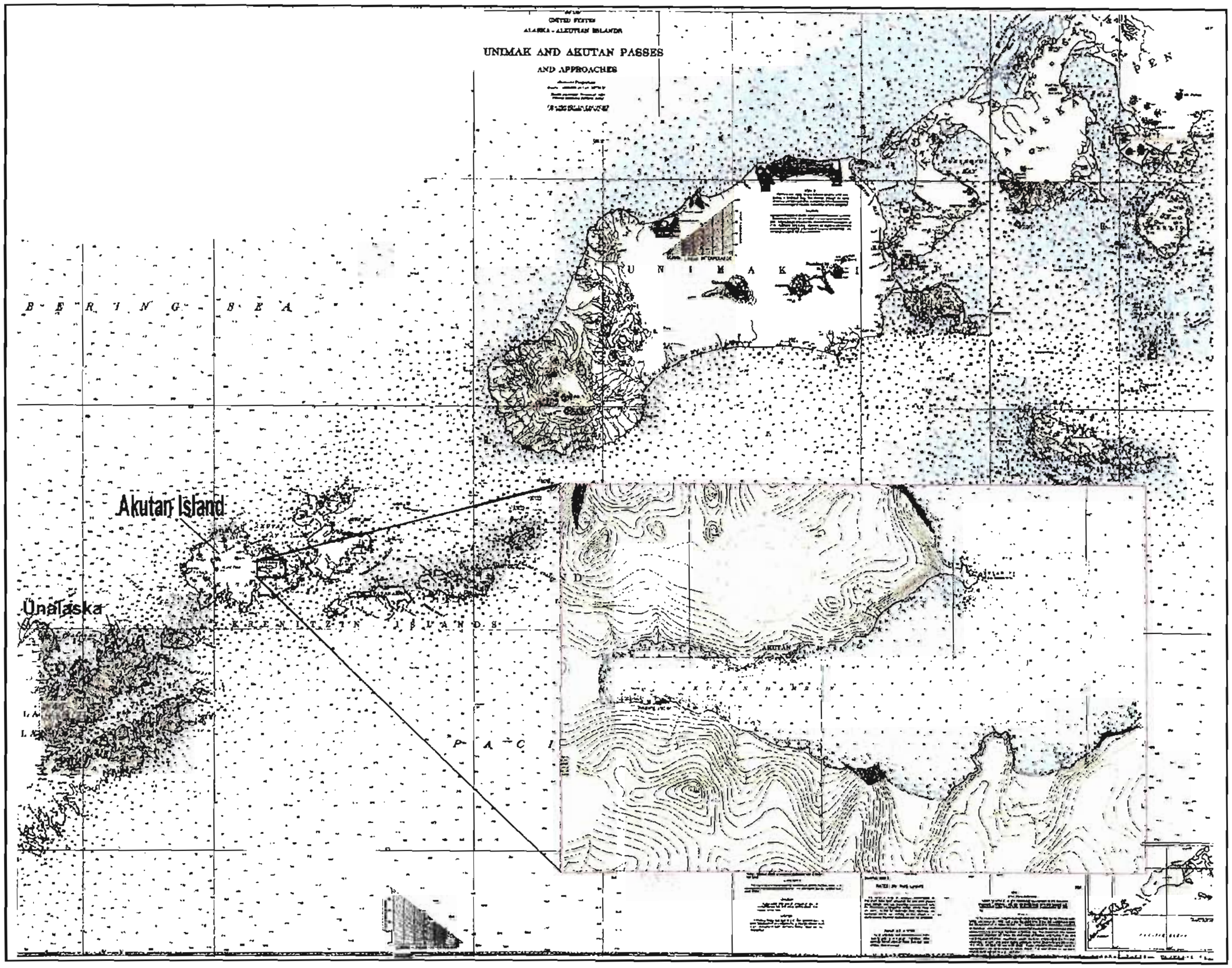

Figure 2. Portion of Aleutian Islands containing Akutan Island and enlargement of Akutan Harbor

The Aleutians are known for their winds and Akutan is no exception. There is generally a wind of a few knots blowing up or down the harbor.

1.1 Small Boat Basin Study

The U. S. Army, Corps of Engineers (Corps) is investigating the feasibility of a small-boat-harbor at the head of the harbor. The design being considered consists of a 12-arce, rectangular basin about 300 meters (1,000 feet) long by 245 meters (800 feet) wide. The longer axis runs north-south. The entrance is located on the northeast corner and is about 60 meters (200 feet) wide and 150 meters (500 feet) long. The entrance is directed roughly to the southeast from the basin into Akutan Harbor. The basin is subdivided into three distinct regions that differ from one another by depth. The shallower inner basin has a design depth of –4.3 meters (–14 feet) relative to mean-lower-low-water the middle and outer basins are –4.9 and 5.5 meters (–16 and -18 feet), respectively. The plan is to allow smaller boats access to the entire basin and restrict the access to larger vessels.

To reduce the marine footprint of this project, the basin is to be dredged completely from upland real estate. Some of dredge spoils will be used for constructing upland facility sites and the remainder dumped offshore. There is considerable likelihood that fresh water will enter the basin through its side slopes.

1.2 Potential Concerns

The outfalls at the Trident plant discharge significant quantities of possessing wastes directly into Akutan Harbor. Those discharges have been the subject of past studies during the process of securing NPDES discharge permits by various processors. These concerns will not be revisited in this report.

The Corps is primarily concerned with what effects these discharged wastes may have on the boat harbor project and, in turn, what impacts the boat harbor might have on Akutan Harbor water quality and on certain bird species that are known to over-winter in the southwestern portion of the harbor. There has been no effort to attempt to correlate the discharge distributions with timing or type of plant or animal activities.

Mixing in boat harbors in Alaska and elsewhere is highly dependent on tides. Generally speaking, larger tidal ranges produce better water quality in a boat harbor than do smaller ranges. However, there is ample evidence that harbor design shape and entrance configuration can substantially impact water quality.

The tides in Akutan Harbor are mixed showing about equal contributions by diurnal and semidiurnal components. The diurnal range is 1.2 meters (3.9 feet) and the semidiurnal range 0.73 meters (2.4 feet). This is small in comparison to most of the mainland sites in south-central and southeast Alaska. Added to this is the large entrance width to basin cross-sectional area ratio. The smaller this ratio, the greater the chance of developing momentum in the incoming and outgoing flow. Higher momentum generally results in better mixing. To accommodate larger vessels and still create a basin that is reasonably priced, this ratio needs to be relatively high but unfortunately, at the expense of improved mixing.

The Corps also expressed concern about the fate of spilled substances that tended to float on the water column. Such spills might occur at the boat basin or from vessels traveling to or from the basin. There are certain areas near the proposed basin where birds are known to over-winter. The Corps wanted to be able to observe the trajectory of this material to determine when and under what conditions a spill could come in contact with these areas used by birds. Presumably the primary concern here is with petroleum products. A series of questions were developed to address these and other issues. They will be stated in the following section.

1.3 Purpose of this Report

Several issues will be addressed in this report some probably with more clarity than others. For example, a primary concern is whether fish wastes from Trident's operation can buildup in the boat harbor. To assess this, at least three discharge types may need to be investigated: the soluble portion, the suspended material and the heavier fraction that comprises the solids piling up on the bottom of the harbor directly under the discharge. Clearly, this latter portion cannot directly affect the boat basin that will be located over a mile to the west. The suspended material might travel this distance but if it does reach the basin, will it remain in the basin? Finally there is the dissolved fraction characterized by its BOD content. This is the fraction that will likely have the greatest impact to the boat harbor (it is the most easily transported) and it is the fraction that has been considered in the greatest detail.

The questions that have been addressed include:

1. The possible buildup of fish processing wastes in the harbor.
2. The flushing rate/volume exchange that is anticipated in the boat basin due to tides and winds.
3. The direction of flow of the effluent from the boat basin.
4. The potential for exceeding the State's water-quality standards for certain substances within the basin.
5. Under what conditions would there be a BOD/DO problem in the mooring basin.
6. If settleable solids have enough residence time in the basin to accumulate in the basin sediments.
7. The influence of freshwater intrusion into the mooring basin on the possible enhanced buildup or discharge of contaminants.

Some of these questions will be answered directly such as fish waste concentrations in the vicinity of the boat basin and the flushing characteristics of the basin. Others like the likelihood of material settling in the harbor and of freshwater effects in the harbor are more subjective. An attempt will be made to address each issue on some level.

The next section will present the **Methodology** used to conduct the analysis. The **Results** section will describe the information that was generated and conditions under which it was developed. The **Conclusions** section readdresses each of these concerns in order and presents the best explanation in view of the analysis conducted. There are two appendices: The **Equations of Motions** which is a compilation and description of the equation used and solved in the model POM; **The POM Code** is a listing of the Fortran code that POM requires to solve the pertinent equations. There is also a CD Rom containing a **Spill Trajectory Model**. When installed on a standard PC, it will permit a user to investigate the fate of a spill consisting of a floating substance by tracking its trajectory. The spill can be transported by a combination of winds and currents.

1.4 Past Studies

Studies associated with Trident's operations date back to 1983; Trident began its shore-based operation in 1982. Tetra Tech (1993) summed up the past studies quite succinctly.

> "The adverse effects on benthic biota of the accumulation of seafood waste solids on the harbor bottom has been documented in previous studies (Jones & Stokes Associates 1983, 1993; Jones & Stokes Associates and Tetra Tech 1984a,b, 1989; Tetra Tech 1986). The effect of these seafood waste piles on overlying water quality has also been investigated; particularly the effect of release of ammonium nitrogen and hydrogen sulfide from the waste piles on water column dissolved oxygen (DO) concentrations (Jones & Stokes Associates 1983; Jones & Stokes Associates and Tetra Tech 1984b; Tetra Tech 1986) "

The Environmental Protection Agency, Region 10 (Seattle) conducted further water-quality modeling of Akutan Harbor (1996). The velocities used for the model were predicated on the assumption that circulation in Akutan Harbor (in the absence of wind) is assumed to resemble a 2-layer system driven by outflow on the surface caused by land runoff and flow in at the bottom to account for entrainment by the outflow. This probably over-simplifies the process and the combination of wind and tidal action appears to generate a horizontal gyre that assists in flushing pollutants from the harbor.

1.5 Spill Trajectory

In an attempt to determine the fate of spill substances in the harbor, a spill trajectory model was developed that could be run as a stand-alone program. It provides users with input controls for wind speed and direction and a means to adjust spill properties. The spill model uses a general circulation pattern developed with the hydrodynamic model POM (an acronym for Princeton Ocean Model). In addition the random motions associated with turbulence are taken into consideration. This model can quickly look at combined wind and current scenarios to determine areas that might be more or less exposed to the effects of a spill.

2. Methodology

2.1 General

In this project, two 3-dimensional models have been constructed: a 100-meter grid element by 20 layers for the outer harbor and a 7.62-meter (25-foot) grid element by 10 layers for the boat basin. They are used to calculate velocities and material transports. In the Akutan Harbor case, an assumed discharge of biological oxygen demand (BOD-taken from past documentation and Trident's NPDES permit) at the Trident Seafoods outfall is used as the material substance. We have treated the BOD as a conservative property, but to the extent that it is reduced, a like reduction in dissolved oxygen (DO) can probably be assumed.

In the boat basin, the problem is treated differently. A initial basin concentration is assumed for all points in the basin (3-dimensionally distributed) and the change in this concentration is tracked over time by modeling the primary processes affecting this distribution.

A basic difference between these models and of those of earlier studies is the fact that wind and other forcing functions can cause the water at different depths to move in different directions; material transports similarly and show marked vertical variation.

2.2 Princeton Ocean Model

The model chosen to use for this study is often referred to as the Princeton Ocean Model (POM). The principal attributes of the model are as follows:

- It contains a turbulence closure sub-model to provide vertical mixing coefficients. In other models it is necessary to guess the values of these parameters.

- It is a sigma coordinate model in that the vertical coordinate is scaled on the water column depth.

- The horizontal time differencing is explicit whereas the vertical differencing is implicit. The latter eliminates time constraints for the vertical coordinate and permits the use of fine vertical resolution in the surface and bottom boundary layers.

- The model has a free surface and a split time step. The external mode portion of the model is two-dimensional and uses a short time step based on the CFL condition and the external wave speed. The internal mode is three-dimensional and uses a much longer time step.

- This model has the largest user base of any 3-D ocean model and as such has been subjected to considerable and constant scrutiny for nearly 20 years. This scrutiny includes verification of velocities and material transport.

Some of the following information is from the "User's Guide for a Three-Dimensional, Primitive Equation, Numerical Ocean Model" by George Mellor. This report can be found at the home page for the Princeton Ocean Model (http://www.aos.princeton.edu/WWWPUBLIC/htdocs.pom/).

The layers in the model are incorporated using a so-called Sigma-coordinate system that is described briefly in Appendix A, Equations of Motion, which is available upon request. To use the model it was necessary for Coastline Engineering to make significant modifications to the model to make it usable for the application in Akutan. To use the model it was necessary to:

- Construct a numerical depth grid for Akutan Outer Harbor and for the small boat basin.

- Generate appropriate subroutines to input the depths and other information and output velocities, concentrations, times, and other output.

- Create the necessary tidal boundary conditions for the outer solution. Create boundary conditions for the inner or layered solutions. These include: water velocity, salinity, temperature, material to be transported.

- Create suitable subroutines to provide a material source for the model.

The reader is probably not interested in the details of this code. Following are brief comments on the parts that are pertinent to a review of the output. It is anticipated that the code will not be of significant interest; however, it is available upon request to answer any questions that may arise.

2.3 Grid Development

Being a finite-difference model, POM requires an external, rectangular grid; intersection points form nodes. The model generates the vertical nodes internally. The grid is generated in the program MapInfo after a NOAA chart of the area has been displayed as a raster image. Using MapInfo, two grids are generated; the first is a rectangular grid encompassing the entire model area and the second is a "clip-out" of that grid and encompasses only the watered area of that grid. The nodes' positions are converted to UTM coordinates. A flag is attached to each of these to indicate whether the node is a land (0) or a water node (1) point and then output as text (ascii) files. Outside of MapInfo these are combined into a single file, but the appropriate value for the flag will be retained. This is, in essence, just changing the flag value in the original grid from 0 to 1 if it is located in water. To get the depths for these points then requires that it be combined with a bathymetry file.

The digitized chart depths (bathymetry) were acquired from NOAA and the program GEODAS was used to output the depths and their position (in latitude and longitude) that specifically pertain to the model area. These positions are then converted to UTM in

MapInfo and then output as text files. Using this depth file, software was then written to associate depths for each of the grid points that have a flag value of 1. Several grid sizes were used from 25 meters between nodes to 400 meters between nodes before the final sizes used for the two applications were chosen.

2.4 Akutan Harbor

The grid for the outer harbor is 64 grids in the X or east direction and 39 in the Y or North direction. The grid spacing is 100 meters. The grid also contains 20 layers for a total of 49,920 grid cells. The grid is shown in Figure 3.

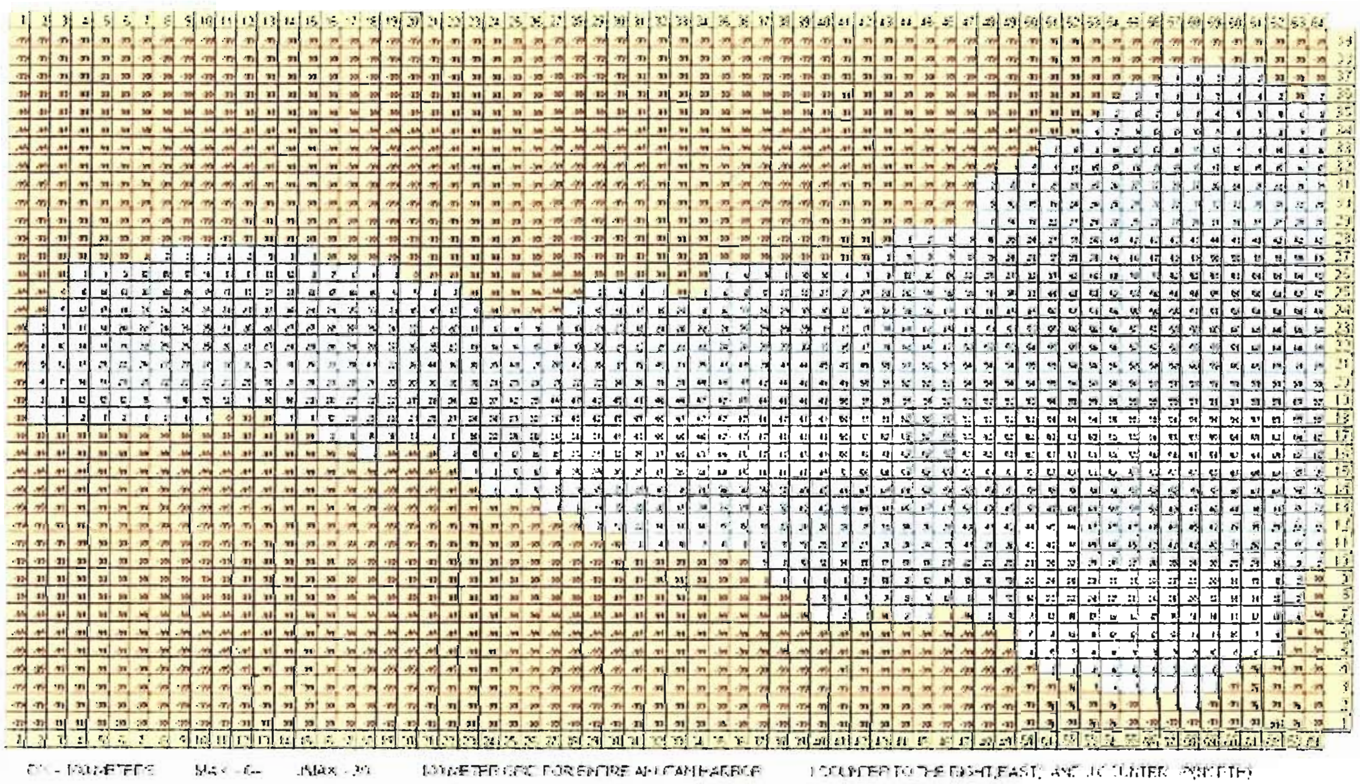

Figure 3. 100 meter grid of Akutan Harbor—depths in meters.

Part of the solution (external) used by POM is completely explicit and requires that the computational time step must be related to the water depth and the grid size. Given the selected grid size and the maximum water depths in Akutan Harbor, this required that the time step for this external part be no larger than one second. Therefore to produce a simulation of one tidal cycle (12.4 hours), 44,640 calculations over the entire grid must be accomplished. For each run (most of which were never used) about 20 tidal cycles were simulated. Fortunately, not every parameter needed to be calculated with this frequency; salinity, temperature, and material substance concentrations, which are part of the internal solution, are calculated at each 30th step of the external solution. However, even with the availability of today's rapid computers, each run consumed about 8 hours.

A simplification of the two modes is shown in Figure 4. In the figure the external mode is 2-dimensional and calculates the average (vertically) velocities and the

surface elevations. The time step is limited by the Courant-Friedrichs-Lewy (CFL) condition, as briefly described above. Many external time steps are made for each internal-mode step. In that time step, the velocities and concentrations are calculated for each layer. For each grid cell the velocities, surface elevations, and concentrations are calculated as shown in Figure 5.

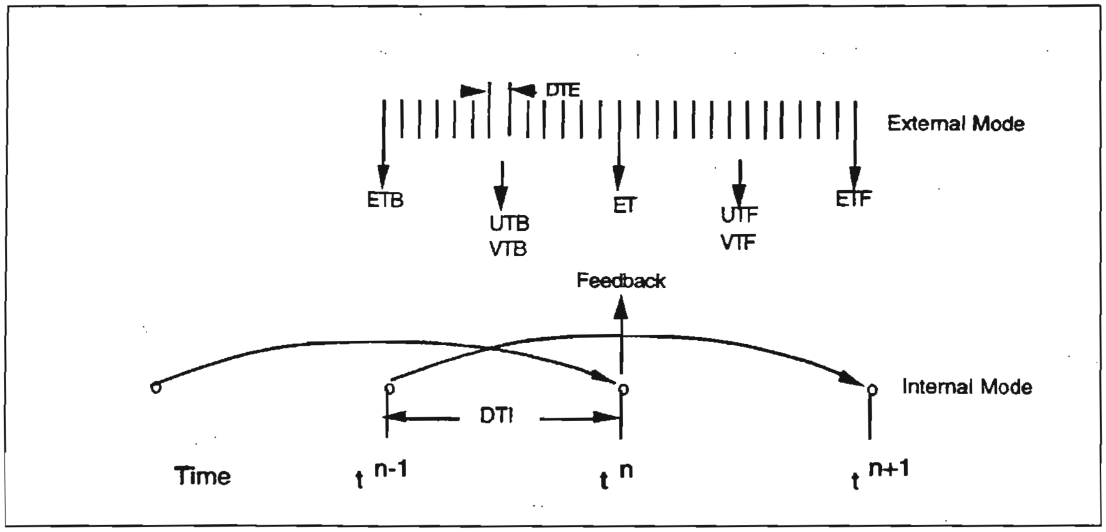

Figure 4. Time step scheme for the external (explicit) and internal (semi-implicit) modes.

2.5 Boat Basin

The small boat bain envisioned for development at Akutan is shown in Figure 4. The grid used to generate flows and concentration pattern in the boat basin was different, and much simpler, than for Akutan Harbor. To attain reasonable resolution in the boat basin, a node spacing of 7.62 meters (25 feet) was used. This produced a 45 by 42 point horizontal grid to capture the entire basin and entrance. Ten layers were used to describe the vertical distribution. A time step of 0.333 seconds was permitted by the CFL condition for the exterior mode of POM. The grid used for the boat basin is shown is Figure 6.

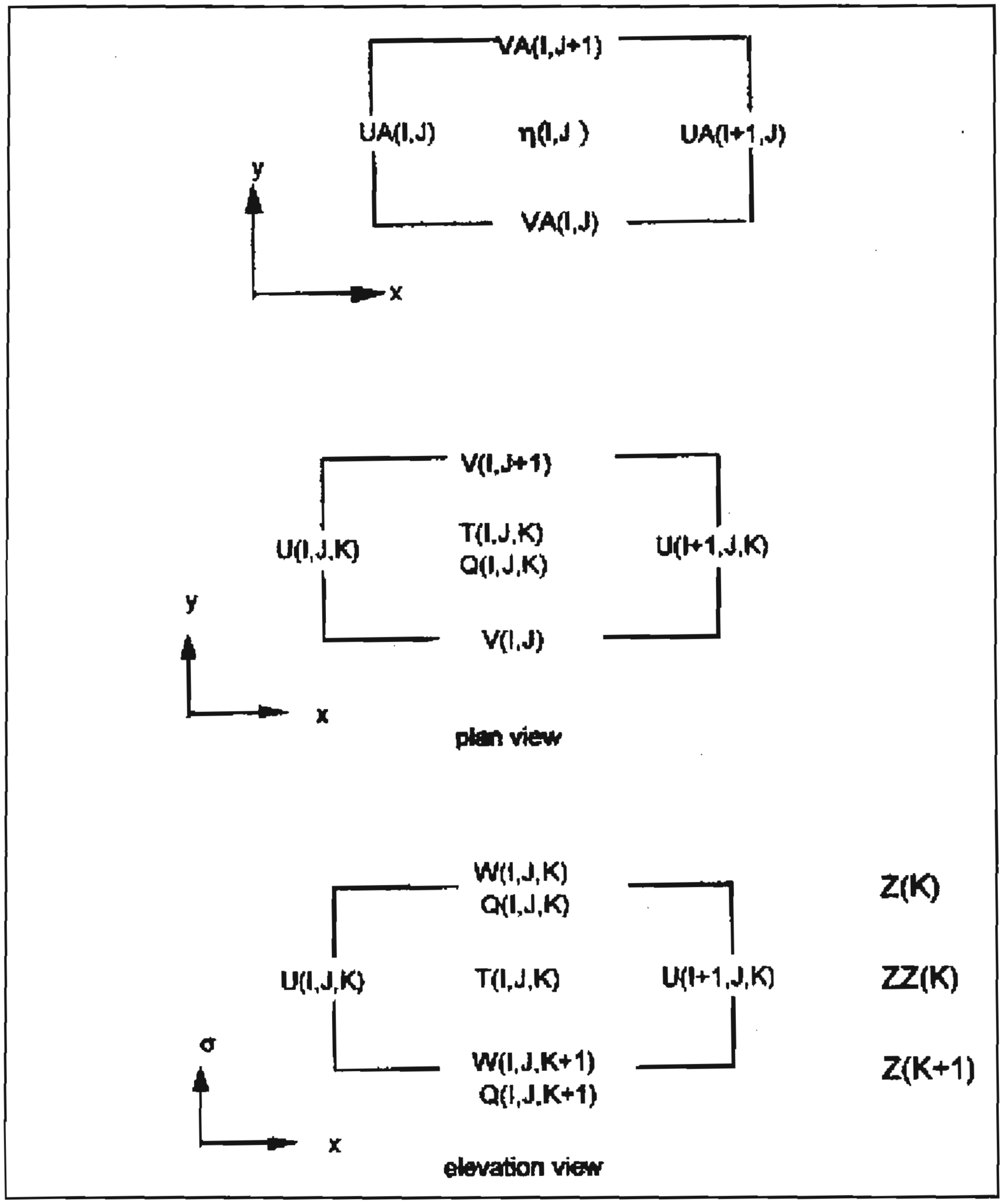

Figure 5. The grid cell at the top shows what parameters are computed and where (relative to grid cell) in the external mode and the bottom two cells show calculations and their locations in the internal mode.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
45	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	45
44	-3	-2	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	-3	-3	-3	44
43	-3	-1	0.1	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	-1	-1	43
42	-3	-1	1.6	2.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	4	1.6	1.6	1.3	1.3	42
41	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	6.2	6.5	6.5	6.5	6.5	4	4.3	4.3	4.3	41
40	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	6.2	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	40
39	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	6.2	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	39
38	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	6.2	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	38
37	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	6.2	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	37
36	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	6.2	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	36
35	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.6	5.2	5.9	6.5	6.5	6.5	6.5	6.5	35
34	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	4.9	2.5	2.8	4.3	5.2	6.5	6.5	6.5	6.5	34
33	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	4.9	1.3	1.6	1.9	1.9	4	5.2	6.5	6.5	33
32	-3	-1	1.6	3.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	4.3	1.3	0.4	0.4	1.6	2.8	5.2	6.5	6.5	32
31	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.6	3.7	1.3	-1	-1	-3	0.7	1.6	4	4	31
30	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.4	0.7	-1	-3	-3	-3	-2	0.4	0.4	30
29	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	0.7	-1	-3	-3	-3	-3	-2	-2	29
28	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	0.7	-2	-3	-3	-3	-3	-3	-3	28
27	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	0.4	-2	-3	-3	-3	-3	-3	-3	27
26	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	0.4	-2	-3	-3	-3	-3	-3	-3	26
25	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	1	-1	-3	-3	-3	-3	-3	-3	25
24	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	1	-1	-3	-3	-3	-3	-3	-3	24
23	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	1	-1	-3	-3	-3	-3	-3	-3	23
22	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	1	-1	-3	-3	-3	-3	-3	-3	22
21	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	1	-1	-3	-3	-3	-3	-3	-3	21
20	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	1	-1	-3	-3	-3	-3	-3	-3	20
19	-3	-1	1	3.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	3.1	1	-1	-3	-3	-3	-3	-3	-3	19
18	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	18
17	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	17
16	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	16
15	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	15
14	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	14
13	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	13
12	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	12
11	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	11
10	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	10
9	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	9
8	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	8
7	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	7
6	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	6
5	-3	-1	1.3	3.3	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	3.3	1.3	-1	-3	-3	-3	-3	-3	-3	5
4	-3	-1	1.3	2.5	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	2.5	1.3	-1	-3	-3	-3	-3	-3	-3	4
3	-3	-1	0.7	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	0.7	-1	-3	-3	-3	-3	-3	-3	3
2	-3	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-3	-3	-3	-3	-3	-3	2
1	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	1
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	

Akutan Small Boat Harbor Grid
Depths are in Meters

Up is North (J Counter)
Right is East (I counter)
JMAX=45 IMAX=42

Grids are square with dx = 25 feet or 7.62 meters

Figure 6. 7.62-meter grid used for Akutan boat basin model—depths are in meters.

One of the concerns in the boat basin is water quality. Basins often restrict flow and therefore limit the amount of mixing that can occur. The mixing efficiency will be investigated by describing the flow in the basin and by predicting how the assumed concentrations will change due to the exchange of water between the basin and Akutan Harbor.

For this analysis, the initial concentrations of a generic conservative pollutant (no bio-chemically changes nor other sources or sinks present) were set to a value of 1 which represents 100 percent. All incoming water was assumed to be of value 0, that is completely devoid of the pollutant. The change in the concentrations within the basin were then tracked with time through several tidal cycles. The rate of change of the concentration can be related to a mixing efficiency through an exchange coefficient (Nece, et. al., 1979) calculated as:

$$E = 1 - \left(\frac{C_n}{C_o} \right)^{\frac{1}{n}}$$

Where C_o is the initial concentration and C_n is the concentration after n tidal cycles. This coefficient is established for each measurable point in the basin. It can be shown that, if the residence time of a contaminant in the basin is defined as the time required to decrease the concentration by 1/e (where e is the constant 2.718) of its original concentration, the residence time can be expressed as:

$$T_f = -\left(\frac{T}{\ln(1-E)} \right)$$

Where T is the tidal period.

According to Cardwell et. al. (1981), in a report for the State of Washington's Department of Fisheries the basin wide-averaged exchange coefficient should be equal to or greater that 0.30 for the basin to be considered sufficiently well mixed to maintain adequate water quality. He further recommended that at least 95 percent of the points sampled should have individual exchange coefficients of 0.15 or larger.

Besides mixing in the harbor, there was concern that whether suspended material that enters the harbor would likely settle in the basin and require periodic dredging. Mobilizing a dredge to this part of Alaska would be expensive, and if required frequently, could have serious consequences to the overall cost of the project as well as reducing water quality if this material was predominately suspended organic material resulting from fish process at Trident Seafoods plant. To investigate this possibility, the dispersion of soluble and suspended material that is discharged at Trident will be tracked for various conditions. The purpose will be to determine the potential quantities that could arrive near the mouth of the basin.

During the modeling of the basin, no consideration was given to possible entrainment of the outgoing flow from the basin by the return flow. It is assumed that the incoming flow is a completely new batch of water that was never in the basin. As we shall see, this may be a little unrealistic unless wind is assumed to be present.

Also the primary pollutant concern is with BOD. The longer this water remains in the shallower, more agitated waters of the basin and at the head of the bay, the greater the likelihood that dissolved oxygen will enter the through surface and reduce its deleterious effects.

2.6 Spill Trajectory

The spill model included as a part of this report is a program created with Micosoft's Visual Basic. The model provided is still in development, but, in the present form, it functions sufficiently well to provide the user with a visual interpretation of the path that a spilled substance might take should its source be anywhere within Akutan Harbor. It seemed that, given the infinite number of places that a spill could occur, it would be more informative to provide the Corps with a method for testing nearly any scenario that they believed to be possible.

Certainly many assumptions went into developing this program. For instance, the spill substance is assumed to float on the water within the surface boundary layer. Without wind, the transport will be entirely dictated by tidal current. The currents within Akutan Harbor have been described using a 3-dimensional, finite difference hydrodynamic program referred to as POM and described above.

POM is appropriate for describing these processes in a deterministic mode, but a portion of the motion of a particle in a fluid is based on random turbulence. This turbulence aids in the spreading of the substance as it is carried along by wind and tide-generated currents. This can be cast as a random process based on physical realities.

To incorporate this non-deterministic part, the random walk theory is employed. The use of random walk presumes that the spreading substance has reached a stage where the physical processes in the ocean such as wind, waves, and currents are more important than the flow of the substance governed by gravity and molecular viscosity. That is, the substance is not simply piling up on the water's surface and flowing "downhill" and the spreading of the mass is not being resisted by viscous attraction.

The dynamics of substance transport by winds and waves are complicated. It is probably easier to discuss the processes than to quantify them (Delvigne, 1993; Overstreet and Galt, 1995). Some particles become entrained by waves and once entrained, because of buoyancy, slowly return to the surface. At this point some particles are at the top of the wind-generated, surface layer while other particles are deeper. This results in the particles moving horizontally at different speeds. The net result of the wind-generated boundary layer and wave entrainment is to usually move the particles from about 1 to 4 percent of the wind speed relative to the water column. To provide a conservative estimate of the range of movement of the spill, a scheme used by NOAA HAZMAT has been adopted where each particle is randomly assigned an additional speed of between 1 and 4 percent of the wind speed.

To keep the model as simple as possible, a linear decay to account for weathering has been used. In addition, when a particle tries to "jump" onto land, it is either stuck to the shore and lost from the simulation or returned to the simulation based on the probability that it will stick to the shore. Both of these processes have built-in default values but can be easily modified by the user.

The model consists of five windows. The primary window that is used to interact with the model is the "Main Window." It is here that the user sets the source location of the spill, the weathering and sticking properties, the time of the spill (relative to the tidal stage), the mode of the spill, and several other parameters that are all described in the

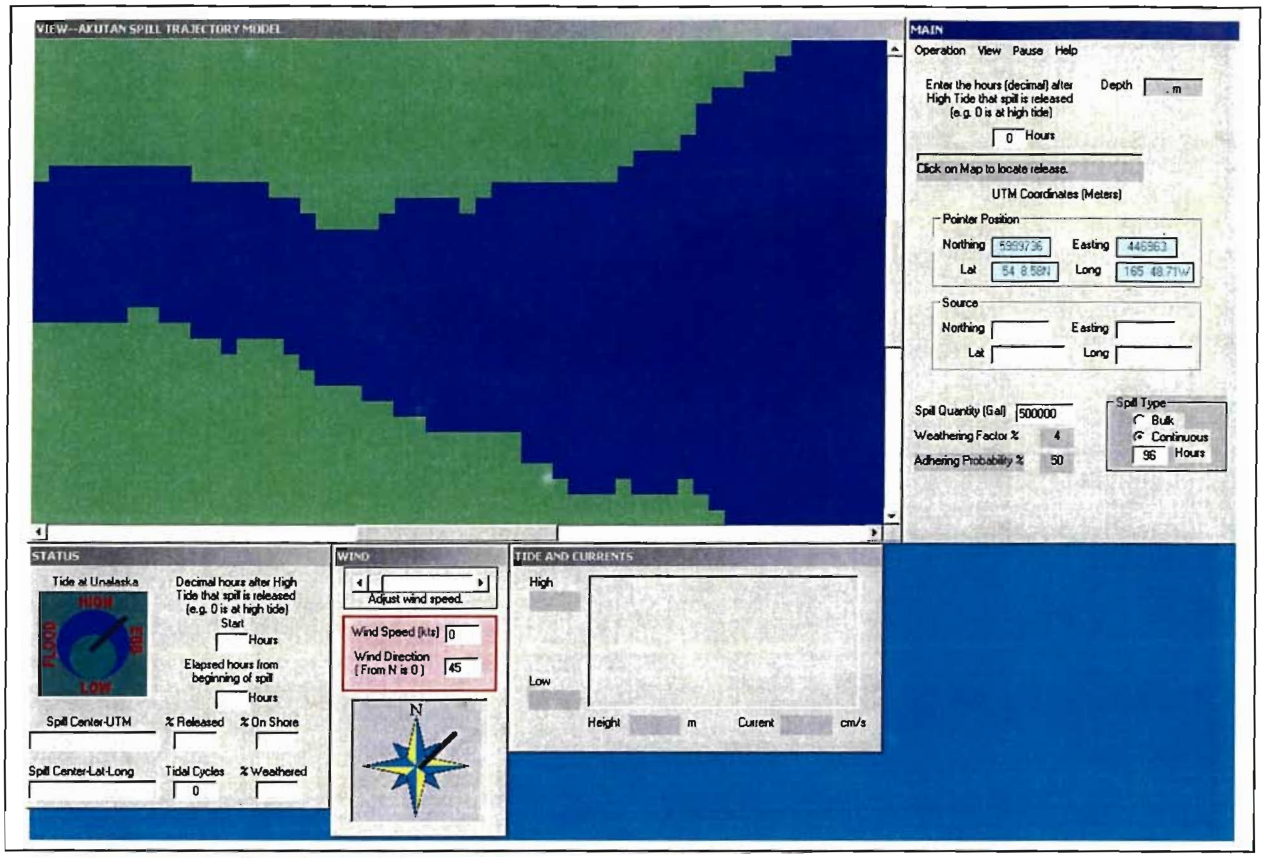

Figure 7. Screen image of windows of Akutan Spill Model

"Help" section of the model. Each spill is described by 1,000 individual points which the model accounts for independently. In the instantaneous mode, all 1,000 points are released at a single instant in time. In the continuous mode, the 1,000 points are released uniformly over time.

The "Status Window" keeps track of the fate of the spill both its and the simulation time. While a file is created that records the spill location in latitude and longitude as well as UTM coordinates, the most practical way to maintain a history of the spill's track is by turning on the "Trace" mode. A track of everywhere the spill has been is then visible on the screen. Also shown on this window is the percentages of oil that have weathered and been lost by sticking to land.

Using the "Wind Window," the user can set the wind speed and direction and change these properties at any time during the run. It should be kept in mind the steep slopes surrounding Akutan Harbor channel the winds so that they are quite constrained to be either easterly or westerly. The model is able to track wind from any direction, but the user probably should exercise some care in generating realistic conditions.

The "Tide and Current Window" provides an interface to check the currents and tidal heights at any location within the harbor. Since Akutan Harbor is small, tidal heights will

vary only a small amount throughout the harbor. More variation will be seen in currents as they respond to water depths, proximity of side boundaries and the varying cross-section.

All of this is displayed, as it occurs, on the "View Window." This is the window that displays the spill's trajectory, and provides the user with up to 100 (user selected) locations where velocity "telltails" can be positioned to demonstrate the velocity vectors (not to any scale). The model is "user friendly" and it only takes a few tries to learn how operate.

3. Results

3.1 Akutan Harbor Modeling

Cases were run for no wind and for 20-knot winds from the east and west. Clearly, Akutan is a windy location and, according to the NPDES permit, winds occur over 70 percent of the time, but rarely exceed 20 knots. It was the intent to bracket the no wind case, which is suspected to have the least amount of mixing, with the extreme wind cases from the directions expected to have the largest effect on mixing in the harbor. Several figures will be presented that attempt to display the spreading process occurring in the harbor.

To observe the material spreading, it is necessary to introduce a material with a given concentration into the harbor at a particular location. The location chosen was the grid cell at or close to the present Trident Seafoods outfall. Referring to the Harbor Grid (Figure 3), this would be grid cell I=22, J=23, and K=20; where I is the grid counter in the X (east) direction, J is the counter in the Y (north) direction, and K indicates the grid at the bottom layer. An error of a couple of grid cells in either direction should not have any significant effect on the outcome.

There are several substances that are discharged at the outfall(s) that are quite different in character. There is soluble material that simply becomes part of the water column either immediately upon contact with the receiving waters or shortly thereafter. There is also a suspended constituent, generally referred to as the total suspended solids or TSS. Other solids settle directly and join the waste pile on the harbor bottom. These probably continue to emit BOD with time at a rate dependent on several variables. There is a floatable fraction that probably consists primarily of oil and grease. What the first three all have in common is biological oxygen demand (BOD or BOD_5). The subscript is often used to distinguish the consumption mode of BOD; the "5" being the amount that is consumable in 5 days. Generally, this part is consumed by dissolved oxygen. Hereafter, it will simply be referred to as BOD.

For the purpose of running the model, a value of 10,000 pounds per day of BOD is the assumed discharge from the plant operations. In reviewing the permit, this seems to be a reasonable amount. The permit states that a monthly average of 115,314 pounds per day of BOD is discharged, combined among the constituents already described. Part of this is as 148.933 pound per day of TSS. This is screened before reaching the receiving waters and more than 75 percent of the BOD is removed and more than 97 percent of the TSS is removed. Therefore. the total daily BOD reaching the harbor is about 29,000 pounds, and the total TSS is about 4,500 pounds. Of that BOD quantity, some contributes directly to the waste pile. We suspect that the 10,000 pounds per day is a reasonable number that will be transported by the currents in the harbor. It is also a convenient number to multiply by any number if another is believed to be more reasonable.

3.1.1 Maximum Concentrations

One of the first runs was to follow the maximum BOD concentrations that could be found anywhere within a particular layer as a function of time. The set of three plots (Figure 7) shows these maximum concentrations for two layers (10 and 20 meters) for the three different wind conditions. The BOD source strength is assumed to be 10,000 pounds per day. The fact that flooding and ebbing bring different layers through those particular elevations is evidenced by the variations on the tidal frequency. The actual depth of the discharge is assumed to be about –20 to –22 meters. The purpose of including these plots is two-fold: first it demonstrates the concentration level of the introduced material (the

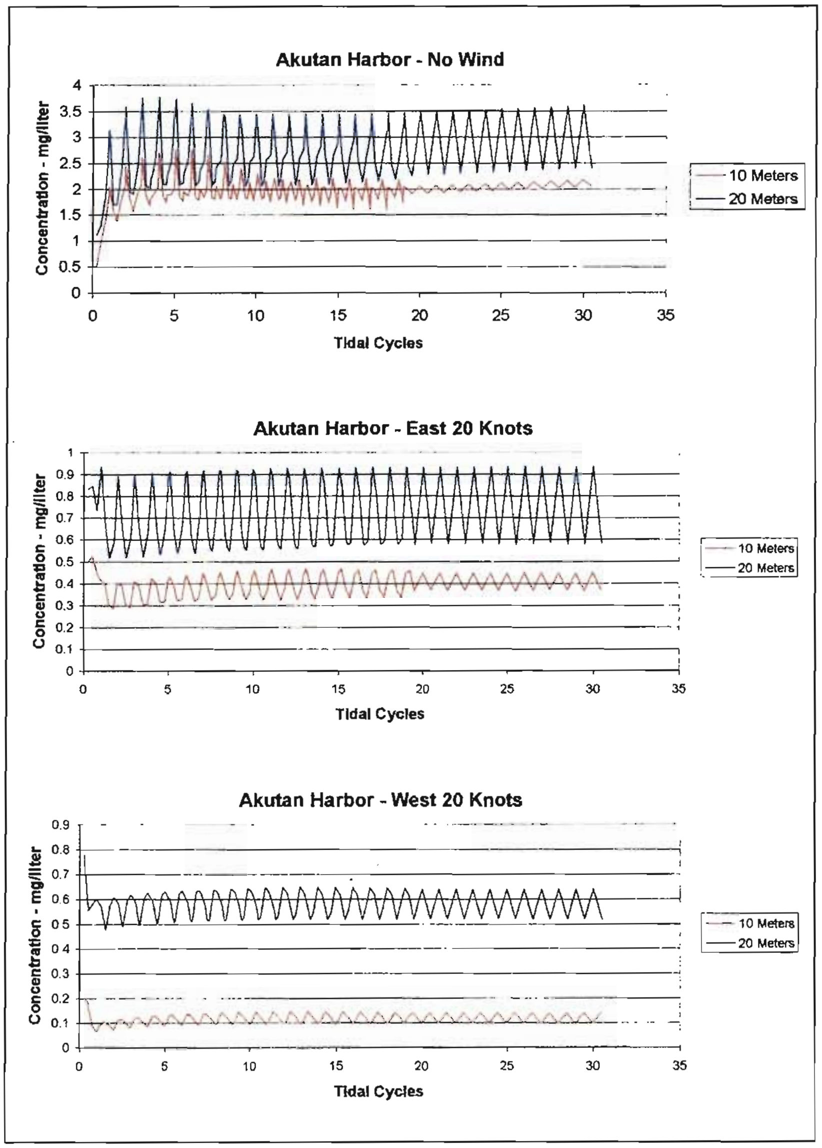

Figure 8. Maximum concentrations at each depth versus tidal cycles for Akutan Harbor for given winds.

pounds per day have been converted to mg/liter), and it shows that, at least for the wind situations, a steady state condition will eventually be reached. It also shows that winds are effective in reducing maximum concentrations in the harbor.

This should be of no great surprise when the wind-generated currents are compared with tidal currents (with no wind). Figure 8 shows the maximum surface currents (should be similar throughout the water column) in Akutan Harbor for the "no wind" case. Figures 9 and 10 show the maximum wind-generated velocities for east and west 20-knot winds, respectively. The wind-generated currents are in places an order-of-magnitude greater than the tidal currents alone

3.1.2 Distributions in Harbor

Runs were made to characterize pollutant distribution throughout the harbor for the three wind conditions by examining three distinct layers (1, 10, and 20 meters). Theses are shown in Figures 11, 12, and 13. The model was run for 15 tidal cycles so that a steady state condition had, or nearly had, been attained. The "no wind" case shows that there is a slight cross-harbor transport from the outfall. Transport into the harbor from the discharge point is slightly increased along the southern shore; and out of the harbor it is slightly increased along the northern shore. Concentrations near the head of the bay are less than 0.02 mg/liter.

For the "east wind" case, the distribution appears a little more confusing toward the head of the bay while toward its mouth the major transport seems to be along the southern shore, just opposite of the "no wind" case. Judging by the surface layer, the transport inward appears to be also along the southern shore, but is not apparent at 10 or 20 meters. In the surface layer, there appears to a concentration of 0.06 mg/liter but considerably less than that in the lower layers.

The "west wind" case shows a strong transport both in and out of the harbor along the north shore. Concentrations at the head of the bay can reach 0.04 mg/liter. It would appear that vertical mixing may be much more intense for this case.

3.2 Small Boat Basin Modeling

The boat basin at the head of the harbor is oriented so the short axis (width) is aligned east-west in line with the major wind directions. Since the wind in blowing in either of these two directions nearly continuously, it's probably reasonable to consider its effects in analyzing the basin's mixing efficiency. In an enclosed region such as a boat basin, winds will tend to generate surface flows in the wind direction and subsurface flows in the opposite direction. To describe this process in a model, it must be capable of capturing 3-dimensional effects. We had originally intended to use the 3-dimensional modeling only for the Akutan Harbor motions and to use 2-d modeling in the boat basin. It was obvious early in the analysis that such a description did not reflect the more realistic 3-d effects and would predict a mixing situation untenable to most water-quality standards. Therefore, we changed plans and began the more complex 3-dimensional model in the basin as well. These 3-d flows had a large effect on the vertically averaged concentrations in the basin.

This analysis also produced concentrations that varied in the vertical as well. However, for the method that was selected to analyze the mixing (exchange coefficients) it seemed more reasonable to vertically average these and thereby produce a single concentration for each horizontal grid point in the basin.

After considering several scenarios, three were ultimately selected for inclusion into this report. They included the no-wind situation in which all to the exchange is driven by tidal velocities; a 10-knot east wind superimposed on the tidal flow; and similar situation for a 10-knot west wind. The exchange coefficients for those cases are presented in Table 1. The residence time for a pollutant to remain inside the harbor is also provided.

Table 1. Vertically-averaged Exchange Coefficient in boat basin.

	No Wind	**10-knot Wind**	
		East	**West**
Vertically-Averaged Exchange Coef.	0.08	0.15	0.23
Residence Time (days)	6.25	3.2	1.9

These are typically low values indicating poor exchange within the small boat harbor. The mixing is significantly improved by adding wind. The west wind is even more instrumental for increasing the mixing than the east wind. This imbalance between east and west winds of the same magnitude is probably due to the location and orientation of the outlet

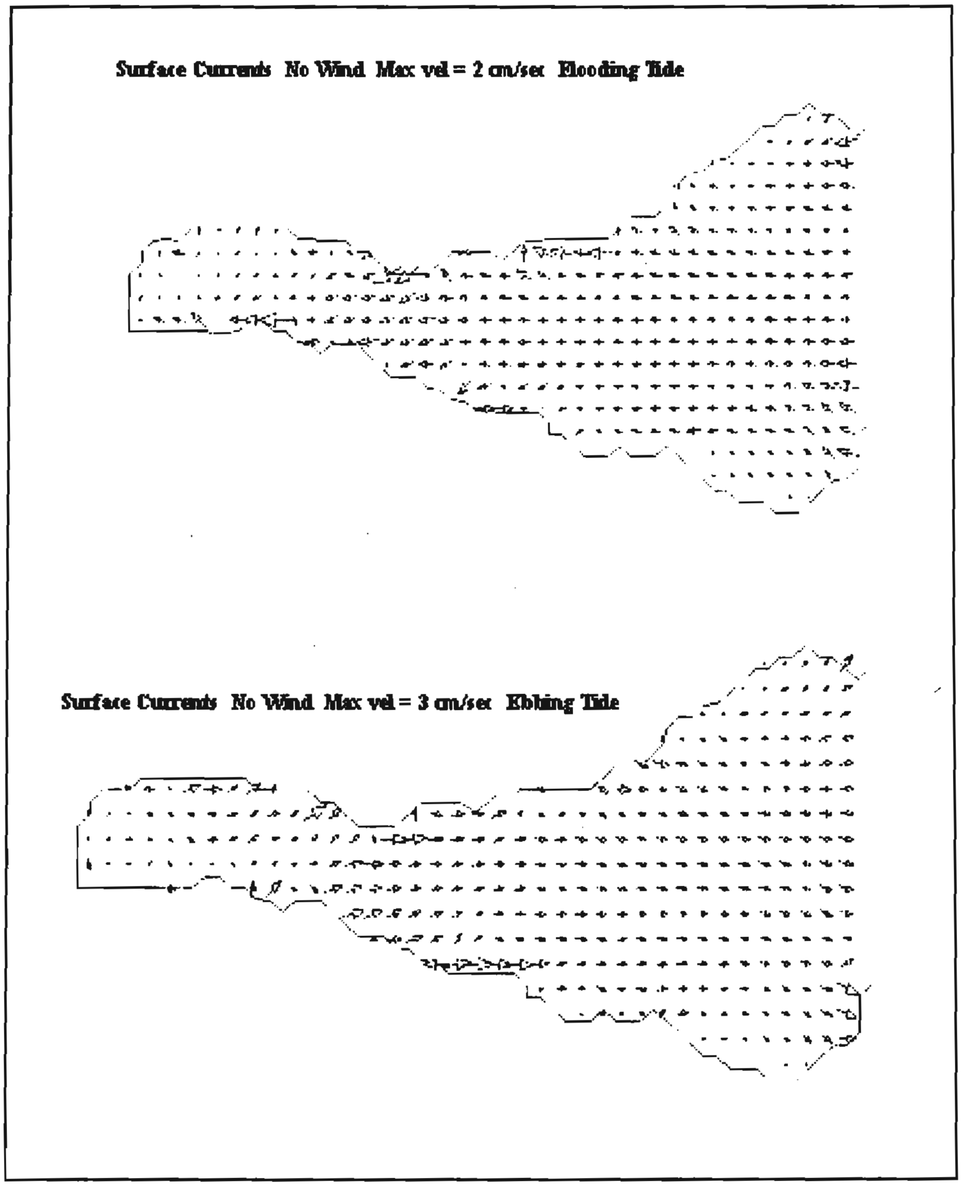

Figure 9. Surface currents in Akutan Harbor for the "no wind" case (tidal currents only)

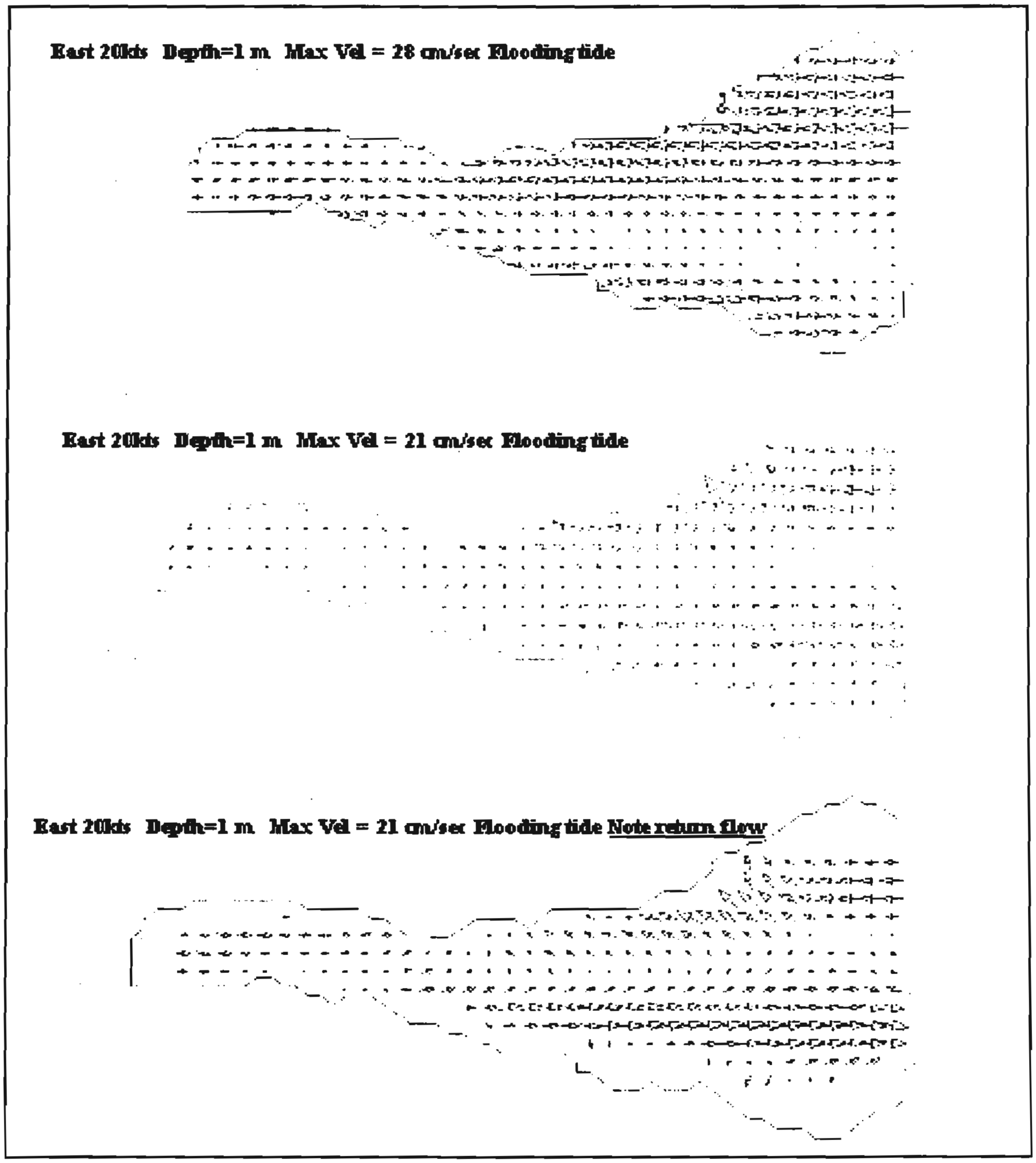

Figure 10. Currents in Akutan Harbor at three depths for case of 20-knot east winds.

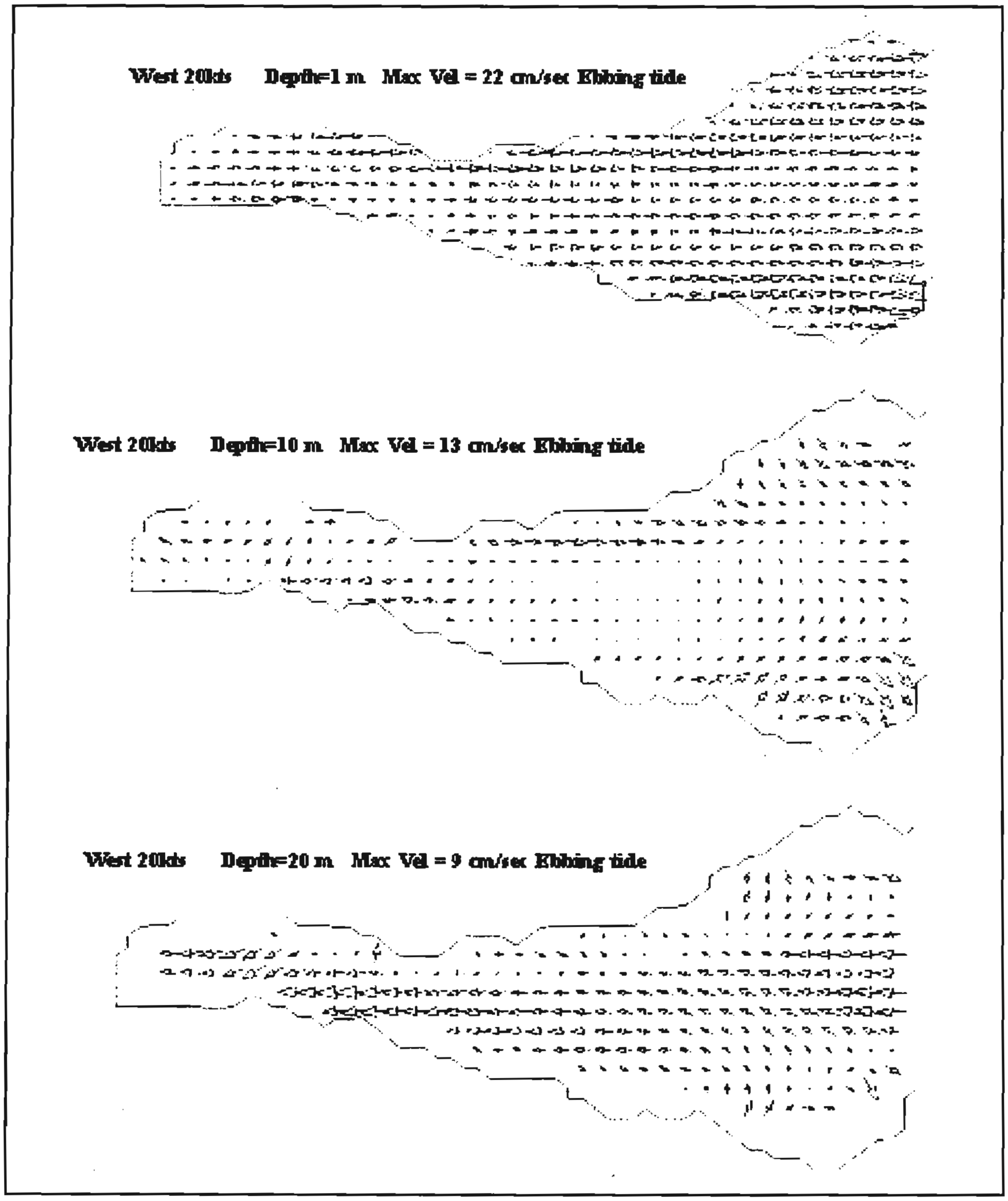

Figure 11. Currents in Akutan Harbor at three depths for case of 20-knot west winds.

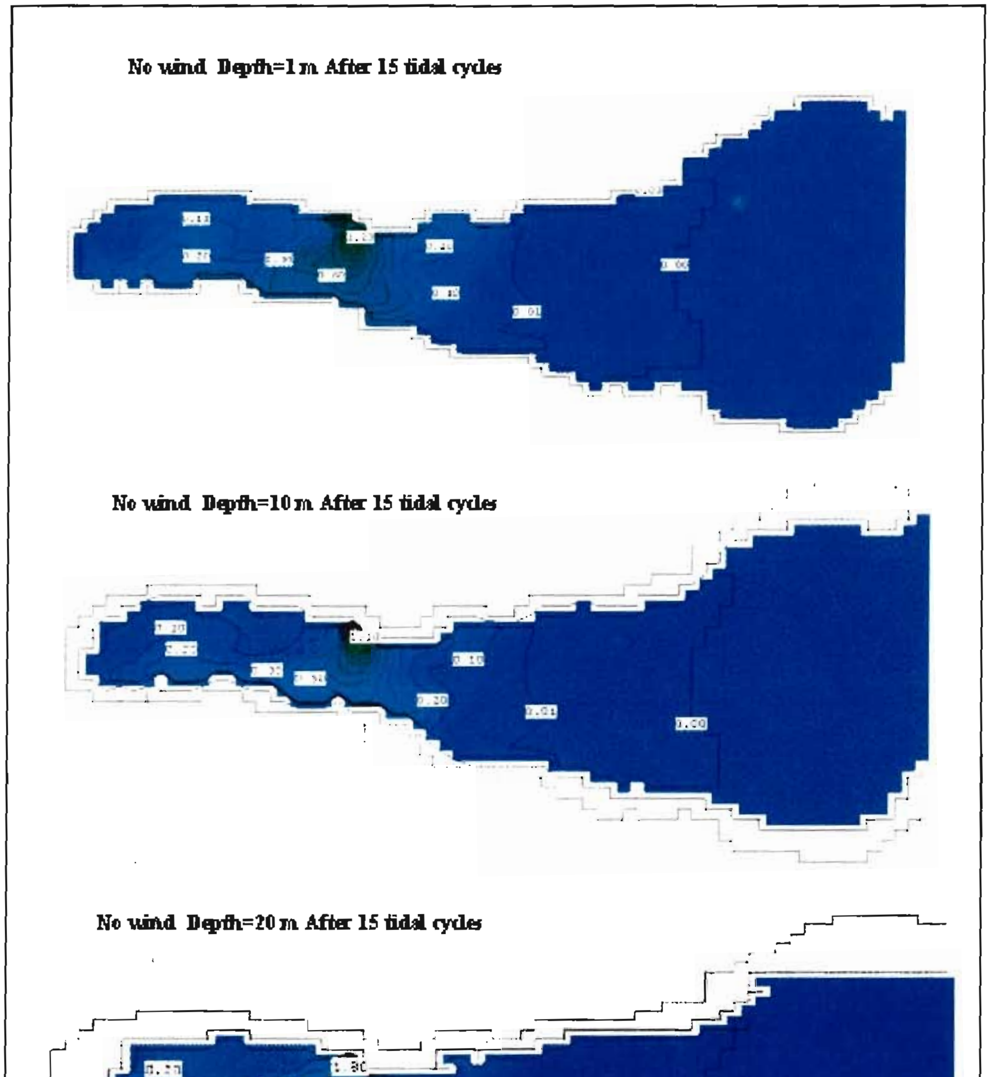

Figure 12. BOD concentrations levels in Akutan Harbor during calm conditions, after 15 tidal cycles

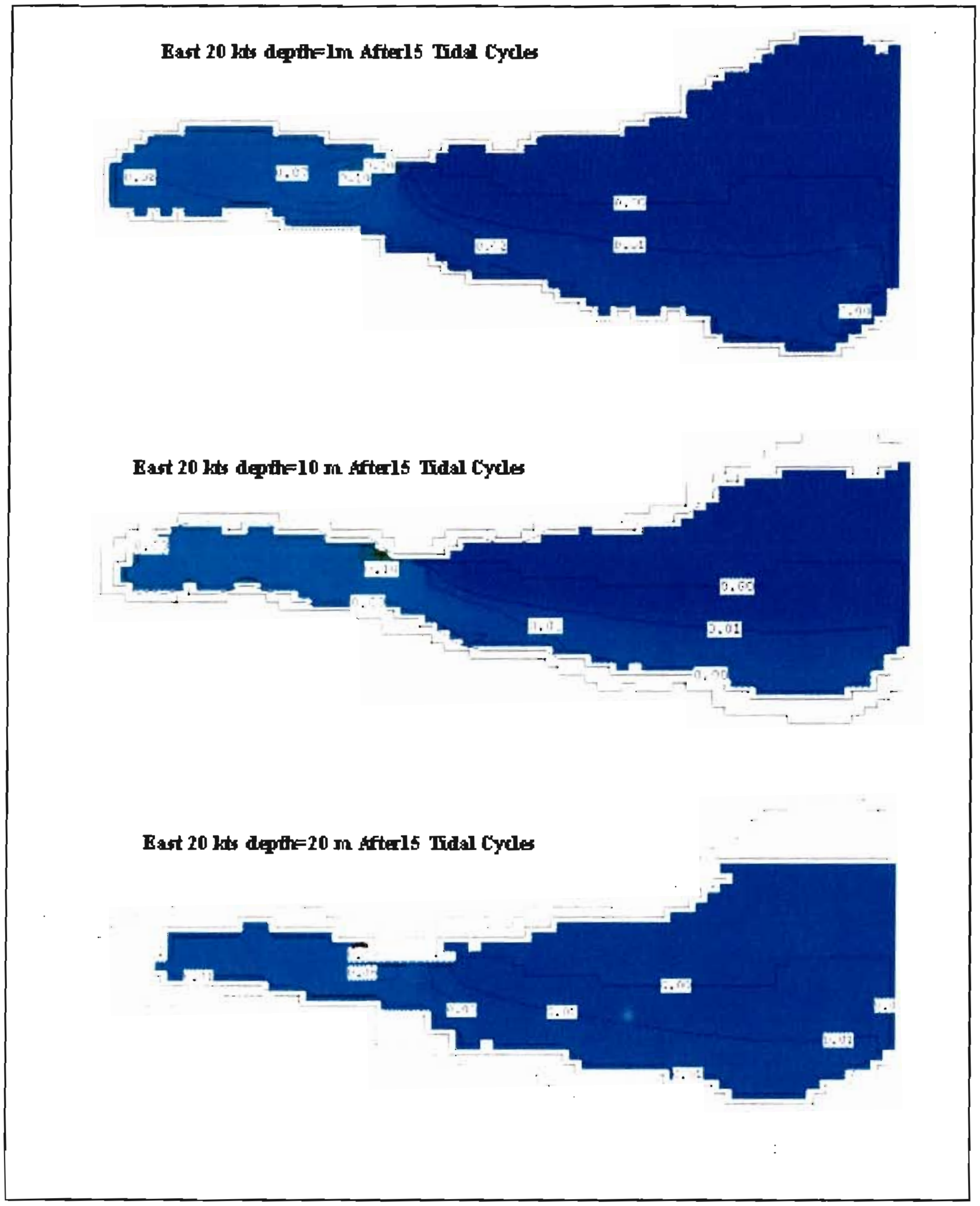

Figure 13. BOD concentrations levels in Akutan Harbor for east winds, after 15 tidal cycles

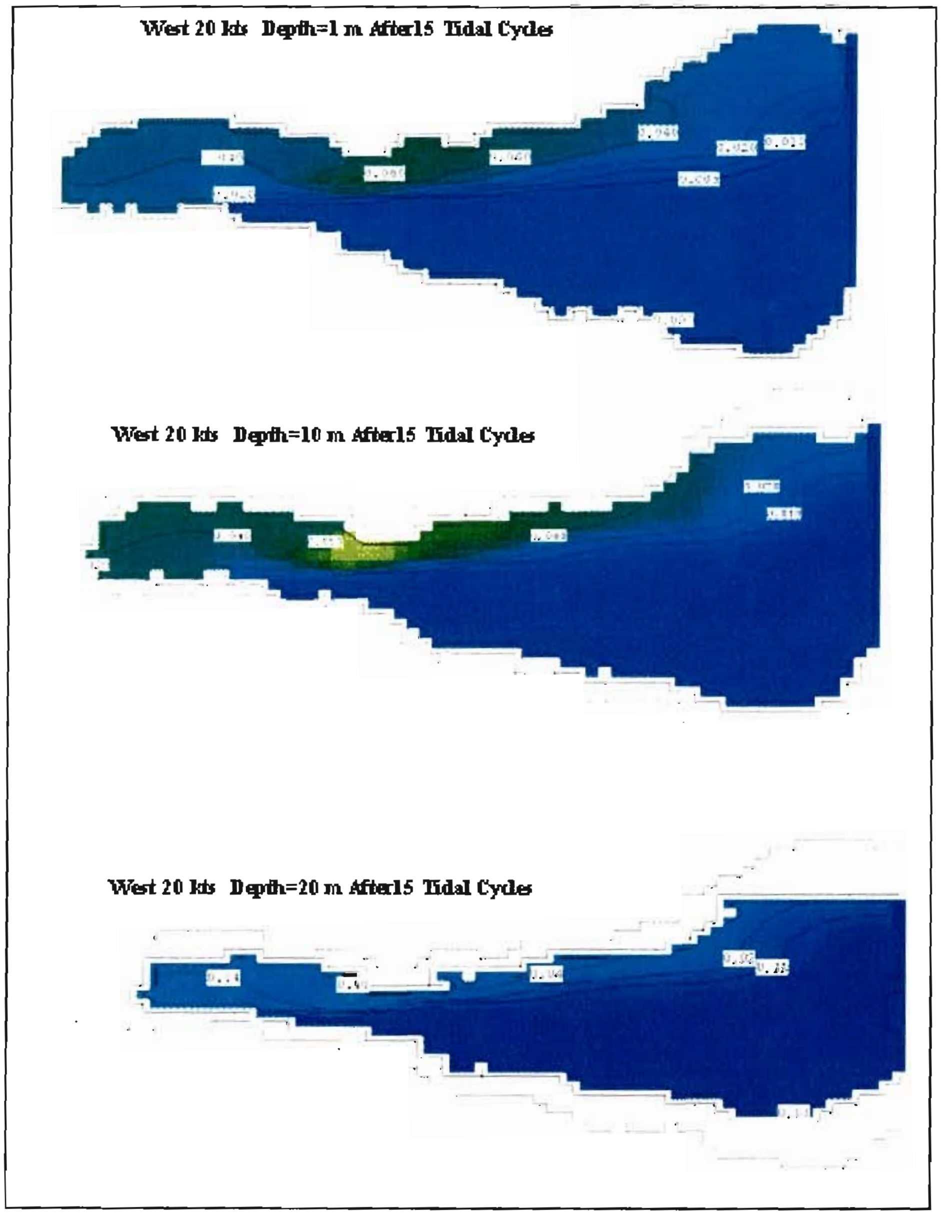

Figure 14. BOD concentrations levels in Akutan Harbor for west winds, after 15 tidal cycles

4. Conclusions

A series of computer runs were undertaken to investigate the fate of discharges from Trident's Seafood plant and the mixing capacity of a small boat harbor under consideration for the head of the harbor. A number of concerns were delineated at the beginning of this report which were to be addressed by these applications. Each will be individually addressed.

1. *The possible build up of fish processing wastes in the boat basin.*
   Three wind conditions have been investigated in which the basin-wide concentrations at three separate layers has been investigated. In no cases did the concentrations near the head of the bay, which would serve as the source of basin water on flood tide, exceed 0.06 mg/liter. Now these concentrations have been treated as conservative materials. Clearly, BOD would not be conservative, but would decrease with time as dissolved oxygen was consumed. It appears that this should not have noticeable impact on DO. It was stated early on that although it was felt that the 10,000 pounds per day of BOD was thought to be a reasonable number, it could be low by a hundred percent. If such were the case, then it appears that mixing would still be more than sufficient to maintain good DO levels in the boat basin. This does not even take into account any increased absorption of DO in the basin due to more active mixing by wind.

2. *The flushing rate/volume exchange that is anticipated in the boat basin due to tides and winds.*
   The exchange coefficients were estimated for the boat basin for three wind conditions. The usual "no wind" was investigated as were cases for 10 knot east and west winds. Recall that for the Akutan Harbor modeling the wind cases were 20-knot winds. In that case, the attempt was being made to bracket the conditions, but lower winds were considered in the boat basin case. This was done because it was soon realized that mixing by tidal activity alone was poor. Therefore, realistic wind values were sought which could assist in the mixing process.

   For those cases the average exchange coefficients varied between 0.08 and 0.23 with the largest being for west winds and the smallest for no winds. The east-wind case was in between at 0.15. According to the Washington State, Department of Fisheries Report authored by Cardwell (op.cit, 1981), adequate boat harbor mixing begins when the average coefficient value reaches 0.3. It appears that the low tidal range coupled with the relatively small, deep basin, and wide entrance all combine to limit mixing.

3. *The direction of flow of the effluent from the boat basin.*
   The same parameters that indicated poor exchange through the basin entrance when considering mixing inside the basin also apply to water exiting the basin. The momentum to carry this water well away from the mouth just doesn't exist.

In addition, tidal currents are extremely low at head of the bay. The water leaving the basin will be moved almost in total response to the winds; east winds will pile the water against the shore and create offshore transport at depth and west winds will cause the basin water to move nearly due west toward the mouth of Akutan Harbor.

4. *The potential for exceeding the State's water-quality standards for certain substances within the basin.*
   Since the exchange of water through the boat basin entrance is limited, it is likely that nearly any substance that is regulated by the State's water-quality program and has the potential to be in the basin at those levels could meet or exceed standards. A good deal of care will probably need to be exercised to keep materials from entering the basin waters.

5. *Under what conditions would there be a BOD/DO problem in the mooring basin.*
   The conditions that might introduce excess amounts of BOD or create a depleted DO content would probably be from the discharges from vessels or non-point sources into the basin itself. It is apparent from the modeling that it is highly unlikely that BOD from Trident's outfall would create a problem in the basin.

6. *If settleable solids have enough residence time in the basin to accumulate in the basin sediments.*
   Assuming that there are no local sources of settleable solids, then it is highly unlikely that they will create a problem in the boat basin. There could be ample wave activity in the northern end of the basin given the location and orientation of the entrance. If sands and finer material were available, they could certainly be transported into this end of the basin. However, this material is extremely limited and the indication for such transport activity is small. The settleable solids that are introduced at Trident's outfall are extremely small. Most is deposited on the seabed shortly after leaving the outfall. It we also include the TSS in this category, their concentrations at the head of the harbor would be about half of that designated for BOD assuming none settled out in transit and that is highly unlikely. Unless there is some local source or a wind-blown source, settleable solids should not create a problem at the boat basin.

7. *The influence of freshwater intrusion into the mooring basin on the possible enhanced buildup or discharge of contaminants.*
   Freshwater could be either a net benefit or detriment to the build up of pollutants in the harbor. If the water was introduced near the bottom, then the freshwater might enhance the vertical exchange of water which, in turn, might have a positive effect on harbor mixing. However, mixing due to wind effects would clearly mask the effects of entrainment by rising freshwater. If the freshwater were introduced higher in the water column, it could actually limit vertical mixing by capping the system. As a general rule, every attempt to exclude freshwater should be considered due to the increased likelihood of ice formation in the basin.

A 3-dimensional computer model has been applied to the circulation in Akutan Harbor and in the proposed small boat basin. The model clearly indicates that Akutan Harbor cannot be thought of as a simple 2-layer flow. Winds can clearly introduce horizontal as well as vertical circulation in the harbor.

The model was also used to examine flows and substance transports in the boat basin. The primary concern that this demonstrated was that mixing in the basin will be quite limited. Mixing enhancements by east and west winds will double or triple the efficiency as measured by exchange coefficients. The residence time for pollutants in the harbor could be as much as 6.25 days for the "no wind" case and 1.9 days for the "west wind" case.

5. References

Cardwell, Rick D., and Robert R. Koons, 1981, Biological considerations for the siting and design of marinas and affliated structures in Puget Sound, State of Washington Department of Fisheries, Tech. Rept. No. 60,31 pp.

Nece, Ronald E., Eugene P. Richey, Joonpyo Rhee, and H. Norman Smith, 1979, Effects of planform geometry on tidal flushing and mixing in marinas, University of Washington, Charles W. Harris Hydraulics Laboratory. Tech. Rept. No. 62, 70 pp.

Tetra Tech ,1993, Akutan Water Quality Study-September 1993

Yearsley, John, 1996, EPA Report on Water Quality Modeling in Akutan Harbor, Alaska (Name approximate)

ADDITIONAL WAVE AND WATER QUALITY ANALYSES FOR THE POTENTIAL BOAT BASIN AT AKUTAN HARBOR, ALASKA

FOR:
TRYCK NYMAN HAYES, INC
911 WEST 8TH AVENUE
ANCHORAGE, ALASKA 99501

BY:
COASTLINE ENGINEERING
5900 LYNKERRY CIRCLE
ANCHORAGE, ALASKA 99504

OCTOBER 28, 2003

1.0 INTRODUCTION

An earlier report[1] was issued that described the potential water quality in the small boat basin under consideration for the head of Akutan Harbor (Figure 1). Those analyses investigated several wind conditions and used a semidiurnal tide as the driving force for supplying water and momentum to the basin. It came as no great surprise that mixing was quite restricted in the basin. Somewhat earlier than that, a report was delivered that contained a wave analysis using the wave program STWave to calculate the design wave conditions for the head of the harbor. The 50-yr design significant wave height was determined to be 3.1 ft. with a period of 5.0 seconds.

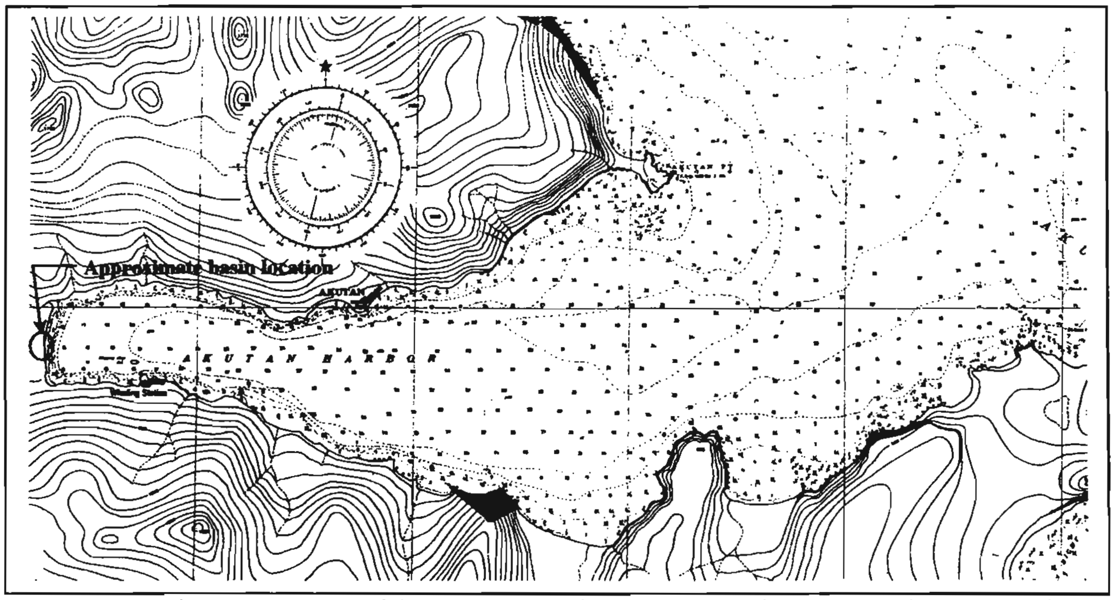

Figure 1. Akutan Harbor with the community on the north side. The boat basin is being designed for the head of the bay.

Since the issuance of those reports, concern has arisen to develop ways to improve the mixing by modifying the shape of the boat basin while keeping most other factors such as basin depths and total volumes the same. In addition, since adding a breakwater to reduce wave heights seems impractical, concern has arisen as to the possibility of relatively high waves entering the boat basin, therefore, most of the wave attenuation will be left to the basin entrance.

An investigation of these two concerns was undertaken and is the subject of this report. The mixing potential for the existing configuration was determined using three tidal conditions. Then the basin entrance was reconfigured to increase entrance velocities and the analysis was redone using the same inner basin geometry as called for in the existing configuration. Then that geometry was modified and the analysis and using the altered entrance configuration the analysis was repeated. In wave conditions for the inner basin were determined using the latest version of REFDIF, a wave program that treats

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[1] [1] Coastline Engineering, Circulation modeling in Akutan Harbor and the potential impacts by and to the proposed small boat harbor, October, 2001.

refraction and diffraction in a unified way. Each of these concerns was treated separately and is reported herein.

The proposed boat basin is to be located on the western head of Akutan Harbor. The harbor is about 3½-long embayment in the east-west direction. For the west 2 miles the width is about on half mile. Tidal currents in the harbor are low and respond to wind by setting up a three-dimensional flow system with the surface currents responding directly to the wind and the deeper currents opposing the surface flows to maintain continuity.

2.0 MIXING IN THE BOAT BASIN

The configuration chosen as the likely preferred plan is as shown in Figure 2. It consists of a 12-acre inner harbor (excluding the entrance acreage) and has a stepped depth. The northern most depth is 18 feet, the middle portion at 16 feet and the southernmost at 14 feet relative to MLLW. The entrance depth is the same as the deepest portion of the basin, 18 feet

The Alaska Department of Environmental Conservation (ADEC) wanted answered was whether there was a design possible that might provide significantly better mixing while not interfering with the navigation. The approach to answering this question consisted of first modeling the existing configuration and to calculate the appropriate mixing parameter: mean and variation of the exchange coefficient. Tides are known to play an important role in facilitating mixing in boat basins. Generally, the highest tides produce the greatest mixing. Akutan has a complex tidal curve, albeit, with a small range. It transforms from a nearly pure diurnal signal to a fairly strong semidiurnal signal during the course of two weeks. During the highest tides the signal is semidiurnal. We have chosen to simulate three tide conditions for this investigation. They are shown in Figure 3.

The analysis uses a computer model to simulate the mixing of a hypothetical substance in the boat basin. The scheme used was initially developed to investigate mixing in St. Paul Island boat harbor and has been used on numerous boat basins and natural bays in Alaska. It was recently used on over 140 theoretical basins for the ADEC. For that project, a procedure to observe the mixing process was implemented to observe the mixing process in colored animation. The actual effectiveness of the mixing process is determined by calculating the mean and standard deviation of a quantity referred to as the Mixing Coefficient[2] (E) after a certain elapsed time. This coefficient is calculated from the concentrations as:

$$E = 1 - \left(\frac{C_t}{C_0} \right)^{T/t}$$

Where *t* and ***T*** refer to time and the length of the tidal period and

[2] Nece,Ronald E., Eugene P. Richey, Thee Joonpry, and H. Norman Smith, 1979, Effects of planform geometry on tidal flushing, in marinas, Tech. Rept. No. 62, Charles W. Harris Hydraulics Lab., Dept. of C.E., U. of WA, 71 pp.

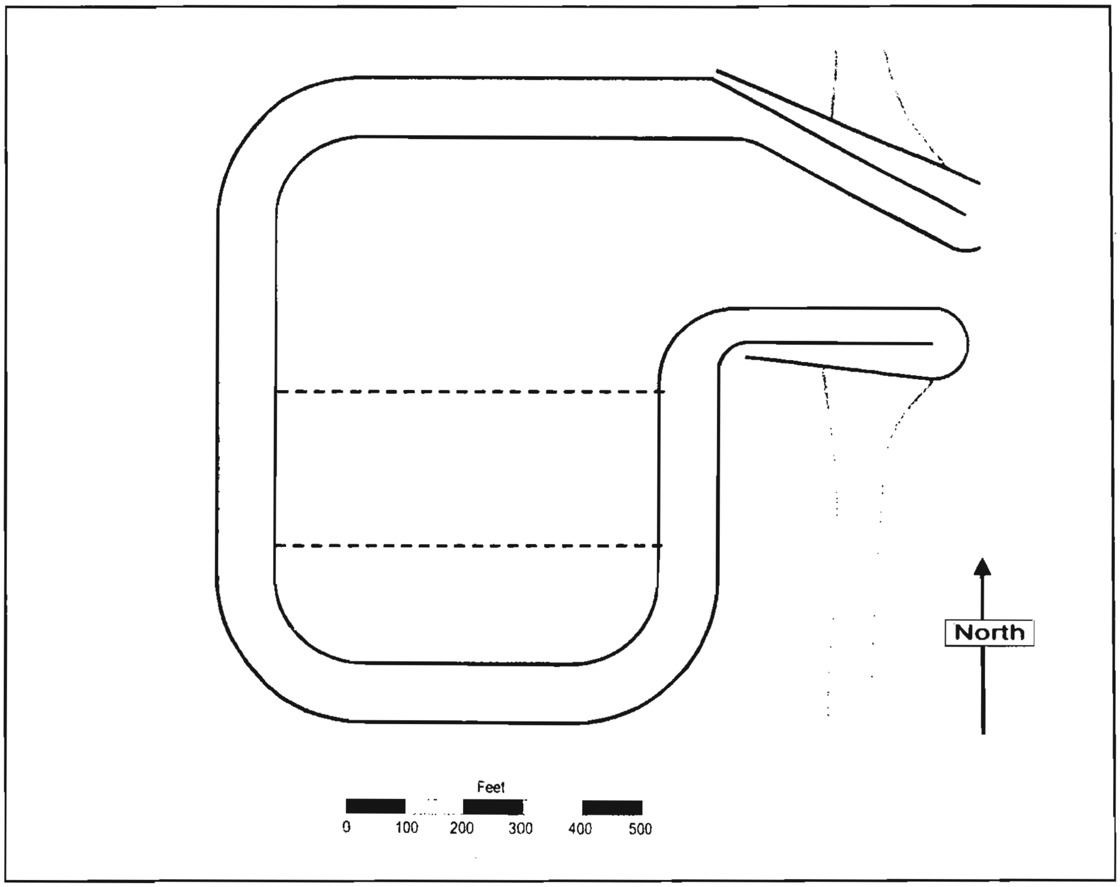

Figure 2. The configuration believed to be the preferred plan. The wide inner entrance was to enhance navigation.

Where *t* and *T* refer to time and the length of the tidal period and the C_t and C_0 are the concentrations at time *t* and the initial concentration. By a simple transformation, this can be shown to be a function of the number of tides. Due to the difference in periods between diurnal and semidiurnal tides, it was decided to calculate the exchange coefficient based on time.

The initial simulation produced the distribution of the exchange coefficients as shown in Figure 4. This images, and those that follow are for the high water slack during the fourth tidal cycle. The results are presented in terms of the mean and standard deviation of E in Table 1. In this figure, the white indicates complete mixing the mixing decreases as the color approaches black. The red color signifies almost no mixing.

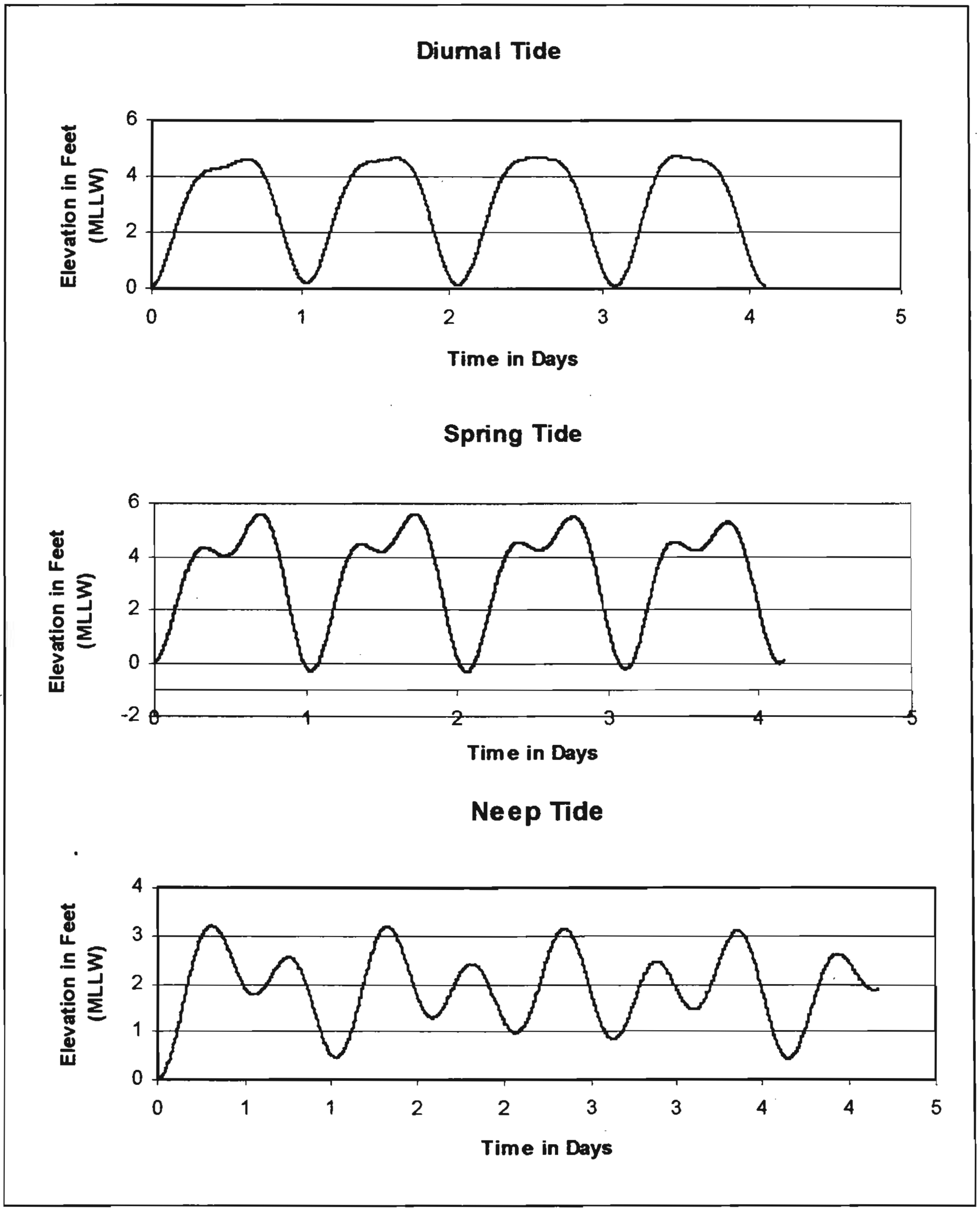

Figure 3. Three tidal conditions used for modeling. These represent actual tides as predicted from tidal constituents.

Table 1. Basin means and standard deviations for the Exchange Coefficients for the given configuration.

CONFIGURATION	EXCHANGE COEFFICIENT	
	Mean	Std. Dev.
Original Rectangular Basin	0.05	0.10
Modifiedctangular Basin	0.17	0.11
Modified Circular Basin	0.17	0.11

The entrance was then altered to maintain the same width over its entire length. This configuration is shown as Figure 5. Figure 6 shows exchange coefficient distribution for this configuration. There is a significant improvement in the circulation and mixing in comparison to the original configuration. This improvement is quantified in Table 1. The third option consisted of the same basin area and water volume as the previous two. It also had the modified entrance—uniform width, but it had a more circular shape than the previous alternatives. This configuration is shown in Figure 7 and its exchange coefficient distribution is shown in Figure 8. It was anticipated from previous studies that this configuration would produce the most well mixed inner basin. While there

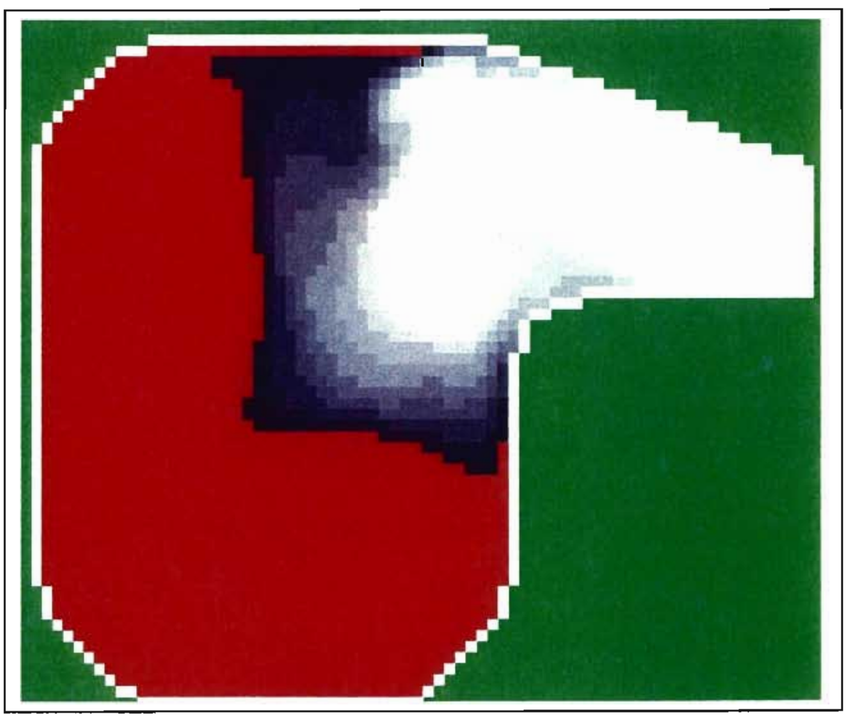

Figure 4. Shows the distribution of exchange coefficient in the rectangular basin with the wide inner entrance (the original preferred alternative). White indicates well-mixed areas while the red signifies poorly mixed areas.

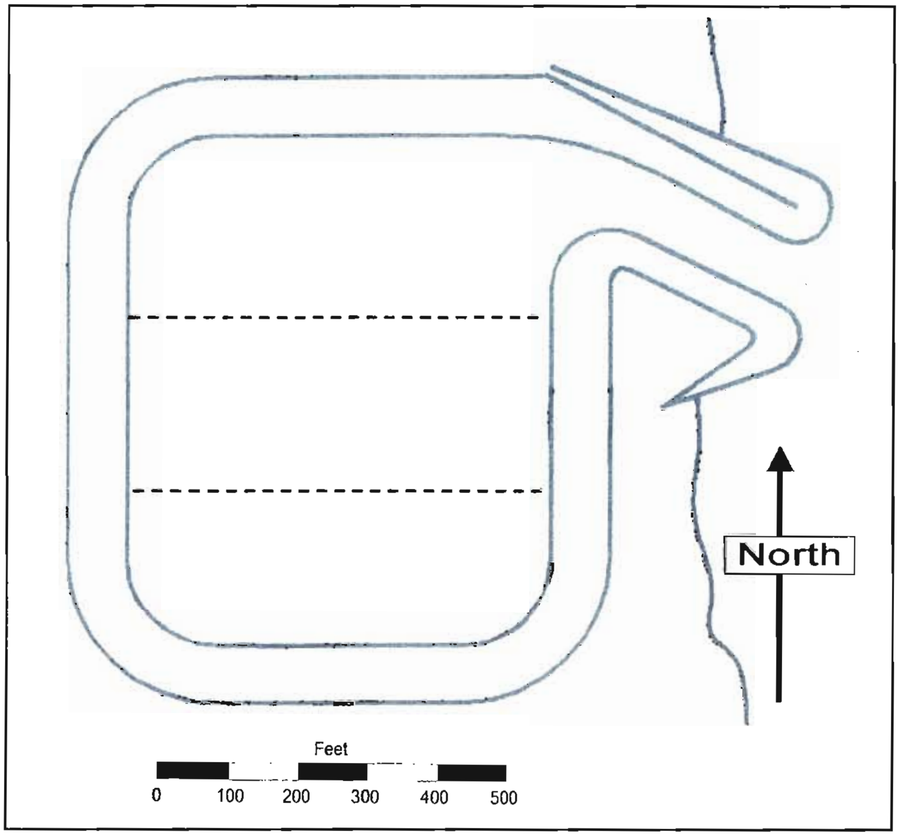

Figure 5. Rectangular configuration with the modified entrance.

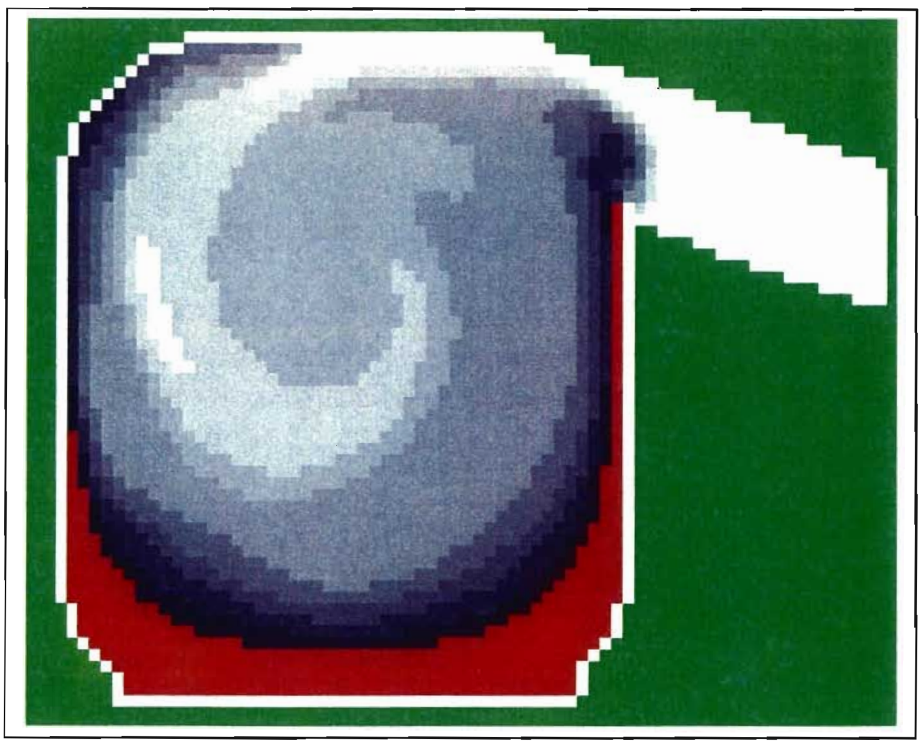

Figure 6. Shows the distribution of exchange coefficient in the rectangular basin with the narrow inner entrance. White indicates well-mixed areas while the red signifies poorly mixed areas.

was a marginal improvement in water quality with this shape, it cannot practically be distinguished from the previous configuration on the bases of improved water quality (Table 1).

It is believed that there are two possible reasons why the circular shape did not show a demonstrable increase in mixing efficiency when compared to the more rectangular shape. The first was that the tidal ranges were just too small to generate any excess momentum to take full advantage of this shape, and the second was that the entrance had such a high volume capacity that most of the incoming flow was retained in the entrance and water was not allowed to exchange between the basin and the water on the outside of the entrance.

To examine this possibility, the entrance was shortened for configurations 2 and 3. This forced greater exchange between waters inside and outside the basin. This did yield a mean exchange coefficient a few percent greater than the comparable basin with a longer

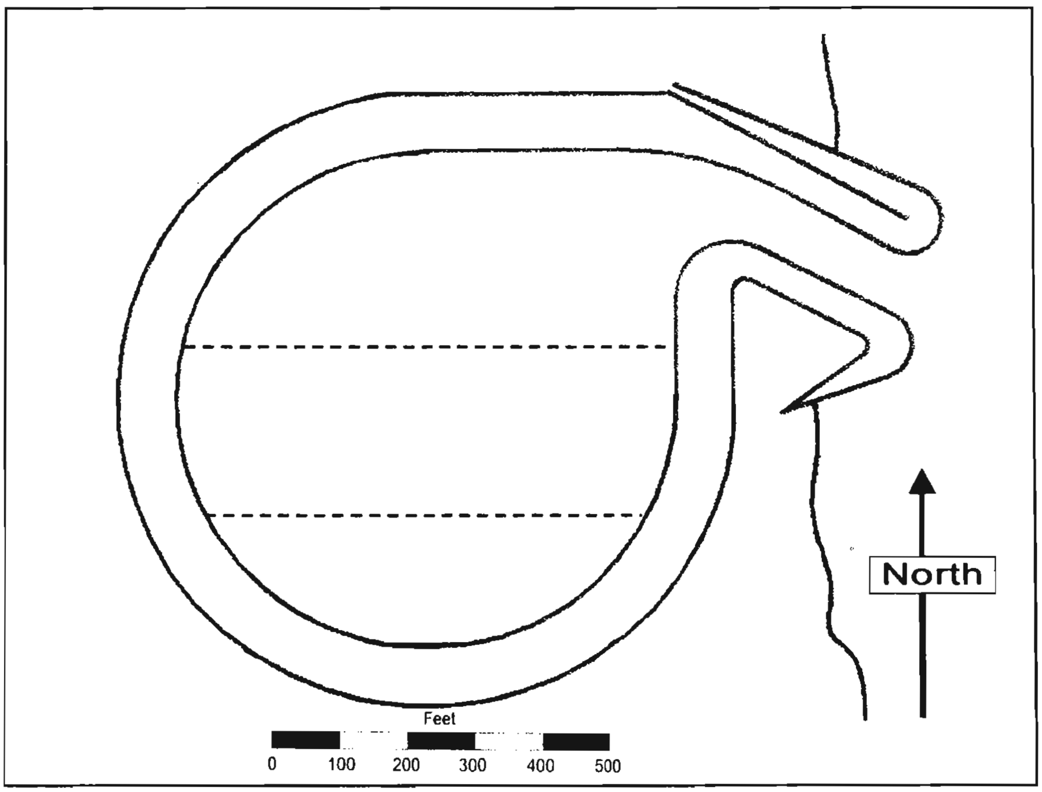

Figure 7. Rectangular configuration with the modified entrance.

entrance; it also showed that the circular basin was somewhat better than the rectangular basin. The difference has not substantial. So the most likely reason the rectangular basin performed nearly as well as the circular shape is due to the lack of sufficient momentum to take full advantage of the circular shape.

Clearly, the initial modification involving changing the width of the inner entrance did generate a marked increase in amount of mixing and exchange within the basin in comparison to the original design. It is also suspected that this alteration will further reduce wave heights in the basin as described in the subsequent section.

While additional designs did generate some efficient mixing, the difference was subtler than between the first two options investigated.

3.0 BASIN WAVE ANALYSIS

Another concern for the designers and the Corps of Engineers was whether the preferred entrance would permit waves higher than allowable for prudent boat basin design. The Corps has often limited these to a significant height of 1 foot or less for the given 50-year design wave. In the present harbor, the anticipated fleet is to be composed of vessels

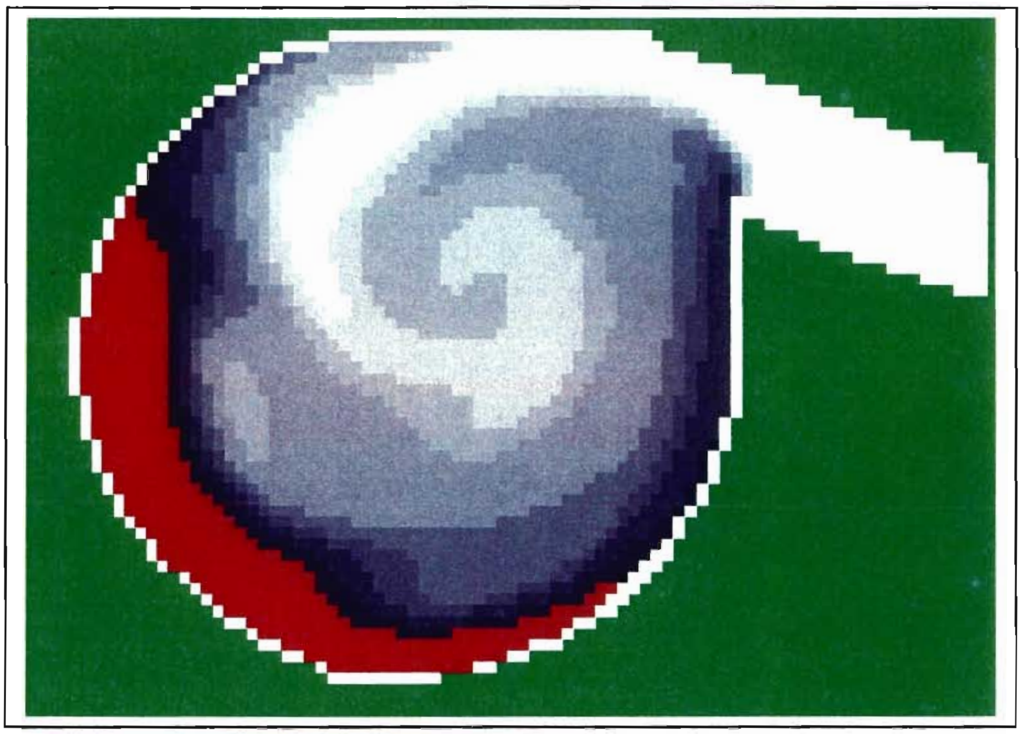

Figure 8. Shows the distribution of exchange coefficient in the circular basin with the narrow inner entrance. White indicates well-mixed areas while the red signifies poorly mixed areas.

whose length will be longer than 100 feet. Therefore this height restriction seems somewhat severe. The design significant wave height at the entrance to the basin has been determined to be 3.1 feet.

The wave program REFDIF (version 2.5) was used to investigate the transformation of the design wave as it enters the basin. REFDIF solves the refraction and the nonlinear

diffraction processes in a unified way. Figure 9 presents the general contours of the wave height in the entrance and inside the basin for the given design wave.

The program indicates that wave heights are well attenuated in the basin entrance and only a small region of the basin will see waves over 0.4 feet high. No waves exceeding 1.0-foot high propagate into the basin.

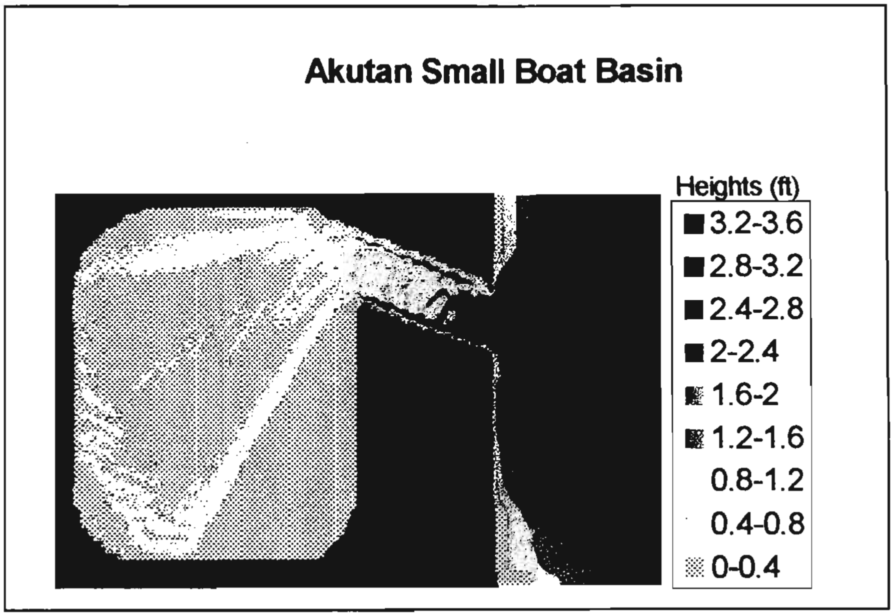

Figure 9. Wave heights in small boat basin. Most of the heights in the are less than 0.4 feet high. Waves a foot high only exist in the entrance channel.

A note on fluid velocities

The equations used to obtain the fluid velocities are referred to by different names, but they are forms of the Navier-Stokes momentum equations. These describe, by way of Newton's second law of motion, the process whereby external (surface and body) forces alter the fluid's momentum (mass * velocity). Besides the forces provided by the more obvious head differences, they are also applied as surface forces such as drag (friction) along the bottom and sides and on the top of the fluid as wind stress. Other forces that are integral parts of the N-S equations include the differences in density between adjacent water particles, the coupling (or friction) between adjacent particles moving past one another and Coriolis forces. These are treated mathematically several different ways. While these forces are probably the most important for describing nearshore circulation, there are more and this is merely a simplified description.

The velocities obtained by solving these equations are then used in another set of equations (the convection-diffusion equations) to predict the distribution of substances in the water. This is where the mixing or the changes in concentration as functions of time and space are determined. Then these results can in turn be used to obtain the exchange coefficients or other mixing efficiency measures.

The convection-diffusion equation equations (just as the actual process) operates with whatever velocities are provided to them. It doesn't matter whether they are the result of tides, winds, or density differences. Often only tides (plus some type of friction) are used to drive the flow because it is either the most dominant force or the only one that is continuous, or both. But when winds are reasonably constant and of sufficient magnitude, then a case can definitely be made that they should be used in the mixing process. That's all we did for the Akutan boat basin mixing situation.

APPENDIX E
REAL ESTATE PLAN
NAVIGATION IMPROVEMENTS
AKUTAN, ALASKA

REAL ESTATE PLAN
AKUTAN HARBOR PROJECT
AKUTAN, ALASKA
28 January 2004

Purpose of Report: The final Feasibility Report for this project is scheduled for completion in late 2004. A Feasibility Study, Phase I Preliminary Site Assessment Report was completed in July 1998, and the Reconnaissance Report was completed in August 1997. The proposed Akutan Harbor project will be located approximately 1.5 miles west of the City of Akutan, within Township 70 South, Range 112 West, Seward Meridian, Alaska. This report identifies and describes the Lands, Easements and Rights of Way (LER) required for construction, and operation and maintenance of the Reconfigured 12-Acre Alternative Harbor Project for 58 vessels. Federal General Navigation Features (GNF) include the following: an entrance channel; two (2) rubblemound breakwaters; a turning basin; an excavated and dredge material disposal, construction and staging area; and a mitigation area for creek rerouting and removal of a fish barrier. The local sponsor is the Aleutians East Borough, and their Local Service Facilities (LSF) include: a mooring basin; an excavated material and dredge disposal area; one (1) acre within the Federal GNF material disposal area that will be designated for a Harbormaster Building and essential port facilities; and an additional mitigation area only.

Project Summary: The project site is located mid way along the Aleutian chain, on the western end of Akutan Harbor off the Bering Sea. The harbor will be constructed on an old glacier bed adjacent to the shore, which is flanked by mountains, and is considered to be the only suitable site within the Harbor. Project excavation and dredging will begin at the mooring and turning basins and move outward, with the excavated and dredged material deposited in designated disposal areas to the south and southwest side of the harbor. An existing creek that runs in an eastwardly direction from the northwest into the proposed harbor will be rerouted to the north of the harbor and reconnected with the original creek above the harbor. Additionally, a project access road will be constructed from the north side of the harbor around the western side to tie in with the dredge disposal, construction and staging area. Mitigation required for the loss of habitat due to project construction includes a 100± foot buffer area with several streamlets on both sides of North and Rust Creeks. For planning and costs estimating purposes, fee simple acquisition of mitigation lands has been assumed in this Real Estate Plan and Feasibility Report, although the final decisions on the nature and extent of the required real estate interest may change after project authorization. Total mitigation costs for the Federal GNF and LSF lands for the Feasibility Report are shown below the Real Estate Cost Estimate Table, with a proportional split of 35 percent of the costs attributed to the GNF, and the remaining 65 percent to the LSF.

Current Land Ownership: The Akutan and Aleut Native Corporations, own the surface and subsurface estates respectively, which is a majority of the uplands required for the harbor project. Lands within U.S. Survey 766 are owned by the City of Akutan. The Government's dominant rights of Navigation Servitude will be exercised for tidelands below the Mean High Water (MHW) Line. A map depicting the real estate required for the Akutan Harbor Project is shown as Exhibit A, and the legend is described in Exhibit A-1.

Summary of Required Real Estate Interests:

	ACRES	OWNERS	INTEREST
FEDERAL GENERAL NAVIGATION FEATURES			
Entrance Channel and Breakwaters BMHW*	3.48	State of Alaska	Navigation Servitude
Entrance Channel AMHW**	0.48	City of Akutan	Fee
Breakwaters AMHW	1.44	City of Akutan	Perpetual Easement
Turning Basin AMHW	8.20	Akutan and Aleut Corporations	Fee
Excavated & Dredge Material Disposal, Construction & Staging Area AMHW ***	7.00	Akutan and Aleut Corporations	Three (3) Year Temporary Easement
Rust Creek Rerouting Mitigation Area AMHW	9.98	Akutan and Aleut Corporations	Fee
LOCAL SERVICE FACILITIES			
Mooring Basin AMHW	12.72	Akutan and Aleut Corporations	Fee
Excavated & Dredge Material Disposal Area AMHW ***	20.50	Akutan and Aleut Corporations	Three (3) Year Temporary Easement
Access Road AMHW	1.02 0.07	Akutan and Aleut Corporations and City of Akutan	Perpetual Easement
Harbormaster Building Area within the GNF Excavated & Dredge Material Disposal, Construction & Staging Area AMHW	1.00	Akutan and Aleut Corporations	Fee
Mitigation Area Only AMHW	28.71 2.00	Akutan and Aleut Corporations and City of Akutan	Fee
Project Boundary	98.57	N/A	N/A

* Below Mean High Water ** Above Mean High Water

*** The Local Sponsor plans to acquire additional easements for the use of these areas for storage of excavated and dredged material from the project that will be used throughout the Aleutians East Borough.

Non-Standard Estates: It has been recommended by State and Federal Fish and Wildlife Agencies, but not yet determined, that the local sponsor obtain a Conservation Easement in perpetuity from the Akutan and Aleut Corporations and the City of Akutan for the mitigation lands. The intent of the Conservation Easement would be to protect the natural integrity of the creeks and their contiguous wetlands for fish and wildlife habitat; personal or subsistence harvests of fish, wildlife, and plant resources could continue, but no development or commercial use of any kind would be allowed.

Federally Owned Lands Within the Project Boundary: There are no identified federally owned lands within the project area that have been discovered.

Potential Flooding Induced by Construction, Operation or Maintenance of the Project: No flooding is predicted due to construction, operation or maintenance of the project.

Baseline Cost Estimate for Real Estate: The real estate costs are based on a gross appraisal performed by the staff appraiser on 14 January 2002, and a supplemental update completed on 27 January 2004. Should another gross appraisal be prepared, the values provided herein could substantially change. Administrative costs are for mapping, title work, surveying, appraisal and the final crediting process. A 20 percent contingency for value changes over time has been included in the land costs.

Federal General Navigation Features (GNF)				
Item	**Federal**	**Local**	**Subtotal**	
Administration	20,000	$15,000	$35,000	
Real Estate Land Costs		$78,500	$78,500	
Relocation		$0	$0	
Local Service Facilities (LSF)				
Item	**Federal**	**Local**	**Subtotal**	
Administration	$10,000	$20,000	$30,000	
Real Estate Land Costs		$171,500	$171,500	
Removals		$0	$0	
Total Cost				**$315,000**

The total mitigation land costs for the Feasibility Report are $83,000.00, with 35 percent/$29,050.00 attributed to the Federal GNF, and the remaining 65 percent/$53,950.00 attributed to the LSF.

Relocation Assistance Benefits: No persons or businesses will be displaced by this project. Therefore, no relocation assistance benefits under Public Law 91-646 will be required.

Mineral Activity: No known mineral activity has occurred within the project area, nor is any anticipated.

Non-Federal Sponsor's Legal and Professional Capability and Experience To Acquire and Provide LER: The Aleutians East Borough has full eminent domain authority for public purposes. An Assessment of the sponsor's Real Estate Acquisition Capability is shown as Exhibit B.

Application or Enactment of Zoning Ordinances: No enactments or applications for zoning have been located that affect the project area.

Schedule of All Land Acquisitions:

	Corps of Engineers		Local Sponsor	
Activity	**Initiate**	**Complete**	**Initiate**	**Complete**
Receipt of final Drawings from Engineering/Project Manager		May-07		
Execution of PCA		Feb-07		
Formal Transmittal of final Real Estate maps to LS with notification to acquire LER	Feb-07	Mar-07		
Mapping, legal descriptions, title evidence			Feb-07	Mar-07
Conduct appraisals, negotiations & closing			Mar-07	May-07
Certify that all necessary LER is available for project construction	May-07	May-07		
Submit credit requests			May-07	Sep-07
Review & approve or deny credit requests	Jun-07	Oct-07		

Relocations of Facilities, Roads, and Utilities: There are no utilities, roads, or facilities that will need to be relocated due to this project.

Impact on Real Estate Acquisition Due to Suspected or Known Contaminants: No contaminants have been found that will adversely effect real estate acquisition.

Known or Anticipated Support of Opposition to the Project: The City of Akutan, and the Borough support construction of the harbor, and no known opposition has been expressed by area residents, or is anticipated.

Non-Federal Sponsor's Notification of Acquisition Risks Prior to Signing of the Project Cooperation Agreement (PCA): The schedule above may be shortened if the sponsor begins acquisition (at its own risk) prior to signing of the PCA. The sponsor was notified of the risk of early acquisition in January 2002.

The original Real Estate Plan was prepared by Ann P. Hardinge, Real Estate Appraiser in August 2002, and revised by Karen L. Pontius, Realty Specialist, in January 2004.

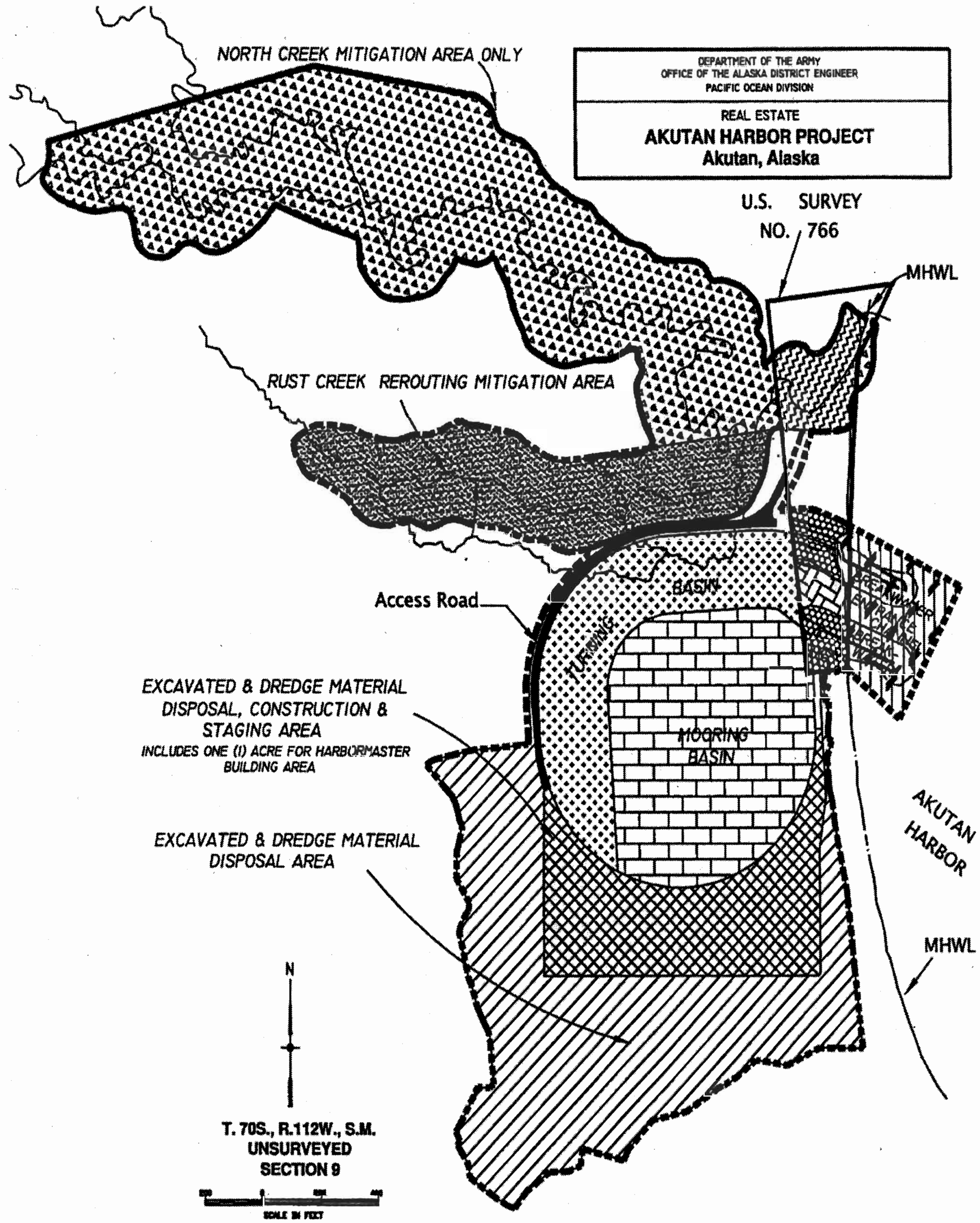
DEPARTMENT OF THE ARMY
OFFICE OF THE ALASKA DISTRICT ENGINEER
PACIFIC OCEAN DIVISION
REAL ESTATE
AKUTAN HARBOR PROJECT
Akutan, Alaska
NORTH CREEK MITIGATION AREA ONLY
U.S. SURVEY
NO. 766
MHWL
RUST CREEK REROUTING MITIGATION AREA
Access Road
TURNING BASIN
MOORING BASIN
EXCAVATED & DREDGE MATERIAL
DISPOSAL, CONSTRUCTION &
STAGING AREA
INCLUDES ONE (I) ACRE FOR HARBORMASTER
BUILDING AREA
EXCAVATED & DREDGE MATERIAL
DISPOSAL AREA
AKUTAN
HARBOR
MHWL
N
T. 70S., R.112W., S.M.
UNSURVEYED
SECTION 9
SCALE IN FEET

EXHIBIT A

AKUTAN HARBOR PROJECT

GENERAL NAVIGATION FEATURES (GNF)

Entrance Channel = 0.48 ± Acre

Breakwaters = 1.44 ± Acres

Turning Basin = 8.20 ± Acres

Excavated & Dredge Disposal, Construction & Staging Area = 8.00 ± Acres Includes one (1) Acre Area, to be determined for Harbormaster Building Area

Mitigation Area for Creek Rerouting = 9.98 ± Acres

Navigation Servitude = 3.48 ± Acres

Project Boundary = 98.57 ± Acres

LOCAL SERVICE FACILITIES (LSF)

Mooring Basin = 12.72 ± Acres

Excavated & Dredge Disposal Area = 20.5 ± Acres

Access Road = 1.02 ± Acres

Access Road = 0.07 ± Acres

Mitigation Area Only = 28.71 ± Acres

Mitigation Area Only = 2.00 ± Acres

EXHIBIT A - 1

ASSESMENT OF NON-FEDERAL SPONSOR'S REAL ESTATE ACQUISITION CAPABILITY

AKUTAN HARBOR: AKUTAN

I. Legal Authority:

a. Does the sponsor have legal authority to acquire and hold title to real property for project purposes? Yes,

b. Does the sponsor have the power of eminent domain for this project? Yes, ~~with voter approval~~

c. Does the sponsor have a "quick-take" authority for this project? ~~N/A~~ Yes

d. Are any of the lands/interests in land required for the project located outside the sponsor's political boundary? No

e. Are any of the lands/interests in land required for the project owned by an entity whose property the sponsor cannot condemn? No

II. Human Resource Requirements:

a. Will the sponsor's in-house staff require training to become familiar with the real estate requirements of Federal projects including P.L. 91-646, as amended? No

b. If the answer to II a is yes, has a reasonable plan been developed to provide such training? N/A_

c. Does the sponsor's in-house staff have sufficient real estate acquisition experience to meet its responsibilities for the project? Yes

d. Is the sponsor's projected in-house staffing level sufficient considering its other work load if any, and the project schedule? Yes

e. Can the sponsor obtain contractor support, if required, in a timely fashion? Yes

f. Will the sponsor likely request USACE assistance in acquiring real estate? No

EXHIBIT B

III. Other Project Variables:

a. Will the sponsor's staff be located within reasonable proximity to the project site? Yes

b. Has the sponsor approved the project/real estate schedule/milestones? Yes_

IV. Overall Assessment:

a. Has the sponsor performed satisfactorily on other USACE projects? Yes

b. With regard to this project, the sponsor is anticipated to be: higbly capable/ Fullycapable

V. Coordination:

a. Has this assessment been coordinated with the sponsor? Yes

b. Does the sponsor concur with this assessment? Yes

SOURCE:

Bob Juettner
Borough Administrator
Aleutians East Borough
907/274-7555
Date: 1/16/02

Prepared By:

Name: Ann P. Hardinge
Title: RE Appraiser
Date: 17 Jun 2002

Reviewed and approved by:

Harold D. Hopson
Acting Chief, Real Estate Division

APPENDIX F
CORRESPONDENCE
NAVIGATION IMPROVEMENTS
AKUTAN, ALASKA

ALEUTIANS EAST BOROUGH

SERVING THE COMMUNITIES OF
■ KING COVE ■ SAND POINT ■ AKUTAN ■ COLD BAY ■ FALSE PASS ■ NELSON LAGOON

May 2, 2002

Colonel Steven Perrenot
District Engineer
Alaska District
Army Corps of Engineers
PO Box 6898
Anchorage, AK 99506-6898

Dear Col. Perrenot,

The Aleutians East Borough is the local sponsor of the Akutan Boat Harbor Project. As such, it is responsible for the non-federal portion of any project authorized and constructed by US Army Corps of Engineers as a result of Congressional action. The Aleutians East Borough recognizes that it responsible for the payment of 20% of the General Navigation Features and 100% of the Local Service Facilities.

The financial components of the project can be summarized as follows:

	Total Project	Federal Share	Local Share
GNF	$ 10,567,000	$ 9,510,000	$ 1,057,000
LERR, GNF	$ 226,000		$ 226,000
Addition Funding		$ (831,000)	$ 831,000
Subtotal GNF	$ 10,793,000	$ 8,679,000	$ 2,114,000
Aids to Navigation	$ 15,000	$ 15,000	$ -
Local Service Fac.	$ 5,095,000	$ -	$ 5,095,000
Lands	$ 968,000	$ -	$ 968,000
Subtotal LSF	$ 6,063,000	$ -	$ 6,063,000
Final Cost	$ 16,871,000	$ 8,694,000	$ 8,177,000

The Aleutians East Borough will meet its financial commitment of $8,177,000 by utilizing both GO Bonds and revenue bonds, a cash donation and in kind contributions of land as follows:

❐ CLERK/PLANNER
P.O. BOX 349
SAND POINT, AK 99661
(907) 383-2699
(907) 383-3496 FAX
e-mail: AEBCLERK@aol.com

❐ BOROUGH ADMINISTRATOR
1600 "A" STREET, SUITE 103
ANCHORAGE, AK 99501-5146
(907) 274-7555
(907) 276-7569 FAX
e-mail: aeboro@gci.net

❐ FINANCE DIRECTOR
P.O. BOX 49
KING COVE, ALASKA 99612
(907) 497-2588
(907) 497-2386 FAX

❐ RESOURCE DEPARTMENT
211 4TH STREET, SUITE 314
JUNEAU, AK 99801
(907) 586-6655
(907) 586-6644 FAX
e-mail: beth@ptialaska.net

Contributor		GO Bonds	Revenue Bonds	Lands for LSF	Cash Grant
Aleutians East Borough		$ 5,000,000	$1,123,000		
City of Akutan				$1,204,000	
APICDA					$850,000
TOTAL	$8,177,000	$ 5,000,000	$1,123,000	$1,204,000	$850,000

GO Bonds: The Aleutians East Borough has issued GO Bonds for a number of capital improvement projects including school construction, docks, airports and boat harbors. It issues the bonds through the Alaska Municipal Bond Bank Authority. The financial strength of the Aleutians East Borough and the Alaska Municipal Bond Bank Authority results in the issuance of bonds at a very favorable interest rate. The Aleutians East Borough's ability is further enhanced by the fact that it has retired several bonds issued in the late 1980s and early 1990s. The Aleutians East Borough currently holds $1M in GO Bond authorization for this project. The State of Alaska is on the verge of approving a bond debt reimbursement program that will contain $4M of reimbursable bond debt authority for the Akutan Boat Harbor Project. While it is a departure from the dollar for dollar match that the State of Alaska provided on the King Cove Boat Harbor and the Sand Point Boat Harbor, this program is consistent with other shared debt programs administered by the State of Alaska.

Revenue Bonds: Unlike GO Bonds that are tied to tax receipts, revenue bonds must be paid from the receipt of fees. Given the size of the vessels and the number of vessels to be moored in Akutan, the harbor will generate sufficient fees to retire this debt.

Lands for LSF: The City of Akutan and the Akutan Village Corporation are engaged in discussion on this issue. Under section 14C3 of the Alaska Native Claims Settlement Act, the municipality within a native village may claim and receive up to 1,280 acres of land for community related projects. The Akutan Village Corporation supports this project for the economic development benefits it will bring to the community and its shareholders. Therefore, it has agreed to make the land available to the City of Akutan for this project. In turn, the City of Akutan has agreed to give the necessary rights to the land to the Aleutians East Borough for the project.

Cash Grant: The Aleutian Pribolof Islands Community Development Association has agreed to contribute $850,000 in cash on the behalf of its members in the village of Akutan. The Aleutian Pribolof Islands Community Development Association is a federally created economic development organization that receives a percentage of the allowable harvest of fish and crab in the Bering Sea. It uses the profits from its allocation to support economic development activities for its six member communities. The

Aleutians East Borough and the Aleutian Pribolof Islands Community Development Association have cooperated to jointly fund projects in Akutan, False Pass and Nelson Lagoon.

If you have any question or require further documentation, please contact me.

Sincerely,

Robert S. Juettner
Administrator

APPENDIX G
COST ESTIMATES
NAVIGATION IMPROVEMENTS
AKUTAN, ALASKA

Akutan Alternatives For use in Table 3 of FR

Unit prices are from the reconfigured 12 acre basin MCACES estimate

				12 acre basin		15 acre basin		20 acre basin		reconfig 12 acre basin	
item	Units	unit price	Contin	amount	total	units	total	units	total	units	total
Mob & Demob	LS	1,122,652	20%	1	1,347,000	1	1,347,000	1	1,347,000	1	1,347,000
Breakwater & Seawall											
Armor rock	CY	61.36	20%	15,000	1,104,000	15,000	1,104,000	15,000	1,104,000	15,000	1,104,000
B-rock	CY	49.06	20%	8,000	471,000	8,000	471,000	8,000	471,000	8,000	471,000
Core rock	CY	41.72	20%	45,000	2,253,000	45,000	2,253,000	45,000	2,253,000	45,000	2,253,000
Navigation Foundations	LS	24,281	20%	1	29,000	1	29,000	1	29,000	1	29,000
Total BW&SW					**3,857,000**		**3,857,000**		**3,857,000**		**3,857,000**
Dredging											
Entrance/Maneuv Chan											
Slope protection	CY	79.01	20%	9,700	920,000	9,700	920,000	10,700	1,014,000	9,700	920,000
Entrance Channel Dredge	CY	6.43	10%	180,000	1,273,000	180,000	1,273,000	180,000	1,273,000	82,000	580,000
Maneuvering Channel Dredge	CY	6.43	10%	300,000	2,122,000	337,000	2,384,000	366,000	2,589,000	280,000	1,980,000
Temporary Dewater basin	LS	76,842	10%	1	85,000	1	85,000	1	85,000	1	85,000
Hydrographic Survey	EA	14,568	20%	2	35,000	2	35,000	2	35,000	2	35,000
Silt Barrier	LS	145,683	20%	1	175,000	1	175,000	1	175,000	1	175,000
Water Analysis	LS	40,000	20%	1	48,000	1	48,000	1	48,000	1	48,000
subtotal E/M chan					**4,658,000**		**4,920,000**		**5,219,000**		**3,823,000**
Mooring Basin											
Slope protection	CY	83.93	20%	7,500	755,000	8,800	886,000	11,300	1,138,000	10,000	1,007,000
Mooring basin	CY	6.49	10%	370,000	2,641,000	473,000	3,377,000	629,000	4,490,000	481,000	3,434,000
subtotal Mooring Basin					**3,396,000**		**4,263,000**		**5,628,000**		**4,441,000**
Total Dredging	CY				**8,054,000**		**9,183,000**		**10,847,000**		**8,264,000**
Dock Facilities	LS	2,063,848	20%	1	2,477,000	1.26	3,121,000	1.58	3,913,000	1	2,477,000
Uplands Requirements											
Access Spur Road	LS	82,352	20%	1	99,000	1	99,000	1	99,000	1	99,000
Uplands Gravel Surface	LS	254,450	20%	1	305,000	1.26	385,000	1.58	482,000	1	305,000
Total Uplands Requirements					**404,000**		**484,000**		**581,000**		**404,000**
Rust Creek Relocation	LS	267,086	20%	1	321,000	1	321,000	1	321,000	1	321,000
Construction total					16,460,000		18,313,000		20,866,000		16,670,000

Boat Harbor - Akutan, AK
Reconfigures(12) Acre Inland
Basin

Designed By: Tryck Nyman Hayes, Inc.
Estimated By: Tryck Nyman Hayes, Inc.& USACE

Prepared By: Mike Field (TNH) and Clarke
Hemphill (USACE)

Preparation Date: 04/01/04
Effective Date of Pricing: 10/01/03

Sales Tax: 0.0%

Currency in DOLLARS

LABOR ID: 01ANCC EQUIP ID: 01ALAS CREW ID: 01ANCC

This estimate is based on quantities provided by Tryck Nyman Hayes, Inc. engineers for the reconfigured (12) size basin.

This is an estimate of probable construction cost only and actual bids will vary from this estimate. The estimate excludes bid preparation documents, administrative costs, fittings and equipment, except that specifically stated in the estimate.

Prices are based on current Davis Bacon labor rates and current prices for materials, freight and equipment. The estimate is based on the assumption that the project will receive competitive bids from general contractors who will also get subcontractors and suppliers competitive bid.

Schedule Assumptions: Construction will start March 2006, and work completed December 2007.

This estimate assumes normal escalation based on the current economic climate in Alaska. It is assumed that materials for filling and rock will be brought in by barge from Dutch Harbor.

	QUANTITY UOM	CONTRACT	ESCALATN	DGN&ENG	CONTINGN	S&A	TOTAL COST	UNIT COST
01 BASE BID								
01.01 Breakwater								
01.01.01 Material and Placement								
01.01.01.01 Armor Rock	15000.00 CY	920,471	0	0	0	0	920,471	61.36
01.01.01.02 B-Rock	8000.00 CY	392,512	0	0	0	0	392,512	49.06
01.01.01.07 Core Rock	45000.00 CY	1,877,513	0	0	0	0	1,877,513	41.72
TOTAL Material and Placement	1.00 EA	3,190,495	0	0	0	0	3,190,495	3190495
01.01.03 Navigation Foundations	1.00 EA	24,281	0	0	0	0	24,281	24280.57
TOTAL Breakwater		3,214,776	0	0	0	0	3,214,776	
01.02 Entrance & Maneuvering Channel								
01.02.01 Slope Protection	9700.00 CY	766,412	0	0	0	0	766,412	79.01
TOTAL Slope Protection	9700.00 CY	766,412	0	0	0	0	766,412	79.01
01.02.02 Dredging								
01.02.02.01 Entrance Channel	82000.00 CY	527,019	0	0	0	0	527,019	6.43
01.02.02.02 Maneuvering Channel	280000.00 CY	1,799,579	0	0	0	0	1,799,579	6.43
01.02.02.03 Temporary Dewatering Basin	1.00 EA	76,842	0	0	0	0	76,842	76841.93
01.02.02.04 Hydrographic Survey	2.00 EA	29,137	0	0	0	0	29,137	14568.34
01.02.02.05 Silt Barrier	1.00 EA	145,683	0	0	0	0	145,683	145683.42
01.02.02.06 Water Analysis	1.00 EA	40,000	0	0	0	0	40,000	40000.00
TOTAL Dredging	362000.00 CY	2,618,260	0	0	0	0	2,618,260	7.23
TOTAL Entrance & Maneuvering Channel		3,384,672	0	0	0	0	3,384,672	
01.03 Mooring Basin								
01.03.01 Slope Protection	10000.00 CY	839,263	0	0	0	0	839,263	83.93
01.03.02 Dredging	481000.00 CY	3,120,560	0	0	0	0	3,120,560	6.49
TOTAL Mooring Basin		3,959,822	0	0	0	0	3,959,822	
01.04 Local Harbor Facilities								
01.04.01 Float System	1.00 EA	2,063,848	0	0	0	0	2,063,848	2063848
01.04.02 Access Spur Road	1.00 EA	82,352	0	0	0	0	82,352	82351.62

	QUANTITY	UOM	CONTRACT	ESCALATN	DGN&ENG	CONTINGN	S&A	TOTAL COST	UNIT COST
01.04.03 Uplands Gravel Surface	1.00	EA	254,450	0	0	0	0	254,450	254450.01
TOTAL Local Harbor Facilities			2,400,650	0	0	0	0	2,400,650	
01.05 Mob and Demob									
01.05.01 Mobilization	1.00	EA	837,073	0	0	0	0	837,073	837072.65
01.05.02 Demobilization	1.00	EA	285,709	0	0	0	0	285,709	285709.47
TOTAL Mob and Demob			1,122,782	0	0	0	0	1,122,782	
01.06 Rust Creek Relocation									
01.06.07 Redirect Existing Drainage	1.00	EA	267,086	0	0	0	0	267,086	267086.27
TOTAL Rust Creek Relocation			267,086	0	0	0	0	267,086	
TOTAL BASE BID	1.00	EA	14,349,788	0	0	0	0	14,349,788	14349788
TOTAL Boat Harbor - Akutan, AK	1.00	EA	14,349,788	0	0	0	0	14,349,788	14349788