PEBBLE PROJECT
ENVIRONMENTAL BASELINE DOCUMENT
2004 through 2008

CHAPTER 30.
GEOTECHNICAL STUDIES, SEISMICITY, AND VOLCANISM
Cook Inlet Drainages

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ACRONYMS AND ABBREVIATIONS

M	magnitude of earthquake
SPT	standard penetration test
USACE	U.S. Army Corps of Engineers

30. GEOTECHNICAL STUDIES, SEISMICITY, AND VOLCANISM

30.1 Introduction

This chapter discusses the baseline geotechnical and volcanism characteristics of the Cook Inlet drainages study area. A regional overview of seismicity in southern Alaska, including Cook Inlet, is presented in Chapter 6 and is not repeated in this chapter.

The discussion of geotechnical conditions in the Cook Inlet drainages geotechnical study area is based on a review of published information, which includes a previous offshore site investigation program conducted near Williamsport by the U.S. Army Corps of Engineers (USACE) in 1995.

30.2 Study Objectives

The objective of the geotechnical, seismic, and volcanism study was to provide baseline geotechnical, seismic, and volcanism information to characterize the study area.

30.3 Study Area

The Cook Inlet drainages study area is defined by the drainage boundaries of Iliamna and Iniskin Bays, two fjords with a common mouth on the west side of Cook Inlet. The study area boundary is shown on Figure 30-1.

30.4 Scope of Work

This environmental baseline document presents baseline information collected from 2004 through 2008. However, no geotechnical site investigations were completed in the study area during this period; therefore, the information in this chapter is limited to desktop studies and reviews of published information. Details on the regional volcanism were provided by Pentec Environmental.

30.5 Methods

The methods used in this chapter consisted of reviews of previously published data. The information presented in this chapter is based on a review of the following:

- *Cook Inlet Seismicity and Volcanism—Literature Synthesis* (Pentec Environmental, 2006).
- *Dredge Slopes in Iliamna Bay near Williamsport, Alaska* (Golder Associates Inc., 1995).
- *Navigation Channel Feasibility Report and Environmental Assessment, Williamsport, Alaska* (USACE, 1995).

30.6 Results and Discussion

30.6.1 Geotechnical Conditions

The discussion on the geotechnical conditions of the study area is limited to the estuarine deposits in northern Iliamna Bay, in the vicinity of Williamsport.

A preliminary evaluation of the geotechnical conditions for a dredged channel in the estuarine deposits in northern Iliamna Bay was based on a review of the USACE report, *Navigation Channel Feasibility Report and Environmental Assessment* (USACE, 1995). The USACE drilled five drillholes in the northwest arm of Iliamna Bay. The drillholes ranged from 11 to 23 feet deep and were drilled using a hollow stem auger. The locations of the drillholes are shown on Figure 30-2. The existing dock at Williamsport is located at drillhole AP-1. The USACE also collected geophysical measurements near Williamsport and in Iliamna Bay. The seismic refraction survey data indicate that there are approximately 100 to 130 feet of unconsolidated sediments in Iliamna Bay within approximately 3,000 feet of the existing dock at Williamsport.

The tidal flats in northern Iliamna Bay consist primarily of clays, silts, and fine sands, and are dark brown to black in color, indicating the presence of organic matter. These tidal deposits also contain angular gravel and occasional cobbles and boulders. The existing tidelands have scattered large boulders protruding from the tidal flats. A gravelly subgrade is exposed along the natural tidal drainage channels. The gravel content of the sediments is higher closer to the existing dock structure at Williamsport. The soils range from nonplastic to plastic (with liquid limits and plasticity indices to about 50 and 20, respectively). Moisture contents range from about 20 to 50 percent.

An estimate of the *in situ* soil density and index properties was obtained using standard penetration tests (SPTs). This process involves driving a split-spoon sampler into the soil at the base of the drillhole using a hammer of standard energy. The SPT “N” value is the number of blows required to advance the sampler from 6 to 18 inches. The SPT “N” value ranged from two to 10 in the upper 10 feet of the deposits in the tidal flat area and up to 30 below a depth of 10 feet. The SPT “N” values ranged from 24 to 48 in the area of the existing dock at Williamsport; however, a loose sand zone (blow count less than 10) was encountered at a depth of about 15 feet in this area. Details of the site investigation in Iliamna Bay near Williamsport can be found in the USACE 1995 report.

The data indicate that the existing marine and glaciofluvial sediments include localized zones with low blow counts and are potentially subject to liquefaction during seismic events.

30.6.2 Regional Seismicity and Faulting

Alaska is the most seismically active state in the United States, with the level of seismic activity being highest along the south coast, where earthquakes are generated by the Pacific plate subducting under the North American plate. A regional overview of seismicity in southern Alaska, including Cook Inlet, is presented in Chapter 6 and is not repeated in this chapter.

30.6.3 Regional Volcanism

Four active volcanoes along the west shore of Cook Inlet are associated with the convergence of the North American and Pacific plates: Mt. Spurr, Mt. Redoubt, Mt. Iliamna, and Augustine Volcano (also called Mt. Augustine or Mt. St. Augustine). These four Quaternary volcanoes are aligned in a relatively straight line, as shown on the inset on Figure 30-1, trending north-northeast to south-southwest. Mt. Iliamna and Augustine Volcano are the closest volcanoes to the Cook Inlet drainages study area. The Cook Inlet volcanoes represent the eastern limit of the 1,616-mile-long Aleutian volcanic arc formed by tectonic plate collision and subduction (Miller and Chouet, 1994). A view of Augustine Volcano is presented in Photo 30-1.

Lake cores indicate that volcanic eruptions occurred in the Cook Inlet area every 10 to 35 years during the 20th century, with Mt. Redoubt, Mt. Spurr, and Augustine Volcano being the most important sources of tephra (i.e., airborne volcanic debris; Begét et al., 1994). In contrast, the last confirmed eruption of Mt. Iliamna was in 1876. Begét and Kienle (1992) provided evidence that the summit edifice of Augustine Volcano has repeatedly collapsed and regenerated every 150 to 200 years over the last 2,000 years because of sustained lava effusion rates 10 times those normally seen in plate-margin volcanoes.

The major effects of volcanoes include the burial of old substrate by lava, debris, or ash and creation of new substrate; rapid release of meltwater; corrosive rains; noxious gas and dust clouds; and tsunamis (Peterson, 1979). The 1883 eruption of Augustine Volcano produced a debris avalanche that covered at least 8 square miles on the north side of the mountain and extended the coastline by more than 1.2 miles. The avalanche created a tsunami that registered 33 feet in height more than 62 miles from the volcano. Given its history of eruption, Augustine Volcano is likely to repeat this behavior at any time and it entered a new active phase in January 2006. Collapse of the summit could be brought on by earthquakes (Begét and Kienle, 1992). The hazard from a tsunami generated by the eruption of Augustine Volcano is considered to be minor, unless a very large debris avalanche occurred at high tide (Waythomas, 2000) as occurred in 1883. A tsunami could also occur as a result of an earthquake in the area or elsewhere around the Pacific Rim.

30.7 Summary

The Cook Inlet drainages study area is defined by the drainage boundaries of Iliamna and Iniskin Bays, two fjords with a common mouth on the west side of Cook Inlet. The information discussed in this chapter was obtained by reviews of previously published data, as no geotechnical, seismic, or volcanism baseline data were collected for the study area during 2004 to 2008. The geotechnical conditions of the estuarine deposits in northern Iliamna Bay, in the vicinity of Williamsport, were investigated by USACE in 1995. USACE drilled five drillholes in the northwest arm of Iliamna Bay near Williamsport. The drillholes ranged from 11 to 23 feet deep and were completed in tidal flat unconsolidated materials. A seismic refraction survey completed by USACE indicated up to 130 feet of unconsolidated sediments in Iliamna Bay. The tidal flats were composed of clays, silts, fine sand, and organic matter. These deposits also contained varying amounts of angular gravel and occasional cobbles and boulders. Material properties indicated that these sediments may be subject to liquefaction during seismic events. Although Golder Associates Inc. (1995) conducted a study on dredged slopes in Iliamna Bay, soil parameters remain poorly defined and further investigation will be required to support future infrastructure studies for the Pebble Project.

Alaska is the most seismically active state in the United States, with the level of seismic activity being highest along the south coast, where earthquakes are generated by the Pacific plate subducting under the North American plate. A regional overview of seismicity in southern Alaska, including Cook Inlet, is presented in Chapter 6 and is not repeated in this chapter

There are four active volcanoes along the western shore of Cook Inlet, three of which have erupted during the 20th century. The major effects of erupting volcanoes include the burial of old substrate by lava, debris, or ash; rapid release of meltwater; corrosive rains; noxious gas and dust clouds; and tsunamis. The 1883 eruption of Augustine Volcano produced a debris avalanche that created a tsunami that registered 33 feet in height more than 62 miles from the volcano. However, the tsunami hazard generated by the eruption of Augustine Volcano is considered to be minor in the absence of a debris avalanche.

30.8 References

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30.9 Glossary

Crust—term applied to the thin outermost solid layer of the earth.

Debris avalanche—a mass movement that may include volcanic rock, water, snow, glacier ice, trees, and other pyroclastic materials moving down a slope.

Effusion rate—the rate at which lava is erupted.

Estuarine—relating to a semi-enclosed coastal body of water which has a free connection with the open sea and where fresh water, derived from land drainage, is mixed with sea water due to tidal action.

Fjord—A long, narrow, deep inlet of the sea between steep slopes. Geotechnical— of or pertaining to practical applications of geological science in civil engineering, mining, etc.

Glaciofluvial sediments—material transported and deposited by meltwater streams flowing from glaciers.

Hollow-stem auger—an auger used for drilling in sediments, the center of which is hollow and allows for sediment sampling and well installation without borehole collapse.

Holocene—epoch that covers the last 10,000 years, often referred to as Recent or post-glacial.

Liquefaction—the temporary transformation of material to a fluid state due to a sudden decrease in shearing resistance caused by a collapse of the structure associated with a temporary increase in pore fluid pressure.

Liquid limit—the moisture content at which a soil begins to behave as a liquid.

Lithosphere—the outermost layer of the solid earth, comprising all crustal rocks and the brittle part of the uppermost mantle.

Mantle—the zone lying between the earth's crust and core.

Plasticity index—the difference in percentage water content between the liquid limit and the plastic limit.

Plastic limit—the moisture content of a soil where it starts to exhibit plastic behavior.

Plate—a segment of the lithosphere with little volcanic or seismic activity that is bounded by continuous belts of earthquakes and volcanic activity.

Plate-margin—the boundary of one of the plates that form the lithosphere and together cover the surface of the earth.

Pore pressure—the pressure exerted on its surroundings by water present in the pore spaces in soil or rock.

Quaternary—a sub-era of the Cenozoic era that covers the past 1.64 million years and comprises the Pleistocene and Holocene epochs.

Seismicity—the frequency or magnitude of earthquake activity in a given area.

Seismic refraction—a geophysical survey method that uses the refraction of seismic waves on soil and rock units to characterize subsurface geologic conditions and structure.

Split-spoon sampler—a thick-walled tube used to collect a soil sample during a standard penetration test.

Standard penetration test—an in situ dynamic penetration test designed to provide data regarding soil properties.

Subduction—the action of a tectonic plate descending below another plate at a convergent margin.

Tephra—collective term applied to all pyroclastic particles or fragments ejected from a volcano, irrespective of size, shape, or composition. The term is usually applied to air-fall material, rather than pyroclastic flow deposits.

Tidal Flat—an intertidal sand flat, mud flat, and marsh area developed in some lagoons and mesotidal areas, and in protected bays and estuarine areas along macrotidal coasts.

Tsunami—a seismic sea wave of long period, produced by a submarine earthquake, underwater volcanic explosion, or massive gravity slide of sea bed sediment. These waves are barely noticeable in the open ocean even though they may be travelling up to 700 kilometers per hour, but on reaching shallow water they build up to heights of more than 30 meters and can cause severe damage in coastal areas.

Volcanic arc—a series of volcanoes that lie on the continental side of an oceanic trench of a lithospheric plate. The volcanoes result from subduction and occur typically 100 kilometers above the subducting oceanic plate. Volcanic arcs are the sites of strong seismic activity and have distinctive thermal and magnetic properties.

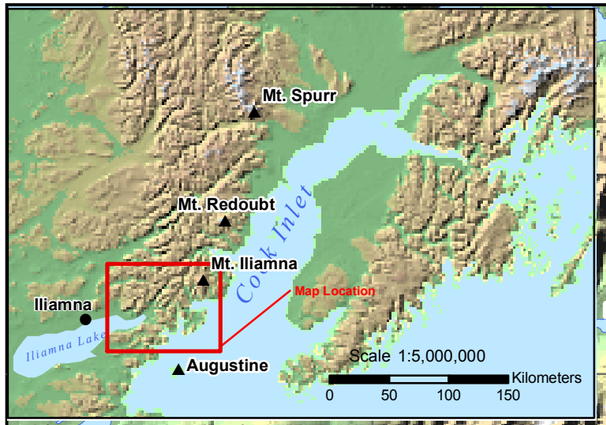
Volcanism—all the processes associated with the transfer of magma and volatiles from the interior of the earth to its surface.

FIGURES

1,600,000 1,700,000 1,800,000

2,200,000

2,100,000



Lake Clark National Park and Preserve

Lake Clark National Park and Preserve

Mt. Iliamna

Pedro Bay

Pile Bay

Williamsport

Iliamna Lake

Iniskin Bay

Iliamna Bay

Knoll Head

Oil Bay

Iniskin Peninsula

Cook Inlet

THE pebble PARTNERSHIP

Figure 30-1
Geotechnical, Seismicity, and Volcanism Study Area
Cook Inlet Drainages

Legend

- Study Area Boundary
- National Park and Preserve Boundary
- BB / CI Drainages Boundary
- Existing Roads
- Population Centers
- Volcano

Notes

1. BB/CI refers to Bristol Bay/Cook Inlet drainages.

0 3 6 9 12 Miles

0 3 6 9 12 15 18 Kilometers

Scale 1:300,000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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Version: 2008-1	Author: Knight Piesold Ltd.

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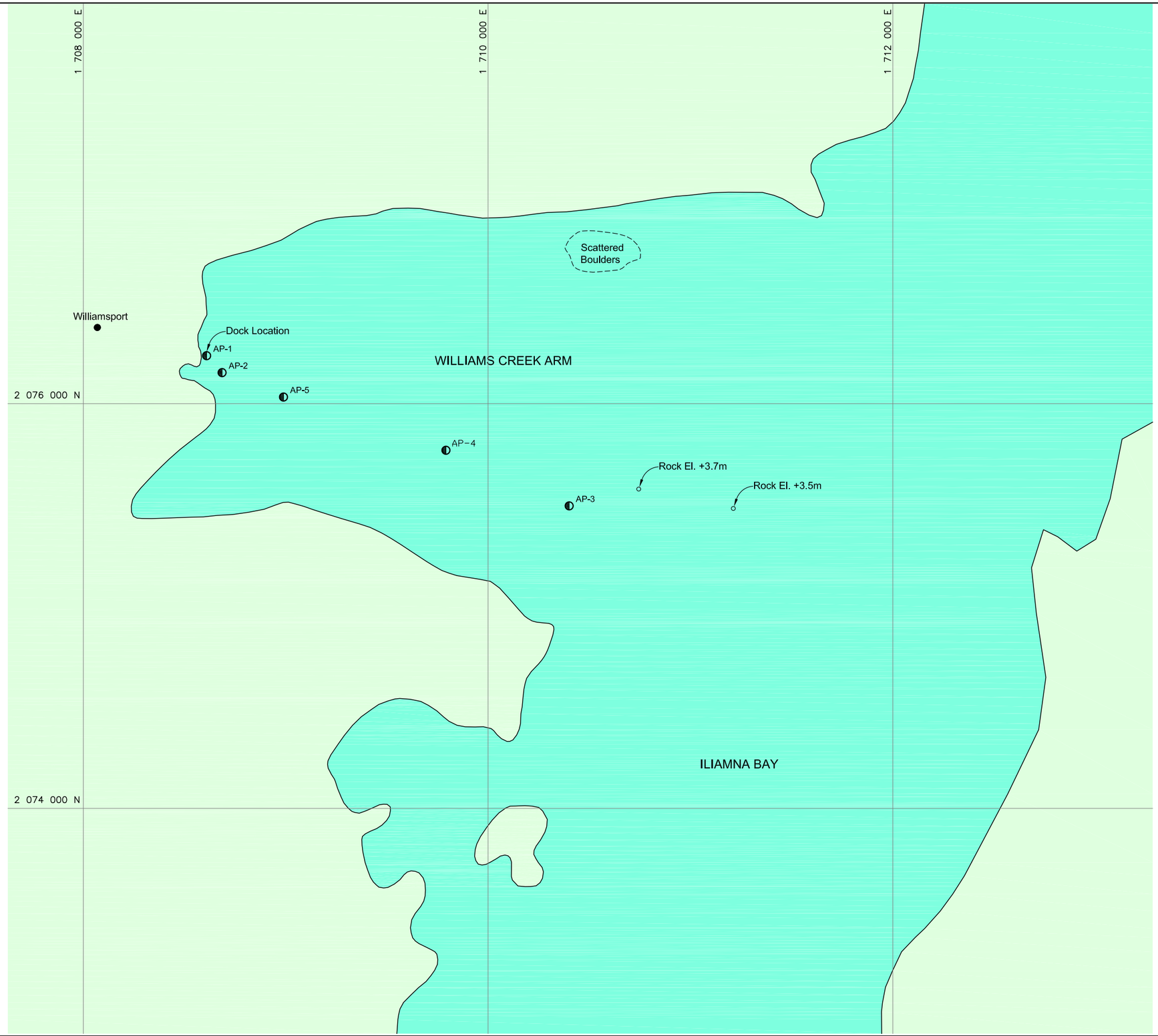


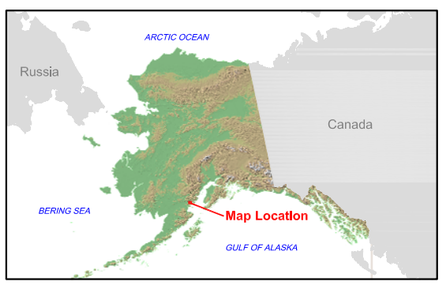
THE pebble PARTNERSHIP

Figure 30-2
Geotechnical Study
1995 Drillhole Locations
U.S. Army Corps Of Engineers
Williamsport and Iliamna Bay

Legend

- Offshore Drillholes
- Population Center
- Water

Source: USACE, 1995.



50 0 50 100 150 200 250 Meters

250 0 250 500 750 Feet

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: B01.dwg	Date: October 15, 2010
Version: 2008-1	Author: Knight Piesold Ltd.

PHOTOGRAPH

PHOTO 30-1: Augustine Volcano, June 2004.