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[12] ABSTRACT (PURPOSE, METHOD, RESULTS, CONCLUSIONS)

In the downtown Honolulu area, detailed site investigations are required prior to the design and construction of high-rise buildings and other engineering structures. Hence, over the years, numerous soil borings, environmental assessments, and groundwater measurements have been conducted. As a result, much data on the subsurface geology of downtown Honolulu exists, but it is spread out among individual consulting firms and various governmental agencies. The purpose of this study is to compile the existing data and interpret the subsurface geology, engineering geology, hydrogeology, and environmental problems within the downtown Honolulu area. This study commenced with collecting and interpreting data from 2,276 soil boring logs from consulting firms in Honolulu, along with data from the Groundwater Index database and environmental databases maintained by the State of Hawaii. The subsurface materials are classified into nine categories: fill, lagoonal (low-energy) deposits, alluvial deposits, coralline debris, coral ledges, cinders, tuff, basalt, and residual soil or weathered volcanics. The study area is divided into 157 quadrangles (1,000 feet × 1,000 feet each). The subsurface conditions within each quad are described in detail, and nine cross-sections are presented for further clarification of the subsurface geology. Foundation-bearing layers and buried alluvial channels are mapped. Environmental problems and groundwater data are summarized in tables and maps. Coral ledges, tuff, and basalt are the most suitable foundation-bearing layers within the caprock. Coral ledges, coralline debris, coarse-grained lagoonal sediments, and cinder sands are characterized by higher hydraulic conductivities than other materials that comprise the caprock. However, the caprock as a whole is characterized by much lower hydraulic conductivities than the underlying Koolau basalt that forms the main aquifer for the island. The caprock groundwater is not only brackish and nonpotable but also highly vulnerable to contamination. Petroleum hydrocarbons and heavy metals from leaking underground storage tanks are the primary soil and groundwater contaminants. Caprock groundwater is generally found within ±5 feet of sea level. Dewatering is often necessary at sites involving the construction of basements.

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SUBSURFACE GEOLOGY AND HYDROGEOLOGY OF DOWNTOWN HONOLULU, HAWAIʻI, WITH ENGINEERING AND ENVIRONMENTAL IMPLICATIONS

Sue A. Finstick

Project Report PR-99-05

October 1998

Project Completion Report
for
"Subsurface Geology/Hydrology of Downtown Honolulu:
Engineering and Environmental Implications, Phases I and II"

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ABSTRACT

In the downtown Honolulu area, detailed site investigations are required prior to the design and construction of high-rise buildings and other engineering structures. Hence, over the years, numerous soil borings, environmental assessments, and groundwater measurements have been conducted. As a result, much data on the subsurface geology of downtown Honolulu exists, but it is spread out among individual consulting firms and various governmental agencies. The purpose of this study is to compile the existing data and interpret the subsurface geology, engineering geology, hydrogeology, and environmental problems within the downtown Honolulu area.

This study commenced with collecting and interpreting data from 2,276 soil boring logs from consulting firms in Honolulu, along with data from the Groundwater Index database and environmental databases maintained by the State of Hawai'i. The subsurface materials are classified into nine categories: fill, lagoonal (low-energy) deposits, alluvial deposits, coralline debris, coral ledges, cinders, tuff, basalt, and residual soil or weathered volcanics. The study area is divided into 157 quadrangles (1,000 feet × 1,000 feet each). The subsurface conditions within each quad are described in detail, and nine cross-sections are presented for further clarification of the subsurface geology. Foundation-bearing layers and buried alluvial channels are mapped. Environmental problems and groundwater data are summarized in tables and maps.

Coral ledges, tuff, and basalt are the most suitable foundation-bearing layers within the caprock. Coral ledges, coralline debris, coarse-grained lagoonal sediments, and cinder sands are characterized by higher hydraulic conductivities than other materials that comprise the caprock. However, the caprock as a whole is characterized by much lower hydraulic conductivities than the underlying Ko'olau basalt that forms the main aquifer for the island. The caprock groundwater is not only brackish and nonpotable but also highly vulnerable to contamination. Petroleum hydrocarbons and heavy metals from leaking underground storage tanks are the primary soil and groundwater contaminants. Caprock groundwater is generally found within ±5 feet of sea level. Dewatering is often necessary at sites involving the construction of basements.

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This study could not have been completed without the cooperation of the consulting firms of Geolabs Hawaii, Dames & Moore, Ernest K. Hirata and Associates, and Hawaii Geotechnical Group. In addition, the State of Hawai‘i's Department of Health and Department of Land and Natural Resources and the City and County of Honolulu's Board of Water Supply, Department of Transportation Services, and Department of Public Works, all provided assistance. To all, I express my sincere thanks.

Furthermore, I thank Professor Frank Peterson, who initiated this project and provided guidance for all phases of the project; the Hawai‘i Water Resources Research Center for grant funding for the project; April Kam and Nancy Hulbirt for the drafting; Karen Tanoue for report editing; Patricia Hirakawa for preparing the camera-ready copy; and GRG Corporation of Wheatridge, Colorado, for providing me with Stratifact, the software package used for analysis and presentation of data.

GLOSSARY

ʻaʻā	rough, jagged type of lava
adobe	a stiff gray-brown clay that is moderately to highly expansive
alluvium	stream-deposited sediments
beachrock	well-cemented coralline sand that formed in the intertidal zone
blue lava rock, blue rock	a hard, slightly weathered, moderately fractured, vesicular dark-gray basalt
caprock	coastal plain sediments and post-erosional volcanics of southeastern Oahu
clinkers	rough or jagged fragments of lava; characteristic of the top and bottom of an *ʻaʻā* flow
ʻewa	to go in the direction of ʻEwa* (generally to the west of Honolulu)
harbor muds, harbor sediments	thick sequences of lagoonal deposits
in situ	formed or deposited in place
kya	thousands of years ago
lagoonal deposits	dark-colored, fine-grained, low-energy sediments that formed in a shallow body of water
makai	on the sea side, toward the sea, in the direction of the sea*
marl	clayey coral
mauka	inland, upland, toward the mountain*
mudrock	local driller's term for tuff
pāhoehoe	smooth, unbroken type of lava*
peat	partly decayed vegetation
puka	hole*; void
puka puka rock	highly vesicular basalt
river-washed tuff	rounded fragments of tuff
river gravel, stream gravel, river-washed gravel	gravel-sized rock fragments that have been abraded and rounded by stream action
saprolite	a residual soil formed by in situ weathering of igneous or metamorphic rocks in tropical or subtropical climates
tuff, volcanic tuff	consolidated aeolian ash
vuggy	containing numerous cavities
vuggy coral	coral with cavities

*Definition from *Hawaiian Dictionary,* revised and enlarged edition, by Mary Kawena Pukui and Samuel H. Elbert (1968, Honolulu: University of Hawaii Press).

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CHAPTER 1. INTRODUCTION

Thirty-five years ago, people traveling to Honolulu by boat would know they had arrived when they spotted the landmark eleven-story Aloha Tower located in Honolulu Harbor. Today, Honolulu's skyline is dominated by high-rise structures that dwarf the Aloha Tower. Because an extensive investigation of the site was required prior to the design and fabrication of each of these structures, a large body of data on the subsurface geology of Honolulu exists in reports and boring logs retained in the files of the consulting firms involved in the site analysis. This report includes a compilation of the information scattered throughout the files of individual engineering firms and an interpretation of the subsurface conditions (Chapter 2), geologic history (Chapter 3), engineering geology (Chapter 4), and hydrogeology (Chapter 5) of the downtown Honolulu study area. Also included is a summary of the environmental problems within the study area (Chapter 6).

Objectives and Scope

The purpose of this research is to summarize the existing information and provide interpretations of the subsurface geology, engineering geology, hydrogeology, and environmental problems of downtown Honolulu. Cross-sections and maps based on interpretations of the raw data are presented. Geologic maps, appended to show important features such as depths to foundation-bearing units (including coral horizons) and locations of old alluvial channels in the subsurface, are provided. Additionally, engineering interpretations are provided for use as comparisons of strengths and foundation-bearing characteristics of the various subsurface materials.

Most of the boring logs used for the compilation also include data on ground surface elevation and depth to the water table. This information was used to prepare a groundwater contour map of the unconfined caprock groundwater. Also, chloride levels in the caprock groundwater are reviewed, and porosities and hydraulic conductivities of the caprock materials are summarized.

Data on environmental issues within the downtown Honolulu area were abstracted from information obtained from the Hawai‘i Department of Health (DOH). Tables and maps were prepared detailing all known information concerning contamination problems within the study area.

Data in the files of private geotechnical consulting firms are actually the property of the client; therefore, exact identification of boreholes and jobs cannot be reported. Nevertheless, the research results can be of use to engineering and environmental companies, state agencies, private individuals, and anyone involved in land-use planning and development and in environmental assessments and remediation. The results of this study are intended to provide an overview of the subsurface geology and contamination problems expected to be encountered at any location within the study area; they should not be used in place of a more detailed site analysis. Additionally, this study can be used to indicate gaps in the record and serve as a guideline for future investigations.

Study Area

Downtown Honolulu is located on the island of O'ahu, Hawai'i, at approximately 21° N latitude and 157° W longitude (Figure 1). For the purpose of this study, downtown Honolulu is considered to be bound by Kalākaua Avenue and Atkinson Drive on the eastern side, Kalihi Stream on the western (or *'ewa*) edge, the shoreline on the southern (or *makai*) side, and the H-1 Freeway on the northern (or *mauka*) side (Figure 2). This area of approximately 6 square miles includes the districts known as Kapālama, Kalihi Kai, Iwilei, and Kaka'ako, in addition to the central downtown Honolulu area. The relatively flat topography slopes gently upward from sea level on the *makai* side to about 50 feet above sea level on the *mauka* border of the study area.

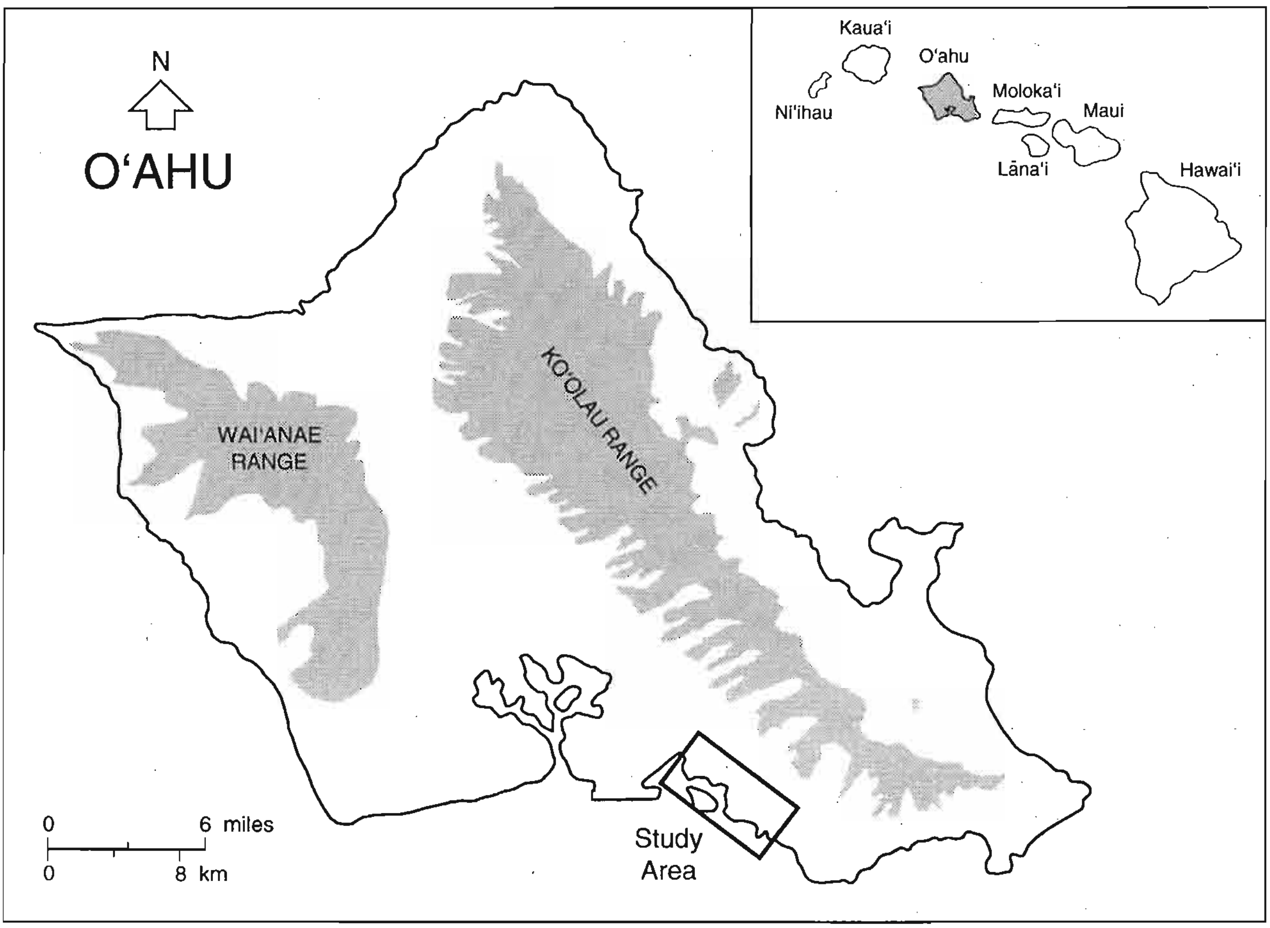


FIGURE 1. Downtown Honolulu study area, O'ahu, Hawai'i

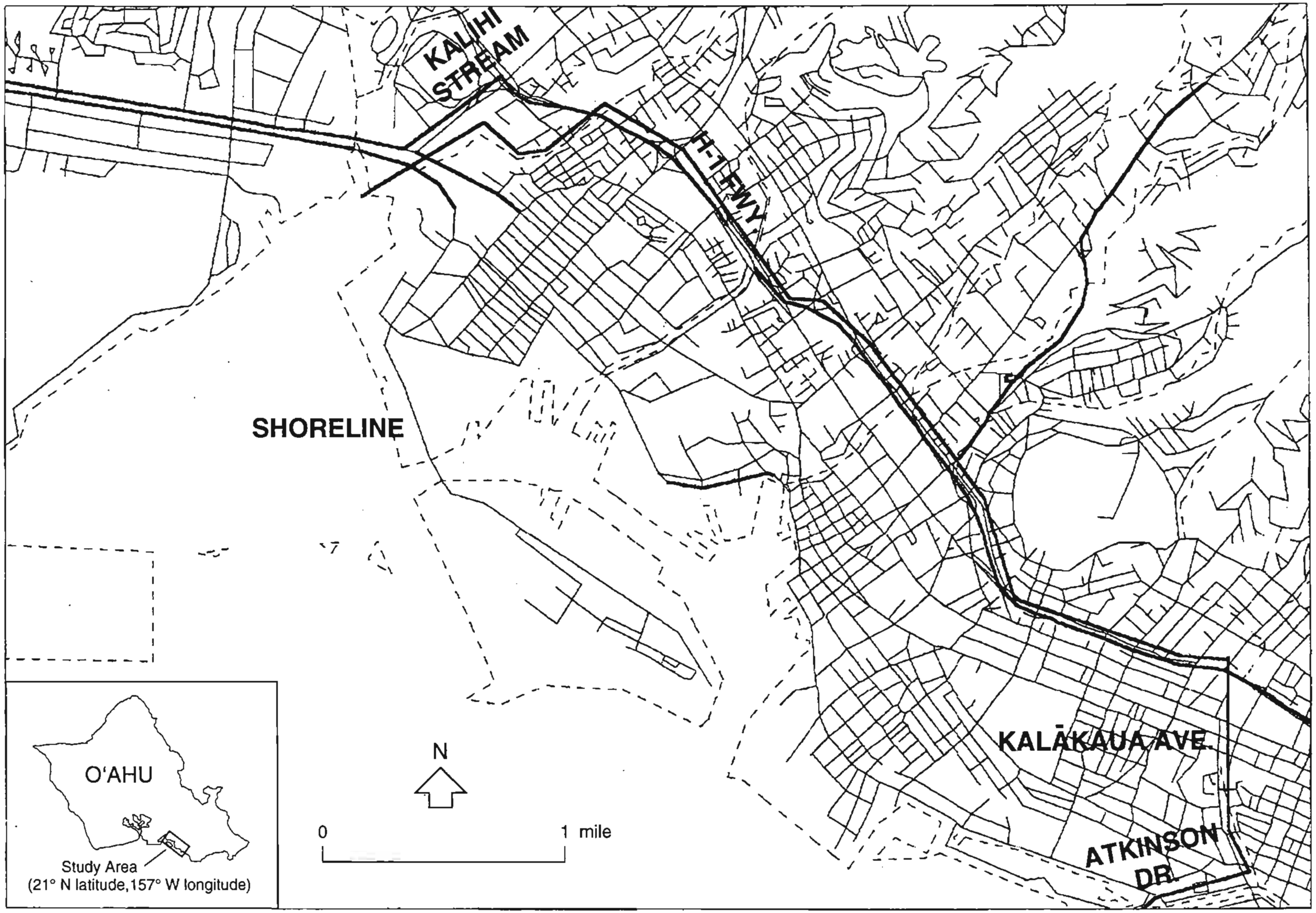


FIGURE 2. Boundaries of the downtown Honolulu study area

Honolulu has a mild climate year-round, with little variation in temperature from month to month. The mean annual temperature is 75°F, with summer temperatures averaging in the high 70s and low 80s, and winter temperatures in the low to mid 70s (Blumenstock 1961). The mean annual rainfall is less than 30 inches, with a winter wet season when over 4 inches of rain may fall in a month and a summer dry season when precipitation can average less than 1 inch per month (Giambelluca et al. 1986).

The vegetation expected in this climatic zone is kiawe, lantana, and lowland shrubs and grasses (Armstrong 1983). However, the vegetation has been much changed due to the urbanization of Honolulu that has been occurring for over a century. Land use is essentially urban and includes residential, commercial, industrial, military, resort, and tourism facilities, as well as parks and public lands (Armstrong 1983).

Previous Studies

Much of the early work on the subsurface geology and hydrogeology of O‘ahu was completed by Chester K. Wentworth and Harold T. Stearns. Wentworth's work includes studies on the pyroclastic geology of O‘ahu (Wentworth 1926) and an examination of the subsurface geology and groundwater resources of the Honolulu and Pearl Harbor areas (Wentworth 1951). Stearns' publications include general descriptions of the geology and groundwater resources of O‘ahu and roadside geology maps (Stearns and Vaksvik 1935; Stearns 1939, 1940). Stearns and Vaksvik (1938) catalogued all the wells on O‘ahu up to that time. Stearns' interests included transgressions and regressions of the sea and Pleistocene stratigraphy as revealed in deep cores and emerged and submerged shorelines (Stearns 1935; Stearns and Chamberlain 1967; Lum and Stearns 1970; Stearns 1974, 1975, 1978). Visher and Mink (1964) examined the groundwater resources of southern O‘ahu. These various studies recognized the complex geologic history of the Hawaiian islands, as exhibited by the complexity of the stratigraphy. Investigations on the groundwater resources of O‘ahu included discussions of the basal groundwater, the brackish groundwater in the coastal plain sediments or caprock, perched groundwater, and high-level springs, as well as examinations of artesian conditions and tunnels tapping groundwater in dike complexes. Both quantity and quality issues have been addressed in these various publications.

The first attempt at a comprehensive study of the engineering properties of the subsurface materials on O‘ahu was made by Charles Ferrall, who examined the subsurface geology of three areas of Honolulu: Waikīkī, Mō‘ili‘ili, and Kaka‘ako (Ferrall 1976). The study report, based on information in approximately 800 boring logs, contains subsurface cross-sections and geologic maps as well as a discussion of the suitability of the various subsurface materials as foundation-bearing layers. A similar study was later completed for the Pearl Harbor area by Kathy Munro; it was based on information obtained from more than 600 boring logs (Munro 1981). Since Ferrall and Munro did their work, much more data have been accumulated, primarily in the form of soil boring logs held by individual consulting firms.

Present Study

The downtown Honolulu area, including Kaka'ako and Iwilei, has been undergoing redevelopment in recent years, beginning with subsurface investigations by drilling and logging boreholes and culminating with the construction of high-rise buildings and other engineering structures. A comprehensive examination of the large body of information that exists will lead to a better understanding of the subsurface geology of the study area, and the results can be used as a summary of the subsurface materials expected to be encountered at any site within the study area. Therefore, it was decided that a timely study would be an examination, similar to that done by Ferrall and Munro, of the downtown Honolulu area. Details are given in the following chapters.

CHAPTER 2. SUBSURFACE GEOLOGY

The purpose of this chapter is to describe the subsurface geology of the study area as revealed in boring logs. A quad-by-quad description of the subsurface geology is given in Appendix A. As the boring logs and reports are proprietary, that is, they belong to the client, only general locations of project sites are given for each quad. The results are summarized in subsurface geologic maps (Appendix B) and subsurface geologic cross-sections (Appendix C).

This study is not intended to take the place of detailed site investigations. Tremendous variability exists in the subsurface of the coastal plain of southeast O'ahu. In addition, there is great variation in the quality of the boring logs used in the present study. However, the information presented here can be used as a first approximation of the subsurface geology at any location within the study area. The subsurface geologic maps and cross-sections, along with the quad descriptions reported in Appendix A, can be used to determine gaps in the information available and guide the future placement of borings and collection of data.

Methods of Investigation

From a survey of the records at the City and County of Honolulu's Department of Public Works, Engineering Division, it was found that four private geotechnical firms did more than 75% of the consulting work for pre-1993 building projects in the downtown Honolulu area. Permission was obtained from Ernest K. Hirata and Associates, Hawaii Geotechnical Group, Geolabs Hawaii, Dames & Moore to access their files to gather information for this research. Project reports as old as 1951 and as recent as 1992 were surveyed, and data from boring logs were collected. Locations of 2,276 borings were plotted on 1:200-scale base maps of the study area. These data were then transferred to a base map of the study area that was created with the geographic information system portion of a database/graphics computer program called Stratifact. A grid, based on the State Plane Coordinate System, was overlaid on the base maps, dividing the area into 157 quadrangles measuring 1,000 feet on each side. Plates 1 through 3 in Appendix B show the division of the study area by quadrangles.

Data in boring logs were then interpreted. Boreholes ranged in depth from only a few feet to as much as 265 feet, with an average depth of 47 feet. In order to be able to correlate data between boring logs written by different individuals at different firms, a classification scheme was devised which uses color, hardness, and grain size as the primary parameters. Boring logs typically contain both descriptions of the color and grain size of materials encountered during drilling and notations on blow counts, which give an indication of the hardness of the material.

Subsurface Materials

The subsurface materials were classified into nine categories: fill, lagoonal (low-energy) deposits, alluvial deposits, coralline debris (including beachrock), coral ledge, cinders, tuff, basalt, and residual soil or weathered volcanics. A physical description of the materials in these nine categories follows. The engineering properties of these materials are discussed in Chapter 4, and the hydrologic characteristics are described in Chapter 5.

Fill

Fill is an extremely heterogeneous unit, consisting of human-placed materials. In general, except at the higher elevations, there is fill over the entire study area. At lower elevations, near the shoreline, fill can be as thick as 20 feet. A large amount of hydraulic fill, consisting mainly of silty coralline sand and gravel, was used in the study area. The color, consistency, and grain size are highly variable. Fill may be white, gray, or brown; it may be soft or dense; and it may contain clay, silt, sand, gravel, cobbles, or boulders. Some fill was compacted when placed; other fill was placed very loose. Identification is usually based on location and on notations in the boring logs of the inclusion of such debris as tires, metal, glass, concrete, and wood.

Lagoonal (low-energy) Deposits

Lagoonal deposits are usually dark gray to black, or sometimes dark brown, and are dominated by clay and silt particles. These deposits can also contain coral fragments, shells, fine sand, coral gravel, and organics, including peat and decomposed wood and other vegetation. They are described in boring logs as wet, soft, loose, and compressible. A local driller's term occasionally used is "marl." Blow counts required to advance a sampler through this material are very low, generally 10 blows per foot or less; but they may be higher if the material is intermixed with alluvium or coralline debris. Thick sequences of these low-energy sediments are found near the coastline in areas of former lagoons behind reefs or within embayments, in wetlands and tidal flats, and inland in drowned stream channels or estuaries. However, not all materials referred to as lagoonal deposits in boring logs or in this report can be correlated with a specific paleoenvironment. The term is used as a description of a particular type of sediment for engineering considerations. These low-energy deposits can be many 10s of feet thick, often 100 feet or more.

Alluvial Deposits

Alluvial deposits consist primarily of terrigenous sediments which have been transported by stream action. Alluvial channels can be found cutting through all the other sediments, including coral ledges. Alluvium is generally dark-colored, mainly brown or a variation of brown. Boring logs frequently use color terms such as mottled brown, red-brown, or orange-brown when describing alluvium. The primary grain-size category is silt, although it can be silty sand, silty clay, or clayey silt. Other size categories include gravel, cobbles, and boulders. Some boring logs include descriptions of "rounded gravel" or "river-washed gravel." Coralline debris and low-energy sediments, including peat or decomposed wood fragments or other vegetation, are often found within alluvial channels. Volcanics—especially cinders, but also tuff and basalt fragments—are also found within alluvial channels. Lava flows often follow stream valleys in their descent from the mountain to the sea; therefore, the bottom of old alluvial channels may be floored with basalt. In general, alluvium is described in logs as stiff in consistency, but it can be soft if it is high in low-energy deposits. In addition to occurring within old stream channels, alluvium exists as slopewash materials coming off the Ko'olau Range as alluvial fan deposits. These are found at higher elevations within the study area and are generally only a few feet thick, in contrast to the stream channel alluvium which may be several hundred feet thick in a former channel.

Coralline Debris

Coralline debris primarily consists of reworked and recemented detritus broken from the reef formation, including material from the back reef, the fore reef, and the lagoons behind the reef. It includes coralline sand and gravel, beach sand, shells, calcareous silt, and coral fragments. It may contain lenses of lagoonal (low-energy) or alluvial deposits. Its color is generally light, such as white, tan, light gray, or yellow. Highly variable in hardness, coralline debris may be well-cemented and quite hard or it may be uncemented, loose, and weak. It is often difficult to distinguish between coralline debris and the coral ledge. Blow counts were used to assist in classification of this unit. In general, counts of less than 50 blows per foot (Dames & Moore system, 140-pound weight falling from a height of 30 inches) and a rock core recovery of less than 50% characterize this unit. However, well-cemented coralline debris can give anomolously high blow count values and thus be misidentified as ledge coral. Coralline debris is very common in the study area and can be quite thick, up to several 10s of feet. Beachrock is included in this category.

Coral Ledge

Coral–algal reefs form from corals and coralline algae growing together symbiotically, producing a rigid, wave-resistant framework of carbonate material. The algal ridge or seaward reef edge is the hardest and strongest portion of the reef. The back reef and fore reef may also contain localized areas of hard and strong coral ledge, where patch reefs grow or cemented coralline rubble occurs.

In boring logs, the coral ledge is referred to as algal coral, massive coral, or coral limestone. Sometimes it is called coralline sand and gravel, in which case classification as coral ledge depends on continuity of the unit (determined by comparing interpretations of this unit as ledge coral in logs of nearby borings) and hardness. The coral ledge is one of the hardest subsurface units in the study area. This unit is also defined by blow counts. Counts of over 50 blows per foot (Dames & Moore system) and a rock core recovery of over 50% distinguish coral ledges from coralline debris. This unit is light-colored, mainly white or tan. It often contains empty solution cavities or cavities filled with soft sand. The degree of cementation and the thickness of the unit are variable, ranging from only a few feet thick to 10 or more feet thick. A highly weathered or weakly cemented ledge may be misidentified in the boring logs as coralline debris.

Four coral ledge classifications are used in this study. The first three are from Ferrall (1976). According to Ferrall, the +5 ledge is first encountered between elevations of +10 feet and –10 feet, the –15 ledge between elevations of –15 feet and –29 feet, and the –30 ledge between elevations of –30 feet and –50 feet. The –30 ledge is generally found seaward of the –15 ledge, and the –15 ledge is found seaward of the +5 ledge. A fourth coral ledge classification is used because records show coral occurring as high as +22 feet. Thus the +20 coral ledge will be considered that massive unit in the study area first encountered in the subsurface between elevations of +22 feet and +10 feet. It is located inland of the +5 coral ledge and is more prevalent in the western portion of the study area (Figure 3). Coral ledges can be anticipated at those elevations where coral is noted on the subsurface geologic maps (Appendix B). However, the laterally continuous presence of coral cannot be assumed, due to the fact that alluvial channels may have eroded through the coral.

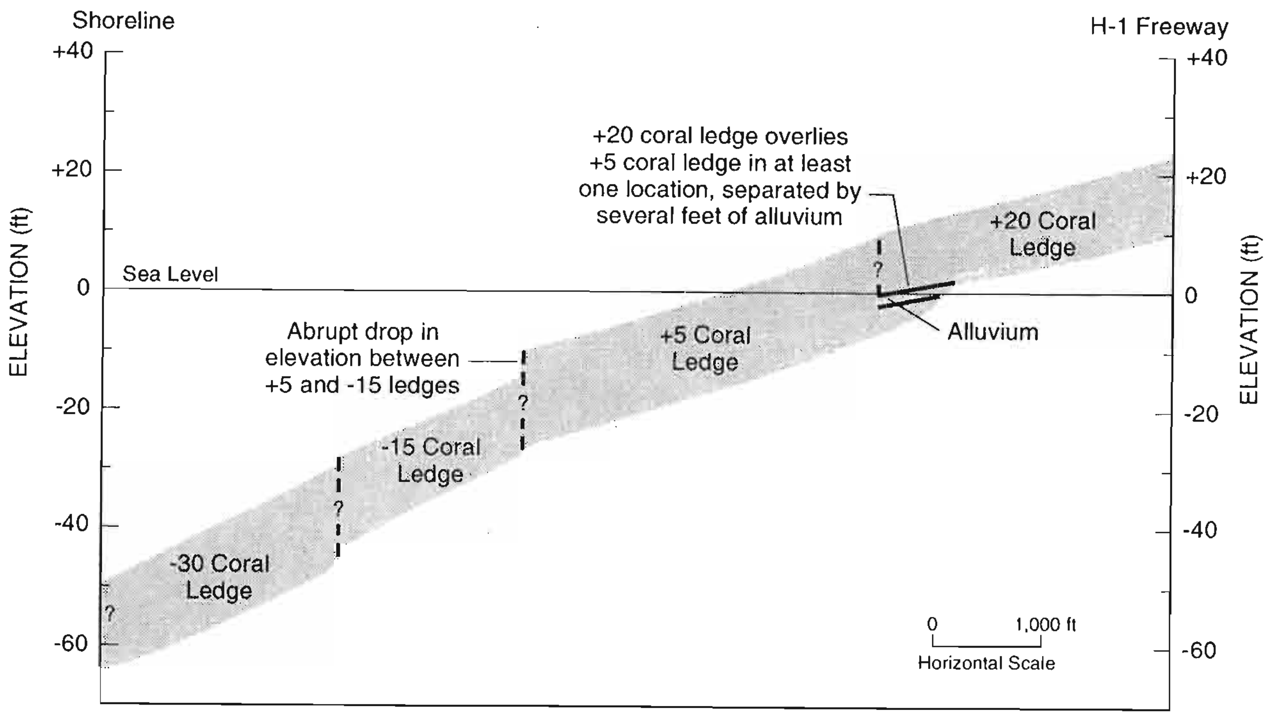


FIGURE 3. Generalized cross-section of the downtown Honolulu study area showing coral ledges only

Elevations reported in boring logs are usually estimated from topographic maps rather than from actual surveys; thus they may deviate from the classifications used in this report. For example, for the surface of the +5 ledge usually first encountered between elevations of +10 feet and –10 feet, elevations of +12, +10, +7, +5, –3, –8, and –12 feet have been reported in a number of logs for boreholes located in the same area. All would still be categorized as +5 ledge, even though some values depart slightly.

As mentioned above, the distinction between coralline debris and coral ledge is not always clear. For the purposes of this report, coral ledge is defined as material that is hard and continuous enough to be of importance for foundation-bearing purposes. Therefore, it actually could be well-cemented coralline debris rather than coral–algal reef framework. The two materials are distinguished by physical characteristics rather than by environment of deposition.

Cinders

The most common description of cinders in boring logs is loose to dense black sand. Its color is generally dark-brown to black; its grain size usually sand or silty sand; and its consistency stiff or firm, although it may vary. Cinders are found throughout the study area, probably resulting from Tantalus/Roundtop volcanic eruptions. In the logs, they are described as separate identifiable layers, generally 5 feet thick or less, and as layers intermixed with alluvium in old stream channels, where they have been reworked and redeposited.

Tuff

Tuff is a hard, brown volcanic rock that can weather to a stiff silt. It is found leeward of, as well as within, tuff cones. It is sometimes found associated with volcanic cinder layers. Tuff is often described in boring logs as hard and fractured. It is referred to as mudrock, siltstone, or tuffaceous siltstone in some logs. Tuff may be reworked by streams and redeposited in old channels, where it is found intermixed with alluvium or lagoonal muds. Tuff can be difficult to distinguish from alluvium in the logs if the only description given, such as "hard brown silt," is vague. In such a case, descriptions in logs of nearby borings would have to be used to categorize the unit. Tuff that has been reworked by streams is similar in engineering properties to alluvium and thus has been classified as alluvium.

Basalt

Basalt is generally dark-brown, gray, or black, although local drillers often refer to it as massive "blue" rock or as "*puka puka* rock" if it is highly vesicular. Consisting of interbedded *pāhoehoe* and *'a'ā* flows, basalt is the hardest subsurface unit found in the study area. Boring logs often contain descriptions of the degree of weathering and fracturing. Clinker layers may be noted on top of the basalt. Sometimes misidentification between basalt boulders in alluvial channels and actual lava flows occurs in boring logs. Information in logs of nearby borings would have to be used to identify the material. For example, if it is obvious that a channel area is involved and other borings do not show evidence of basalt, then most likely a basalt boulder rather than a lava flow is present.

Residual Soil or Weathered Volcanics

Residual soil or weathered volcanics is found overlying unweathered tuff or basalt layers. It is the weathered or decomposed top few feet of a volcanic deposit that grades down to the unweathered rock below. Saprolite is included in this category, although boring logs surveyed for this study did not use this term to describe the material. Generally stiff or hard, but not as hard as the underlying unweathered parent material, this subsurface material often consists of reddish-brown silty clay and clayey silt and may include cobbles and boulders. It is usually only a few feet thick.

Subsurface Geologic Maps and Cross-Sections

Plates 1, 3, and 5 in Appendix B show the locations of the boreholes for which logs were available for this study and the cross-sections prepared. Plates 2, 4, and 6 in Appendix B are the subsurface geologic maps of the study area with the topmost layers of fill and lagoonal sediments removed, so that the first competent layer for foundation-bearing purposes is shown. Data coverage within each quadrangle is indicated by the small crosses that mark the approximate location of boreholes. The quadrangle grids, street names, and locations of the cross-sections are also shown.

Nine cross-sections (Plates 7 through 15) prepared with a vertical exaggeration of 10:1 are presented in Appendix C. Section lines were chosen to take advantage of the maximum data coverage available and to show subsurface geologic features of interest, such as alluvial channels cutting through competent coral layers. The locations of these cross-sections are shown in Plates 1 through 6. Each cross-section includes borings located within 200 feet on either side of the actual line of section. Due to the variability within the subsurface of the study area, conditions on either side of the line of section may differ. In such cases, conditions most representative of the subsurface geology along the actual line of section are shown. The degree of control is also shown for the cross-sections, with three or more borings per 100 feet classified as excellent control, two borings per 100 feet as good control, one boring per 100 feet as moderate control, and no boring within a 100-foot interval as no control.

CHAPTER 3. GEOLOGIC HISTORY

O'ahu is composed of two shield volcanoes. The Wai'anae Volcano, which formed the western portion of the island, probably ceased erupting around 3 million years ago. Eruptions of the younger Ko'olau Volcano, which formed the eastern side of the island, occurred from approximately 2.5 million years ago to 2.2 million years ago. This was followed by a period of erosion that lasted about 1 million years. Then the post-erosional stage of volcanism created the cinders, tuffs, and basaltic lava flows of the Honolulu Volcanic Series. This series formed such landmarks as Diamond Head and Punchbowl (Macdonald et al. 1983). This rejuvenation stage of volcanism continued until at least 32,000 years ago (Stearns 1985) and eruptions may have occurred as recently as 10,000 years ago (F. Peterson, Department of Geology and Geophysics, University of Hawai'i, personal communication, 28 February 1996).

Complicating the geologic history are the Pleistocene sea-level changes that occurred during the last several hundred thousand years. Glacial and interglacial periods resulted in a series of marine transgressions and regressions. During a glacial period, when sea level was low, terrestrial sediments were deposited farther seaward, below present sea level. Conversely, during interglacial periods, when sea level was high, coral reef, marine muds, and beach sand were deposited above present sea level. Added to this complexity were cycles of sedimentation alternating with periods of erosion, and tectonic subsidence of the islands, which may have been as much as 6,000 feet (Stearns 1985).

The coastal plain of southeastern O'ahu is composed of post-erosional volcanics, along with alluvial debris eroded from the Ko'olau Volcano and sedimentary deposits resulting from Pleistocene sea-level changes due to glacial and interglacial periods. These materials, collectively referred to as the caprock, are as much as 1,200 feet thick and overlie the basalts of the Ko'olau Volcano (Stearns 1935).

The alluvial sediments of old stream channels further complicate the subsurface geology. Extensive fine-grained channel deposits, now buried, are in unpredictable locations in the subsurface. These channels cut through a number of thick, laterally extensive coral ledges; they also dissect other marine deposits and older terrestrial sediments.

Overlying much of the study area are low-energy lagoonal silts and clays, with some coralline debris. As sea level stabilized, the area became a wetland. The wetland deposits, which include muds and peat, can be more than 20 feet thick. Overlying the low-energy lagoonal and wetland deposits is a discontinuous layer of heterogeneous human-placed fill, made up primarily of calcareous sand, muds, and coral but also comprised of concrete rubble, broken bottles, old tires, and other trash. This fill material is approximately 5 feet thick over much of the study area.

The purpose of this chapter is to review and summarize the geologic history of southeastern O'ahu and to discuss age relationships between the various rejuvenation stage volcanics, as well as the coral ledges and other subsurface materials defined in Chapter 2 of this report. A speculative geologic history of the study area is outlined in Table 1. The quadrangle locations and subsurface cross-sections are shown in Appendixes B and C.

TABLE 1. Speculative Geologic History of the Downtown Honolulu Area

Event	Time
Present sea level rise	Present
Reclamation and placement of human-made fill	Present
Formation of alluvial slopewash and alluvial soils	Present
Regression from Kapapa high sea stand to present sea level	4 kya to present (?)
Formation of recent coral	(?)
Formation of low-energy lagoonal sediments	(?)
Kapapa high sea stand (~3 to 6 feet, mean sea level)	~6 to 4 kya
Post-glacial transgression to Kapapa high sea stand	21 to 6 kya (?)
Māmala low sea stand (–350 feet maximum)	21 kya (?) (oxygen isotope stage 2)
Tantalus/Roundtop cinders	~67 kya
Erosion and downcutting of deep alluvial channels	115 to 21 kya (?)
Regression to –350 feet maximum (episodic)	115 to 21 kya (?) (oxygen isotope stages 4, 3, and 2)
Formation of –30, –15, +5, and +20 coral ledges	(?)
Waimānalo high sea stand	133 to 119 kya (?) (oxygen isotope stage 5e)
Transgression to +41 feet maximum	180 to 133 kya (?) (oxygen isotope stage 6)
Waipi'o low sea stand	500 to 250 kya (?) (oxygen isotope stage 6)
Punchbowl basalt and tuff	~297 kya
Nu'uanu basalt	~420 kya
Makalapa–Salt Lake tuff	~430 kya
Kalihi basalt	~460 kya
Regression to –350 feet maximum	250 to 180 kya (?) (oxygen isotope stages 7 and 6)
Erosional period/deposition of alluvium	500 to 180 kya (?)
Rocky Hill basalt	650 to 500 kya (?)
Ka'ena high sea stand	650 to 500 kya (?) (oxygen isotope stages 13, 12, and 11?)
Transgression to +95 feet maximum	Pre-oxygen isotope stages 13, 12, and 11 (?)
Erosional period	~2.2 to 1 million years ago
Ko'olau Volcanic Series	~2.5 to 2.2 million years ago

Post-erosional or Rejuvenation Stage Volcanics

Near the Iolani Palace in the downtown Honolulu area, Ko'olau basalts have been found at 707 feet below ground surface (Stearns 1939). At the west end of Waikīkī, Ko'olau basalts have been found as deep as 992 feet below sea level (Ferrall 1976). For the present study the deepest borehole examined was only 265 feet deep, and none of the boreholes entered Ko'olau bedrock.

Within the study area, there are occurrences of Honolulu Volcanic Series basalt, tuff, and cinders. The compositions of lavas from the rejuvenation volcanics include basanite, nephelinite, and melilite nephelinite (Gramlich et al. 1971).

Basalts

The oldest occurrence of the Honolulu Volcanic Series within the study area is probably Rocky Hill basalt (Stearns and Vaksvik 1938), which is found at the eastern edge of the study area (Quad D–2, Subsurface Cross-Sections A–A' and G–G'). It may be present in the subsurface upgradient from the locations described for Quad D–2, but deeper borings are needed for verification. Stearns correlated this basalt with the Ka'ena high stand of the sea, which may be as old as ca. 650 kya (Stearns and Vaksvik 1935; Stearns 1978; Macdonald et al. 1983) and as recent as ca. 450 kya (Brückner and Radtke 1989; Jones 1993a).

A second occurrence of basalt is found at the western edge of the study area, extending from Waiakamilo Road on the east to the *'ewa* border of the study area at Kalihi Stream (Subsurface Cross-Section I–I'). It appears to have advanced almost as far as Dillingham Boulevard, but deeper borings are needed to determine the boundaries of this flow (Subsurface Cross-Section D–D'). It is likely that this basalt is a Kalihi Valley flow, either the east Kalihi flow or the Kamanaiki flow (Stearns and Vaksvik 1935; Wentworth 1951). The Kalihi basalt has been dated at ca. 460 kya (Gramlich et al. 1971).

In the Kaka'ako, downtown Honolulu, and Iwilei districts, between approximately South Street on the east and Kapālama Canal on the west (Subsurface Cross-Sections C–C', H–H', and I–I'), a third occurrence of basalt is encountered at various elevations. This basalt likely originated from a Nu'uanu Valley source. There are several possible reasons for the variations in elevation for the uppermost surface of the Nu'uanu basalt. It may be that erosion on the top of the flow created an uneven surface upon which more recent materials were deposited. Or, there may have been an irregular preexisting topography, and the lava flow merely followed it, filling in stream valleys and cascading over cliffs and ridges now buried.

Another possibility is that there was more than one flow event in this area. It is well-documented that at least two lava flows originated up in Nu'uanu Valley (Wentworth 1951; Macdonald et al. 1983). Several borings in this area indicated the presence of a layer of alluvium within the basalt, which would seem to indicate that two separate flow events occurred. An older, lower flow, referred to as the Luakaha flow, came from the east side of the valley. It extends as far as the Dole cannery site in Iwilei, where it lies below the coral ledges. A number of boring logs report that coral overlies the basalt in this area; therefore, the basalt here is older than the ledge corals. A younger, upper flow originated from the Makuku cone on the west side of the valley. Previously, it had not been identified farther down-valley than the O'ahu Cemetery. There may also have been a lava flow that issued from the Pali cinder cone at the head of Nu'uanu Valley (Stearns 1985). The Nu'uanu lavas have been dated at ca. 420 kya (Gramlich et al. 1971). Supplemental borings, petrographic analyses, and further age-dating could assist in the classification and differentiation of these lava flows.

A fourth occurrence of basalt is encountered downgradient of the Punchbowl cone (Subsurface Cross-Sections B–B', E–E', and G–G'). Punchbowl is primarily a tuff cone, but at least one lava flow has been identified with it. The flow is encountered at various elevations within the study area. This may reflect deposition on an irregular preexisting topography, or there may be more than one flow represented in this area. Some of the basalt here may be Nu'uanu in origin. However, Punchbowl is indicated as the source of the lava flow in this vicinity, as the basalt is located within or just above a tuff unit. A sample of Punchbowl lava has been dated at ca. 297 kya (Gramlich et al. 1971). This date places the time of the eruption during the Waipi'o low stand of the sea (Gramlich et al. 1971).

Tuffs

Punchbowl tuff is found leeward of the Punchbowl cone (Subsurface Cross-Sections B–B' and E–E'). This tuff is first encountered at various elevations within the study area. This may reflect deposition on irregular topography or merely reflect the sloping of the land surface from higher elevations on the inland side to lower elevations near the shoreline at a time when sea level was lower than present. Stearns and Vaksvik (1935) hypothesized that the Punchbowl tuff eruption occurred during the Waipi'o low stand of the sea, as did the Makalapa–Salt Lake tuff eruptions.

Pauoa Stream may have flowed directly to the coast prior to the Punchbowl eruption, which could have diverted the flow to the west side of the Punchbowl cone. Either the HIC Channel or the Alakea Channel could be the former stream channel of Pauoa Stream.

In most boring logs, the Punchbowl tuff is reported as being located below cinders and coral, similar to the report by Stearns and Vaksvik (1935). The tuff is therefore older than the coral, which is presumably Waimānalo in age. However, at five locations, tuff was reported as being above the +5 or +20 coral ledges. It is unclear why tuff is found both above and below the ledge coral, even though it is not found both above and below the coral in a single borehole. One possibility is that two separate phases of tuff eruptions occurred from Punchbowl, but this is relatively unlikely. Rather than erupting sporadically over a period of time, the volcanics of the Honolulu Volcanic Series were generally short-lived events, each erupting once and once only (Walker 1990). Another possibility is that the lower tuff is from a separate, older, unidentified volcanic event. Alternatively, the eruption could have been contemporaneous with the Waimānalo high sea-level stand, thus resulting in tuff interlayered with coral. It is also possible that the tuff described above the ledge coral is either well-consolidated alluvium or cinders, as it is sometimes difficult to distinguish whether the boring logs are referring to tuff or to other deposits. One boring log mentions tuff intermixed with cinders; therefore, it may be that the tuff above the coral is related to the Tantalus/Roundtop cinders rather than to the Punchbowl tuff.

A second occurrence of tuff is near the mouth of Kalihi Stream in the *'ewa* portion of the study area (Quads O–18 and O–19, Subsurface Cross-Section D–D'). This tuff may be a deposit resulting from the Aliamanu, Salt Lake, or Makalapa tuff cones located to the west of the study area boundary, in the Pearl Harbor region. The Salt Lake volcanics have been dated at ca. 430 kya (Stearns 1978). The elevation and location in the *'ewa* portion of the study area seem to indicate that it could be Makalapa–Salt Lake tuff, as Aliamanu tuff is generally found at greater depths and considered to be older (Munro 1981). Wentworth (1951) found tuff at nearby Fort Shafter that he believed came from the Aliamanu eruption; however, Stearns and Vaksvik (1935) thought this same tuff originated from a Kalihi Valley cone, possibly the Pu'u Kahuauli vent. It more likely originated from a Kalihi Valley source than from the Salt Lake cones, as the Salt Lake volcanics are west of this area and the northeasterly tradewinds would not have carried Salt Lake tuff into this vicinity. Stearns (1939) felt that it may be a stream-laid tuff deposit from a Kalihi Valley source. The alternative is that this tuff is the result of some unidentified eruption.

Cinders

Black cinders are found throughout the study area but are especially prevalent in the downtown Honolulu and Kaka'ako districts, between Pi'ikoi Street on the east and Nu'uanu Avenue on the west (Subsurface Cross-Sections A–A', B–B', G–G', and H–H'). Cinders are found downwind of, and even within, Punchbowl Crater, even though Punchbowl is primarily a tuff cone rather than a cinder cone. Previous studies have shown that the cinders originated from the Tantalus/Roundtop firefountaining eruptions (Stearns and Vaksvik 1935; Macdonald et al. 1983). These eruptions have been dated at ca. 67 kya (Gramlich et al. 1971; Stearns 1985).

Sea-Level Changes and Coral Ledges

There is abundant evidence in Hawai'i of Pleistocene sea-level changes occurring over the past several hundred thousand years. Stearns (1985) described 35 shorelines that he attributed to glacioeustatic sea-level changes, based on in situ beach conglomerate and wave-cut horizontal notches. Stearns (1974) named these shorelines for the type localities at which they were first described.

Oxygen isotope curves, which are based on the preferential evaporation of the lighter ^{16}O isotope, can be used to infer glacioeustatic sea-level changes. During a glacial period, when large quantities of water are held within ice sheets, the ocean water will appear enriched in ^{18}O and the glaciers will appear depleted in ^{18}O, due to preferential evaporation and subsequent deposition in the ice of the lighter ^{16}O. During an interglacial period, seawater will appear enriched in ^{16}O and glacial ice will appear depleted in ^{16}O, compared to during a glacial period. Oxygen isotope ratios of the skeletons of marine calcareous microorganisms can be related to the oxygen isotope composition of seawater at the time of formation of the carbonates. In general, an odd oxygen isotope number indicates a warm period or sea-level high stand, whereas an even oxygen isotope number indicates a cold period or sea-level low stand. However, minor events have been recorded within these periods. Thus designations such as 5a through 5e are used to differentiate substages within oxygen isotope stage 5 (Shackleton 1987).

Oxygen isotope records are used to compare sea-level histories of numerous islands and coastal settings around the world, including Hawai‘i (Chappell and Polach 1976; Fairbanks and Matthews 1978; Aharon 1983; Shackleton 1987; Hearty et al. 1992). However, it is likely that the type locality names as designated by Stearns will continue to be used in Hawai‘i. Therefore, this chapter will refer to both oxygen isotope classifications and Stearns' shoreline names.

Stearns believed that the continuity of submerged notches, over many miles, was evidence of tectonic stability of the Hawaiian islands. In this scenario, during a glacial period, when much water was held within ice sheets and sea level was low, streams would cut to the lower base level and terrigenous sediments would be deposited below present sea level. Conversely, during an interglacial period, when much ice had melted and sea level was high, marine sediments would form above present sea level. Therefore, one finds submerged notches (cut by waves when sea level was lower) as well as above-shoreline coral reef material and beach conglomerate (formed when sea level was higher).

Ka‘ena High Sea Stand

Calcareous beach conglomerate and reef limestone, found as high as +95 feet, formed during a transgressive stand of the sea named the Ka‘ena high sea stand by Stearns (1978). Extensive reef growth occurred during the Ka‘ena sea stand, which probably existed for a long time (Stearns 1978). This sea stand may date from ca. 650 kya (Stearns 1978) to as recent as ca. 450 kya and probably falls into oxygen isotope stage 13 (Brückner and Radtke 1989; Jones 1993a, 1993b). Recent dating revealed an age of 5.32 kya for the Ka‘ena sea stand (Szabo et al. 1994). Coral ledges found at depths greater than –50 feet (Subsurface Cross-Sections A–A', B–B', and E–E') and classified as deep coral in this study may date from the Ka'ena sea stand or some other pre-Waimānalo stand of the sea. However, it was felt that there was insufficient information obtained in this study to attempt to correlate the deep corals with any specific previous sea-level stand.

Waipi'o Low Sea Stand

Several relatively short-lived halts in sea level or intervening interglacial cycles may have occurred as sea level regressed from the Ka'ena high sea stand to the Waipi'o low sea stand (Stearns and Vaksvik 1935). During this glacial period, sea level may have dropped as much as 350 feet below present sea level (Stearns 1978). Erosion would have been the dominant geomorphic agent during this time, and winds may have been an important agent of transport. Dunes formed during the Waipi'o low sea stand can be found on several of the Hawaiian islands, including O'ahu, where they are extensive in the Bellows Field area on the southeast portion of the island (Stearns 1978). Channels were probably cut into the coastal plain area of southeast O'ahu during this period. The alluvium found at depth beneath the upper coral ledges, as reported in the quad descriptions and shown on the cross-sections, may date from this period in time. For example, Subsurface Cross-Sections B–B', C–C', E–E', F–F', G–G', and H–H' all show alluvium beneath either the +20 or +5 ledge in a number of locations. According to Stearns (1978), the Waipi'o low sea stand occurred between 500 and 250 kya, probably during oxygen isotope stage 6 (Martinson et al. 1987).

Waimānalo High Sea Stand

There may have been several relatively short-lived halts in sea level as it transgressed from the Waipi'o low sea stand to the Waimānalo high sea stand. During the Waimānalo interglacial high sea stand, sea level on O'ahu may have risen as high as +41 feet above present sea level (Muhs and Szabo 1994). It is likely that water during that time was warmer than today, resulting in more reef growth than at any time since the Ka'ena high sea stand (Stearns 1978). Although Stearns (1978) named it the +25 feet stand of the sea, he suggested that it actually consisted of two shorelines, one at +27 feet and another at +22 feet. However, because the two shorelines could not be distinguished in the field, the Waimānalo sea stand was assigned the nominal elevation of +25 feet. The age of the Waimānalo interglacial high sea stand is ca. 124 kya, which falls into the period now referred to as oxygen isotope substage 5e (Shackleton 1987). It is likely that this substage will continue to be referred to locally as the Waimānalo high sea stand.

At present there is some controversy over the two proposed shorelines of the Waimānalo high sea stand. A double high sea stand is suggested both by stratigraphy and geochronology. Oxygen-isotope chronostratigraphy indicates a double high stand during the 5e substage (Martinson et al. 1987). Age dating of samples revealed two distributions of ages, one averaging 133 kya and another at 119 kya (Jones 1993b). In addition, there is field evidence of two high stand deposits, separated by a regressive in situ beachrock (Sherman et al. 1993). Recent data reveal neither the two age distributions nor the stratigraphic evidence for this double high stand on O'ahu (Muhs and Szabo 1994; Szabo et al. 1994). However, the wide range in ages may indicate that the last interglacial period was long-lived, perhaps as much as 20,000 years (Muhs 1991).

Ferrall (1976) reported the Waimānalo stand coral as high as +20 feet north of the Waikīkī area, based on previous work (Stearns and Vaksvik 1935) which noted reef limestone underlying the basalt in the Mō'ili'ili quarry. Stearns and Vaksvik hypothesized that this limestone correlated with the Waimānalo stand of the sea. Therefore, the four coral ledges defined for this study are probably Waimānalo in age. However, the history of their formation is unclear.

It is possible that all four coral ledges are actually part of the same coral occurrence and that the differences in elevation merely reflect a sloping subsurface topography of the top of the coral. The uppermost surface of the ledges is generally found at lower elevations in the seaward direction.

Another possibility is that the coral ledges are eroded surfaces cut into the reef as sea level receded from the Waimānalo high stand maximum, pausing at the different elevations. However, several boring logs examined for this study indicate that the –15 ledge may overlie the –30 ledge in some locations, separated by several feet of coralline debris. Ferrall (1976) also came to this conclusion. In addition, Ferrall concluded that the –15 ledge is continuous to below –30 feet in many locations. Thus it seems unlikely that the coral ledges are erosional surfaces that cut into the reef as sea level regressed.

Ferrall (1976) concluded that stratigraphic evidence points to the occurrence of separate, distinct ledges, with coral in growth positions. Cores examined by Ferrall revealed the surface of the +5 ledge to be composed of coralline algae and an encrusting coral called *Porites lobata*, both of which typically occur in the high-energy reef flat, in or near the zone of wave action (Ferrall 1976). He believed that this suggested that the sea paused just above this elevation as it receded from the +25-foot Waimānalo high stand. Ferrall found no instances of the +5 ledge overlying the –15 or –30 ledge. Also, he reported that there was an abrupt drop in elevation of the uppermost coral surface at the boundary between the +5 ledge and the –15 ledge. Ferrall's examination of a core for the –15 ledge also revealed *Porites lobata* at the uppermost surface; he interpreted this as an indication that the ledge was in the zone of wave action and therefore would have formed a few feet below sea level. These observations point to two distinct coral ledges formed at two separate stands of the sea, with the sea pausing just above the –15-foot elevation as it regressed after pausing just above the +5-foot elevation on its way down from the Waimānalo high stand. Alternatively, the –15 ledge could have formed as sea level rose after the post-Waimānalo low stand. However, Ferrall felt that *P. lobata* would not thrive in the lagoonal environment, which is indicated by the presence of lagoonal deposits above the –15 coral ledge. Therefore, he concluded that the –15 ledge is more likely to have formed during the regression of the sea from the Waimānalo high stand (Ferrall 1976).

In agreement with Ferrall's study, no evidence was found in the present study that the +5 ledge overlies the –15 ledge. There are several instances where a boring log reveals coral at an elevation indicative of the +5 ledge, and a nearby boring shows coral at a distinctly different elevation that would be indicative of the –15 ledge. This seems to point to an abrupt drop in elevation of the coral surface at the boundary between the two ledges, as reported by Ferrall (1976). However, the steep, abrupt termination of the coral ledges as shown on the plates for the subsurface cross-sections (for example, Subsurface Cross-Section B–B') and in Figure 3 may be overly exaggerated.

Ferrall examined several cores that led him to believe that the history of the –30 ledge was quite complex and that this ledge may have formed over a long period of time. He found a lower layer of coralline debris that may have been deposited as the sea transgressed from the Waipi'o low stand to the Waimānalo high stand. There was then a brief pause in sea level, at about –50 feet, allowing coral growth to cap and cement the coralline rubble, after which time sea level advanced to a height well past this elevation, as evidenced by a layer of coral *(Porites compressa)* that typically grows well below the wave base. Ferrall reported an unconformity (evidenced by a contrast in decomposition) between the underlying coralline debris and the overlying layer of *P. compressa*. He believed that the layer of coral was much less weathered than the underlying coralline rubble and concluded that this coral did not grow until the sea had transgressed to the +25 feet Waimānalo high stand level and then regressed back to the +5 or –15 level. Above the *P. compressa* layer is another layer of coral rubble, which formed as the regression continued. As sea level continued to drop, the coralline debris became cemented and alluvium was deposited over the ledge. Therefore, the history of the –30 ledge may be long and complex, involving pauses in sea level during both transgression and regression.

The +20 ledge designated in this study may actually be continuous with the +5 ledge named by Ferrall. However, there is some stratigraphic evidence revealed in the boring logs pointing to the existence of two separate coral ledges. A coral encountered at a high elevation representative of the +20 ledge overlies (separated by several feet of alluvium) a coral encountered at an elevation indicative of the +5 ledge (Quad Q–17). This would point to two separate ledges, with the +20 ledge postdating the +5 ledge.

The above discussion leads to several possible geologic interpretations for the formation of the coral ledges. According to Ferrall, as sea level advanced during the Waimānalo transgressive period, it paused at about –50 feet and cemented the lower layer of coralline debris that comprises the bottom of the –30 ledge. Then the sea-level maximum was reached during the Waimānalo high stand, followed by a fall in sea level. As regression continued, pauses in sea level resulted in the formation of the +20 and +5 ledges. As sea level continued to drop, another pause led to the growth of the –15 ledge, and another stop at about –30 feet cemented the top layer of coral rubble of the –30 ledge.

A much simpler interpretation is that, during the Waimānalo transgression, sea level may have paused briefly at or just above the –30, –15, +5, and +20 levels on its way up to the maximum level. This interpretation would account for the fact that the –15 ledge overlies the –30 ledge in places and that the +20 ledge overlies the +5 ledge in at least one location. It does not attempt to take into account the complexity of the –30 ledge as revealed by Ferrall's examination of cores. However, this simpler theory does correspond to the widely held belief that most coral growth occurs during sea-level rise. A falling sea level is more likely to result in erosion rather than coral growth (Carter and Woodroffe 1994). According to Ferrall's model, most of the reef growth supposedly took place during sea-level falls.

Alternatively, rather than sea level pausing several times during the Waimānalo transgression, reefs may have been responding to sea-level change by exhibiting a catch-up or keep-up behavior, meaning that vertical growth initially lags behind sea-level rise and then catches up or that vertical growth is rapid enough to keep up with the changing sea level (Carter and Woodroffe 1994).

If the coral ledges are indeed all Waimānalo in age, they may relate to the intervening interglacial events within oxygen isotope stage 5 (Martinson et al. 1987). Thus the warm periods during substages 5a and 5c and the double high stand during substage 5e may all have resulted in the growth of one or more of these ledges. The +20 and +5 ledges may date from the 5e (ca. 124 kya) double high stand, and the –15 and –30 ledges may date from the 5a (ca. 82 kya) and 5c (ca. 104 kya) interglacial events (Shackleton 1987). Because the +20 ledge appears to overlie and thus postdate the +5 ledge, it is unlikely that the +5 ledge dates from the Holocene Kapapa stand (discussed below), which is younger than the Waimānalo high stand.

An alternative theory holds that these upper coral ledges represent a planed-off erosional surface of the Ka'ena high sea stand (D. Fraim, Edward K. Noda & Associates, oral communication, 24 April 1995). However, the elevation at which the coral is found within the study area is highly indicative of the Waimānalo +25 feet high sea stand. Samples from the outcrop on the Honolulu Community College campus were shown to several researchers during the course of the present investigation. All agreed that there would be no reason to assume that this coral is from any stand other than the Waimānalo high sea stand (C. Sherman, Department of Geology and Geophysics, University of Hawai'i, oral communication, 16 June 1995; C. Fletcher, Department of Geology and Geophysics, University of Hawai'i, oral communication, 30 June 1995; J. Resig, Department of Geology and Geophysics, University of Hawai'i, oral communication, 30 June 1995).

To prove that the coral ledges are distinct and were formed at different times, evidence of an unconformity is needed. This could be ascertained through an examination of many cores; however, no cores were available for examination in sufficient detail for this study. Consulting companies only retain the actual cores for a brief period of time before disposing them, due to limited storage space.

Another problem is that reef growth can lag behind sea-level rise, so that studies of reefs lead to information on their accretion histories rather than sea-level histories. In addition, shorelines have probably been occupied by the sea more than once because of multiple glacial cycles, resulting in complex accretion histories (Fletcher and Sherman 1995). Age dating of corals and coralline algae from the different ledges is needed to verify the age relationships. Without further geochronology and core data, any interpretation is only speculative.

Māmala Low Sea Stand

The Waimānalo interglacial high stand of the sea was followed by a glacial low stand. The sea may have paused several times during this regression. The Māmala low stand, at –350 feet, is the lowest post-Waimānalo sea level; it was estimated to have occurred from ca. 21 to 14 kya (Fletcher and Sherman 1995), which is oxygen isotope stage 2 (Martinson et al. 1987). During the post-Waimānalo glacial low stand, erosion dominated and deep alluvial channels were cut through the coral ledges that formed during the Waimānalo high stand. These channels, which are 200 feet or more deep in the study area, are indicated on both the subsurface geologic maps (Plates 2, 4, and 6 in Appendix B) and the subsurface geologic cross-sections (Plates 7 through 15 in Appendix C). They include an old Ala Wai drainage and Makiki Stream on the eastern edge of the study area, Nu'uanu Stream in the downtown Honolulu area (Subsurface Cross-Section H–H'), Kapālama Channel in the Kapālama area (Subsurface Cross-Sections F–F' and I–I'), and Kalihi Stream at the western edge of the study area (Subsurface Cross-Sections D–D' and F–F'). In addition, there are at least three major buried alluvial channels in the study area: the Kāheka Channel at the eastern edge (Subsurface Cross-Sections A–A' and E–E'); the HIC Channel in the vicinity of the former Honolulu International Center, now called Blaisdell Center (Subsurface Cross-Sections B–B', E–E', and G–G'); and the Alakea Channel in the downtown Honolulu area, approximately paralleling Alakea Street (Subsurface Cross-Section H–H').

Kapapa High Sea Stand

In addition to the four coral ledges described previously, there is also some evidence of coral at or near present sea level. Ferrall (1976) referred to this as modern reef growth and theorized that it formed as sea level advanced to its present level after the last glacial low stand, recolonizing the –30 bench. Stearns (1978) listed two post-Waimānalo shorelines that formed within a few feet of sea level: the Leahi at +2 feet and the Kapapa at +5 feet. Stearns dated the Leahi shoreline at ca.

115 kya. It has been suggested that this shoreline may actually represent the second high stand during the Waimānalo transgression (Sherman et al. 1993).

Stearns (1977, 1978) dated the Kapapa shoreline at ca. 4 to 3.5 kya, or during a Holocene stand of the sea. Other researchers concluded that there is no evidence for a Holocene high stand on O'ahu (Easton and Olson 1976; Easton 1977). However, later researchers found a fossil reef tract on O'ahu at about –1.5 to –3 feet below sea level of Holocene age (Brückner and Radtke 1989), indicating a minimum sea-level elevation. The Holocene high stand is well-documented for Kaua'i, as well as for other islands in the Pacific Ocean and Indian Ocean (Jones 1992; Calhoun and Fletcher 1996), and has recently been documented for O'ahu (Fletcher and Jones 1996). Sea level may have been as much as 9 feet higher than present sea level, between 6 and 4 kya (Fletcher and Jones 1996).

It is possible that the coral growth noted close to the present shoreline throughout the study area (Quads C–10, C–11, D–10, D–11, G–11, I–12, K–17, K–18, and L–19) and categorized as modern or recent coral growth could have resulted from the Kapapa stand. These occurrences are patchy and generally less than 10 feet thick. The upper surface is usually located a few feet below to as much as –13 feet below present sea level. This coral is separate and distinct from the +5 ledge and is located closer to the present shoreline than the +5 ledge. In some places, it overlies the –30 ledge, separated from it by thick sequences of coralline debris (Subsurface Cross-Section B–B'). The shoreline was greatly altered in historic times through landfill activities; prior to reclamation it was located landward of the present shoreline in many locations in the study area. Therefore, coral growth noted at or near present sea level close to the present shoreline is now often found covered with a layer of heterogeneous fill.

The fine-grained lagoonal sediments, found below human-placed fill and contemporary soil and above all other units, are widespread in the study area. Thick sequences are found parallel to the shoreline (Subsurface Cross-Sections A–A', B–B', C–C', D–D', E–E', and F–F'). Holocene marine carbonate sediments have been identified in the Kawainui Marsh on O'ahu (Fletcher and Jones 1996). It is possible that the materials classified as lagoonal deposits in this study may represent the Kapapa stand on the Honolulu coastal plain.

After the Kapapa high stand, sea level fell to the present level. It appears that Hawai'i may again be experiencing a slowly rising sea level (Fletcher et al. 1995; Calhoun and Fletcher 1996).

Subsidence and Uplift of the Hawaiian Islands

The geologic history of the area is further complicated by the possibility of tectonic instability. Earlier researchers believed that the Hawaiian islands have been stable for at least the last half million years and, therefore, that O'ahu is one of the best places to determine Pleistocene glacioeustatic sea-level changes (Lum and Stearns 1970; Stearns 1978; Moore 1987). However, recent work suggests that O'ahu has been undergoing uplift for the last half million years and therefore is less a stable location on which to base global sea-level changes than previously thought (Jones 1993b; Muhs and Szabo 1994; Szabo et al. 1994).

The hot spot origin for the Hawaiian islands presents a complex picture of subsidence and uplift. As the Pacific Plate moves to the northwest, the lithosphere passes over the hot spot, where it is heated and expands, causing uplift. This uplifted area is called the Hawaiian Swell. In addition, as the lithosphere becomes loaded with the weight of the newly formed volcanic island and magma is removed at depth, it becomes locally depressed, causing subsidence. This depressed area is referred to as the Hawaiian Deep. The lithosphere cools and thickens as it moves off the hot spot, and subsidence results, so that the volcanoes northwest of Kaua'i become seamounts. Lithospheric flexing results in an upbowing of the plate distant from the loading in order to compensate for the loading and subsidence. Thus the Hawaiian Swell consists of an uplifted Hawaiian Arch which surrounds a depressed area called the Hawaiian Trough or the Hawaiian Deep, which surrounds the Hawaiian Ridge. Temporary uplift of an island occurs as it passes over the Hawaiian Arch. More downbowing occurs at new volcanic centers, where loading occurs, than at areas removed from the recent loading. Therefore, tilting of the islands occurs as they are rafted away from the hot spot by the movement of the Pacific Plate. In addition, local erosion can result in differential rebound, which can also cause tilting (Walker 1990; Jones 1993b; Muhs and Szabo 1994).

Relative rates of uplift, subsidence, and sea-level change are not known, but if sea level falls at the same rate as island subsidence occurs, the shoreline will appear to stay in one place for a long time. This can also occur if sea level rises and the island is uplifted at the same rate. If sea level drops as the island is being uplifted, it may appear that a rapid and large decline in sea level occurred. Conversely, if sea level rises as the island is subsiding, it may appear that the sea transgressed rapidly to a very high level. Reef growth would not be able to keep pace, and the reef would drown, resulting in a submerged carbonate terrace. Another complication is that rates of uplift, subsidence, and sea-level change are probably not uniform through time (Moore and Fornari 1984; Moore and Campbell 1987; Moore et al. 1990).

One theory maintains that the islands are subsiding too fast for any former high stands to have left reef material that would still be above sea level (Moore and Moore 1984). However, recent evidence suggests that compensatory upward lithospheric flexure of several islands (Lāna'i, Moloka'i, O'ahu) distant from the loading at the hot spot (Big Island) has resulted in reefs that formed during interglacial warming episodes and that are now located at high elevations on these islands (Jones 1993a).

Some of the reef material found at high elevations (up to +1,200 feet) on some islands (Lāna'i, Moloka'i) was previously thought to have formed during high sea-level stands (Stearns 1978). A more recent theory suggests that these very high-elevation deposits were placed there by a giant wave, probably resulting from a huge submarine landslide on the slope of one of the islands (Moore and Moore 1984; Moore et al. 1994; Kerr 1994). However, a wide range in ages for these deposits argues against their placement by a single catastrophic event (Rubin et al. 1995). Alternatively, some aspects of these deposits found at high elevations may actually be archeological in origin, consisting of dryland agricultural terraces built by Native Hawaiians (Jones 1993a). However, the widespread nature of the coral ledges in the study area and in Waikīkī (Ferrall 1976) argues against the possibility of their placement by giant waves or by humans.

It is now clear that separating out glacioeustatic sea-level changes from the subsidence and uplift history of the islands is difficult. Variations in isostatic, eustatic, and tectonic processes mean that reconstruction of sea-level changes and comparisons of shorelines from one part of the world to another are difficult. In addition, differential tilting, local deformation, and erosion can make correlating shorelines difficult, even from one island to another (Coulburn et al. 1974; Moore 1987). One can conclude that although worldwide sea-level changes must have occurred, the resultant erosion notches or reef ledges are not uniform in elevation everywhere; therefore, these features should be considered to have local significance only (Dawson 1992).

More age dating is needed on both the post-erosional volcanics within the study area and the corals and coralline algae from the four ledges. In addition, thin sections and petrographic analyses, along with detailed examinations of cores, would be of great help in unraveling the geologic history of the O'ahu shoreline. This would aid in developing a better understanding of sea-level changes and uplift and subsidence in the Hawaiian islands. Table 1 presents a summary of the major events in the geologic history of the study area as discussed above. It should be kept in mind that the geologic history presented here is highly speculative. Without further information, it is difficult to make any statement concerning the ages of the coral ledges or age relationships between the different coral ledges, if they formed during a regression or transgression of the sea, or if they are located at their present elevations due to some combination of regression or transgression along with uplift or subsidence. Age dating of submerged shorelines (Fletcher and Sherman 1995) may provide additional insight into the formation of coral ledges in Hawai'i.

CHAPTER 4. ENGINEERING GEOLOGY

The purpose of this chapter is to delineate the location of the materials (as defined in Chapter 2) within the study area, indicating both the lateral extent and the position in the subsurface. Therefore, elevations and thicknesses are reported, as are descriptions of materials found above or below the unit being described. Another purpose is to categorize the subsurface materials in the study area by physical properties and discuss their strengths and foundation-bearing characteristics. The suitability of each subsurface unit as a foundation-bearing layer is discussed. Problems associated with foundations bearing on certain of the less competent materials within the study area are summarized. Recommendations for foundation design are reviewed.

This chapter provides a general review of the competency of the subsurface materials in the study area. In a study of this magnitude, it is necessary to make generalizations about the subsurface geology and the adequacy of a unit as a foundation-bearing layer. Therefore, it is emphasized that the information in this report cannot substitute for a site investigation. Local variations in subsurface materials must be looked for at each site being investigated, and deviations from the generalizations presented here must be considered in the design and construction of high-rise buildings and other engineering structures.

Methods of Investigation

The project reports surveyed for this study include data on blow counts, rock quality designations, and field and laboratory soil and rock tests. Blow counts are the number of blows of a hammer required to drive a sampler a specified depth into the subsurface. The counts can be used to compare strengths or competency of subsurface units. For example, the subsurface material that requires 100 blows for the sampler to be driven 1 foot in depth is more competent than a unit that only requires 3 blows for the sampler to be driven 1 foot in depth. The less competent material is obviously softer and therefore may cause problems if a building is constructed on it. However, because there are differences even within units, due to factors such as heterogeneity and variations in cementation, blow counts alone cannot be used to categorize the subsurface materials for foundation-bearing purposes. Blow counts are used in this report to compare the strengths of the units relative to each other. Blow count data are summarized in Tables 2 through 4.

A problem with using blow counts to determine strength characteristics of the subsurface materials is that there are several different systems in use. One common system is the Standard Penetration Test, which uses a 140-pound weight falling from a distance of 30 inches to drive a 2-inch split spoon sampler. Dames & Moore uses a similar system, with a 140-pound hammer being dropped 30 inches, but the sampler used is a different size. A third method, also used by

TABLE 2. Blow Counts for Subsurface Materials Using Standard Penetration Test[a]

Material	Blow Counts Per Foot			No. of Values Reported
	Minimum	Maximum	Average	
Deep coral	35	166	87	29
–30 coral ledge	33	210	107	25
–15 coral ledge	5	107	52	59
+5 coral ledge	36	103	66	30
+20 coral ledge	19	99	67	25
Residual soil or weathered volcanics	—	—	—	—
Tuff	19	79	40	14
Cinders	3	170	33	35
Basalt (per 0.3')	10	40	22	5
Alluvial deposits	4	93	42	66
Coralline debris	1	160	37	532
Beachrock	15	170	60	36
Lagoonal deposits	1	37	6	292
Fill	1	146	15	83

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

[a]This test uses a 140-pound weight falling from a distance of 30 inches to drive a 2-inch split spoon sampler into the subsurface material.

TABLE 3. Blow Counts for Subsurface Materials Using Dames & Moore System (140#/30")[a]

Material	Blow Counts Per Foot			No. of Values Reported
	Minimum	Maximum	Average	
Deep coral	90	185	135	6
–30 coral ledge	—	—	—	—
–15 coral ledge (per 4")	50	70	54	6
+5 coral ledge	100	370	219	9
+20 coral ledge (per 3")	75	100	92	3
Residual soil or weathered volcanics	59	59	59	1
Tuff	56	100	75	3
Cinders	6	137	37	28
Basalt	—	—	—	—
Alluvial deposits	5	134	42	126
Coralline debris	5	112	26	73
Beachrock	—	—	—	—
Lagoonal deposits	1	36	10	16
Fill	1	66	26	11

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

[a]This test uses a 140-pound weight falling from a distance of 30 inches to drive a Dames & Moore Type U sampler into the subsurface material.

TABLE 4. Blow Counts for Subsurface Materials Using Dames & Moore System (300#/30")[a]

Material	Blow Counts Per Foot			No. of Values Reported
	Minimum	Maximum	Average	
Deep coral	13	121	67	18
−30 coral ledge	40	108	68	18
−15 coral ledge	25	176	89	33
+5 coral ledge	22	176	74	37
+20 coral ledge	58	160	97	7
Residual soil or weathered volcanics	11	167	38	15
Tuff	24	154	84	14
Cinders	8	185	50	38
Basalt (per 2")	50	80	65	2
Alluvial deposits	6	214	35	218
Coralline debris	1	129	29	571
Beachrock	8	114	40	26
Lagoonal deposits	0	27	4	234
Fill	1	80	14	46

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

[a]This test uses a 300-pound weight falling from a distance of 30 inches to drive a Dames & Moore Type U sampler into the subsurface material.

Dames & Moore, utilizes a 300-pound hammer dropped from a height of 30 inches. Because of these variations in sampler size and hammer weight, blow counts in the logs cannot be directly compared. There is no known correlation among the different systems and therefore no conversion factor available to directly compare blow counts obtained using the different methods. In addition, some boring logs report the counts in blows per inches or some fraction of a foot rather than in blows per foot. This also makes comparisons difficult.

The geotechnical consulting firms' reports also include information on dry densities and moisture contents of the subsurface materials, as measured in the field or laboratory. In general, a material with a high dry density will have greater strength and less tendency to compress or settle than a material with a low dry density. Dry density and moisture content values are summarized in Tables 5 and 6.

When data were available, angles of internal friction for the soils were tabulated. Friction angles for soils generally increase with the relative density of compaction. Therefore this can give some indication of the density of the unit. Consolidation values abstracted from the consulting reports were summarized. Consolidation occurs when excess pore water pressure in a fine-grained soil is slowly released upon loading of the soil. This increases the effective stress, which induces settlement. Therefore, consolidation values can give an indication of the potential of the material to

TABLE 5. Dry Density of Subsurface Materials, Downtown Honolulu, O'ahu, Hawai'i

Material	Dry Density (lb/ft^3)			No. of Values Reported
	Minimum	Maximum	Average	
Deep coral	84	113	100	8
–30 coral ledge	60	60	60	1
–15 coral ledge	74	115	92	27
+5 coral ledge	83	128	101	30
+20 coral ledge	89	113	102	17
Residual soil or weathered volcanics	78	110	91	8
Tuff	56	108	81	19
Cinders	74	103	88	27
Basalt	173	183	179	9
Alluvial deposits	47	115	77	93
Coralline debris	63	116	92	97
Beachrock	—	—	—	—
Lagoonal deposits	41	122	77	59
Fill	46	115	81	39

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

TABLE 6. Moisture Content of Subsurface Materials, Downtown Honolulu, O'ahu, Hawai'i

Material	Moisture Content (%)			No. of Values Reported
	Minimum	Maximum	Average	
Deep coral	20	31	24	6
–30 coral ledge	14	14	14	1
–15 coral ledge	18	46	32	27
+5 coral ledge	—	—	—	—
+20 coral ledge	9	27	18	17
Residual soil or weathered volcanics	9	28	16	8
Tuff	31	72	42	18
Cinders	2	49	18	27
Basalt	—	—	—	—
Alluvial deposits	19	80	45	93
Coralline debris	13	49	29	94
Beachrock	—	—	—	—
Lagoonal deposits	10	128	47	58
Fill	8	90	39	39

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

consolidate and settle, which could result in foundation failure. Friction angles and consolidation values for the subsurface materials are reported in Tables 7 and 8, respectively.

Core drilling is another field method used to obtain samples and determine properties of more competent subsurface materials. A hollow tube core barrel is used to drill the hole and obtain a sample of the material. Several core parameters can be measured to characterize rock properties. Core recovery ratio is the length of core recovered compared to the length of rock cored, as given by the following equation:

$$\text{Core recovery ratio (\%)} = \frac{\text{length of core recovered}}{\text{theoretical length of rock cored}}$$

The rock quality designation is the total length of the pieces of core, 4 inches or more in length, expressed as a percent of the overall core length, as follows:

$$\text{Rock quality designation} = \frac{\Sigma\text{length of recovered pieces equal to or larger than 4 inches}}{\text{theoretical length of rock cored}}$$

The values obtained from the rock quality designation can be used to provide a general evaluation of the in situ rock quality, as presented below:

Rock Quality Designation (%)	Rock Quality
90–100	Excellent
75–90	Good
50–75	Fair
25–50	Poor
0–25	Very poor

Core recovery ratios and rock quality designations obtained from boring logs are summarized in Table 9.

Laboratory tests that measure the strength of materials include the direct shear, the triaxial compression, and the unconfined compression tests. Other tests used to determine the strength of cohesive soils include the vane shear test and torvane test. The results of these strength tests, included in a number of reports surveyed for this study, were compiled for each subsurface unit and are summarized in Table 10.

Other engineering properties that were obtained from the site reports surveyed are bearing capacity and pile-load capacity. The bearing capacity of a soil is the pressure that a foundation can impart to the soil without causing failure or excessive settlement. The value of the bearing capacity for a particular material may be arrived at by using equations or results of soils tests or by relating soil type to a bearing capacity recommended in building codes (McCarthy 1988). In the reports surveyed, when a pile foundation is proposed, the pile type, length, and load capacity are recommended. Where available, soil-bearing capacities and pile-load capacities were summarized

TABLE 7. Friction Angle of Subsurface Materials, Downtown Honolulu, O'ahu, Hawai'i

Material	Friction Angle (°)			No. of Values Reported
	Minimum	Maximum	Average	
Deep coral	—	—	—	—
–30 coral ledge	—	—	—	—
–15 coral ledge	—	—	—	—
+5 coral ledge	—	—	—	—
+20 coral ledge	45	45	45	1
Residual soil or weathered volcanics	—	—	—	—
Tuff	—	—	—	—
Cinders	21	60	38	38
Basalt	—	—	—	—
Alluvial deposits	22	47	34	17
Coralline debris	33	52	45	3
Beachrock	—	—	—	—
Lagoonal deposits	13	53	32	12
Fill	22	63	38	14

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

TABLE 8. Consolidation Value of Subsurface Materials, Downtown Honolulu, O'ahu, Hawai'i

Material	Consolidation Value (%)			No. of Values Reported
	Minimum	Maximum	Average	
Deep coral	—	—	—	—
–30 coral ledge	—	—	—	—
–15 coral ledge	—	—	—	—
+5 coral ledge	—	—	—	—
+20 coral ledge	—	—	—	—
Residual soil or weathered volcanics	—	—	—	—
Tuff	4	4	4	1
Cinders	0	9	4	4
Basalt	5	5	5	1
Alluvial deposits	4	23	14	13
Coralline debris	14	14	14	1
Beachrock	—	—	—	—
Lagoonal deposits	2	56	27	45
Fill	3	18	8	14

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

TABLE 9. Core Recovery Ratio and Rock Quality Designation of Subsurface Materials, Downtown Honolulu, O'ahu, Hawai'i

Material	Core Recovery Ratio (%)			No. of Values Reported	Rock Quality Designation (%)			No. of Values Reported
	Minimum	Maximum	Average		Minimum	Maximum	Average	
Deep coral	8	100	66	33	0	100	41	26
–30 coral ledge	5	100	77	61	0	97	55	33
–15 coral ledge	0	100	78	131	0	95	52	69
+5 coral ledge	10	100	83	270	0	100	72	110
+20 coral ledge	16	100	80	103	0	94	47	28
Residual soil or weathered volcanics	—	—	—	—	—	—	—	—
Tuff	0	100	71	79	0	88	36	23
Cinders	69	69	69	1	36	36	36	1
Basalt	20	100	82	79	17	100	59	216
Alluvial deposits	0	100	66	19	0	100	28	10
Coralline debris	0	100	44	160	0	98	17	133
Beachrock	50	100	86	15	0	100	63	15
Lagoonal deposits	—	—	—	—	—	—	—	—
Fill	—	—	—	—	—	—	—	—

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

TABLE 10. Strength of Subsurface Materials, Downtown Honolulu, O'ahu, Hawai'i

Material	Strength (lb/ft^2)			No. of Values Reported
	Minimum	Maximum	Average	
Deep coral	29,520	374,400	137,664	7
–30 coral ledge	15,264	645,696	117,360	9
–15 coral ledge	11,520	612,000	117,936	28
+5 coral ledge	930	488,880	70,604	66
+20 coral ledge	5,760	814,896	161,712	17
Residual soil or weathered volcanics	600	10,125	3,568	8
Tuff	493	223,200	36,382	11
Cinders	25	104,400	5,073	120
Basalt	956	3,720,960	2,456,868	11
Alluvial deposits	130	540,000	7,876	337
Coralline debris	250	114,480	7,071	121
Beachrock	800	28,450	6,386	17
Lagoonal deposits	50	6,660	972	115
Fill	220	15,600	1,465	101

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

for each unit and included in this report. These data can also be used to compare the ability of the subsurface material to support a structure. Units with higher bearing capacities and pile-load capacities will be less subject to excessive settlement and resulting foundation failure than units with low capacities. The pile length is of interest because shorter piles are less expensive and easier to handle.

Results and Discussion

Fill

Occurrence

A heterogeneous artificial fill of variable thickness blankets the surface of most of the study area. There is a tendency for the fill to be thicker near the shoreline, where many areas formerly under water have been reclaimed by the placement of fill and brought up to grade. Fill thickness varies from less than 1 foot to as much as 30 feet, averaging between 5 and 10 feet throughout the study area. On the *mauka* side of the study area, there is often a negligible layer of fill or topsoil grading down to alluvial slopewash materials. As these materials are usually heterogeneous in nature, consisting of clays and silts with cobbles and boulders, they have generally been considered as one unit. They are described together as one unit in the boring logs.

Engineering Properties

There is a wide range of blow count values recorded for the heterogeneous fill, even though compared to the other subsurface materials, the fill is characterized by low blow counts. There is also a wide range of dry density and moisture content values recorded. Consolidation values reported ranged from 3% to 18%. Friction angles reported for fill varied from 22° to 63°, averaging 38°. Bearing capacities reported varied from 1,500 to 3,000 pounds per square foot.

In general, the placement of fill in the study area has been haphazard. In some areas, hydraulic fill was placed. In many areas, the placement of fill was accomplished by dumping soil, rocks, and trash on the surface. Often, the material was not engineered or compacted to meet foundation-bearing specifications. In many instances, organic material, which can decompose and decrease the stability of the unit, was included with the fill. The heterogeneity of the fill in the study area means that compressible materials could be included; thus changes in volume are possible. A foundation on this material could undergo significant settlement.

Implications for Construction

Excavation of fill is easy and can be accomplished using a backhoe. In general, fill is not an adequate foundation-bearing layer, and the uppermost mantle should be bypassed when constructing a foundation. It may be possible to excavate and remove the loose fill and then replace it with engineered compacted backfill that would be capable of supporting a foundation, such as shallow spread or continuous footings. Fill that has been properly placed and compacted in layers can have adequate strength to support a structure. However, the high groundwater table in the study area often makes such excavation impractical, as soil beneath neighboring foundations could collapse. Another possibility is to scarify, proofroll, and recompact the fill already present at the site. However, the presence of organics could still be a concern for future decomposition and volume change, and there could be a problem with causing additional settlement of underlying soft lagoonal or alluvial materials. A site investigation should be conducted to assess the suitability of the fill to support a foundation or the practicality of recompacting or replacing the fill with controlled select material.

Lagoonal Deposits

Occurrence

Lagoonal deposits are generally the first material encountered beneath the fill. These low-energy deposits are found paralleling the coast in areas of former wetlands and are also found extending inland into drowned stream channels and estuaries. They are dark-colored, fine-grained, soft, loose, and compressible; however, alluvium, coralline debris, and volcanics such as cinders may be found within the thick sequences of these deposits. Lagoonal deposits are often 20 feet thick or more, but some borings conducted offshore have shown that these soft lagoonal deposits, also called harbor sediments in some boring logs, can be as much as 166 feet thick.

Engineering Properties

Lagoonal deposits are characterized by the lowest blow counts of any material in the study area. In addition, these deposits generally exhibit low dry densities, high moisture contents, and low compressive strengths and bearing capacities. Bearing capacity values ranging from 1,000 to 4,000 pounds per square foot were found in reports surveyed for this study, with the higher values reported for consolidated deposits. Lagoonal deposits are also characterized by the highest values for consolidation of any material in the study area, with values as high as 56% reported. Organics, such as decomposed vegetation and peat, are often found within lagoonal materials. In site reports the organic content of lagoonal sediments was estimated to range from 17% to 30%. These can decompose over time and result in consolidation. Permeability is low, thus drainage occurs slowly; and settlement can occur over a very long period of time. Friction angles ranged from 13° to 53°, averaging 32°.

Implications for Construction

Lagoonal deposits are easy to excavate due to their soft and loose nature, but these characteristics also mean that these deposits are difficult to sample. This material is an unsuitable foundation-bearing layer because it is highly compressible. Any structure bearing on lagoonal materials may undergo both overall and differential settlement. Other materials with different strengths, such as cinders and coralline debris, are often found within thick sequences of lagoonal deposits. In addition, some lagoonal materials may be more consolidated than others. This can result in differential settlement and even foundation failure. Only a structure that can tolerate differential settlement should be constructed directly on lagoonal deposits. Consulting reports surveyed for this study suggested the use of mat foundations, combined mat-type, continuous strip-type, spread footings, and individual footings for low-rise buildings that can tolerate settlements. The alternative is to use a foundation that bypasses this material entirely, such as piles bearing on deeper, more competent units. However, the process of pile driving may partly consolidate the lagoonal deposits, creating additional loading on the pile by downdrag. This must be compensated for, to avoid exceeding the allowable bearing capacity or pile-load capacity. A site investigation may determine that it is possible to surcharge this unit by placing excess fill or other heavy materials on the unit to preconsolidate and induce settlement prior to construction. However, as mentioned above, this may take a long time, perhaps six months or more.

Alluvial Deposits

Occurrence

Alluvial deposits occur throughout the study area. They may be found as thin lenses within other materials such as lagoonal deposits, as thick sequences intermixed with coralline debris and cinders in former stream channels that cut through the other units (including the coral ledges), or as slopewash materials eroding off the Ko‘olau Range. The slopewash alluvium, found at the *mauka* edge of the study area at higher elevations, is generally only a few feet thick. In boring logs this material may be referred to as "adobe." In old stream beds, alluvial deposits are found extending to the bottom of drill holes, as deep as 260 feet below grade. Alluvial deposits are also found paralleling Kalihi Stream, Kapālama Canal, Nu‘uanu Stream, Makiki Stream, and the Ala Wai Canal. In addition, deposits occur in three main former stream channels in the study area: the Kāheka Channel at the eastern edge of the study area; the HIC Channel in the Blaisdell Center region; and the Alakea Channel which approximately parallels Alakea Street in the downtown Honolulu district.

Engineering Properties

The blow count data summarized in Tables 2, 3, and 4 indicate that there is a wide range in values for alluvial deposits. In general, this subsurface material is characterized by higher blow counts than fill or lagoonal deposits but by lower counts than the more competent units such as the coral ledges and basalt. Alluvial deposits in the study area are primarily composed of a stiff brown silt, with abundant cinders, coralline debris, and low-energy deposits. This makes this material a fairly heterogeneous unit, with variable engineering properties. Friction angles reported for alluvial deposits range from 22° to 47°, averaging 34°. Dry densities can be low and moisture contents high. The rock quality designations also cover a wide range, varying from 0% to 100%; however, the average of 28% falls into the category of "poor." On average, compressive strengths recorded for alluvial deposits are higher than for fill and lagoonal materials and comparable to that recorded for cinders or coralline debris. Bearing capacities as low as 1,000 and as high as 6,500 pounds per square foot were found in the reports. These values are also higher than those for fill and lagoonal deposits but comparable to those for cinders. Since alluvial deposits almost always include abundant cinders, in many cases, these values could probably be considered for either unit or for an alluvium/cinder material. Consolidation values reported are variable but tend to be high, indicating that this unit can be compressible. Alluvial deposits tend to be more consolidated with depth, due to the weight of the overlying material and the greater age of the deeper deposits, having had more time to dry out and consolidate. A low sea stand can also contribute to consolidation by allowing the sediments to drain and compact. Underconsolidated alluvial deposits are often found at shallower elevations, are more recent, and are characterized by low strength and high plasticity.

Alluvial and low-energy deposits that accumulate rapidly under water and have never been exposed and desiccated will be underconsolidated and subject to settlement. Consolidation values reported range from 4% to 23%.

Implications for Construction

Alluvial deposits are fairly heterogeneous, but in general, this subsurface unit is easy to excavate. The only difficulty in excavation would be caused by abundant boulders, but these occur in localized areas only. Alluvial deposits can be underconsolidated and compressible, which means a foundation bearing on this unit could undergo both overall and differential settlement. Only a light-weight structure or one that can tolerate settlement should be constructed on alluvial deposits. Suggested foundation types are shallow spread or continuous footings, for low-rise structures that can tolerate anticipated settlements. In general, it is better to bypass this unit and utilize a deeper, more competent foundation-bearing layer, such as basalt or a coral ledge. However, this is often not possible. There are instances in Honolulu of buildings being constructed over ancient alluvial channels, so that one section of the building bears on a competent coral ledge, while another section bears on the alluvial deposits within an old channel. This can result in serious differential settlement problems. Extensive consolidation testing at the site is required prior to design and construction. Friction piles, which derive their resistance from skin friction or adhesion, driven to the deeper and more consolidated alluvial deposits, can be used in these circumstances. However, the successful use of friction piles requires a thorough site investigation, combined with good judgment and experience (Das 1990). The adobe found in the slopewash alluvium at higher elevations is highly compressible and should be excavated prior to construction.

Coralline Debris

Occurrence

In general, coralline debris is found paralleling the coast and extending up former stream valleys. It is often found above and below coral ledges, intermixed with alluvial deposits, and within lagoonal layers. The thickness of this unit is extremely variable, ranging from lenses as thin as 1 foot to thick sequences of 50 feet or more. The thicker deposits are often found interlayered with alluvial deposits. In former stream channels, alluvial deposits and coralline debris are found intermixed to as deep as 260 feet below grade. Coralline debris consists primarily of silty calcareous sand and gravel. However, for the purposes of this study, it is also defined by strength, so that in areas where the distinction between coralline debris and coral ledge is difficult, the material is classified as coralline debris when blow counts are too low to categorize the unit as coral ledge. Consequently, a poorly cemented coral ledge may be classified as coralline debris. Often, there is a foot or two of weakly cemented coral on top of a coral ledge. Thus the top of a coral ledge is categorized as coralline debris. In addition, hard ledge coral often grades down into weaker material, which then would also be classified as coralline debris. Coralline debris tends to be more prevalent in the eastern part of the study area than toward the west.

Engineering Properties

The engineering properties of coralline debris depend to a large extent upon its degree of cementation. This is reflected in the wide range in blow counts reported in Tables 2, 3, and 4. Well-cemented hard coralline debris, like beachrock, is characterized by high blow counts. Dry densities for coralline debris tend to be high and moisture contents low, compared to other subsurface units. The rock quality designation for coralline debris is highly variable but averages only 17%, which puts it in the category of "very poor." By comparison, beachrock averages 63%, which is considered "fair." Compressive strengths for coralline debris are also variable, again reflecting the degree of cementation as well as the intermixing of coralline debris with other subsurface units. Munro (1981) reported compressive strengths ranging from 1,000 to 5,000 pounds per square foot for uncemented coralline debris and 3,000 to 10,000 pounds per square foot for cemented coralline debris lenses in the Pearl Harbor area. Reports surveyed for this study revealed compressive strength values ranging from 250 to nearly 115,000 pounds per square foot, with an average of about 7,000 pounds per square foot—comparable to values reported by Munro. Ferrall (1976) did not report any values for the Waikīkī area, stating that the strength properties of coralline debris were too difficult to generalize. Reports examined for this study indicated bearing capacities ranging from 2,500 to 4,000 pounds per square foot. Munro (1981) reported bearing capacities of 2,000 to 4,000 pounds per square foot for coralline debris in the Pearl Harbor area. Reports surveyed for this study provided only one consolidation value for coralline debris; therefore, no generalizations can be made about compressibility of this unit. However, it can be assumed that if intermixed with compressible alluvial deposits or lagoonal materials, coralline debris can undergo significant consolidation. The angle of internal friction varied from 33° to 52°, averaging 45°.

Implications for Construction

The ease of excavation of coralline debris depends on the degree of cementation, as this material may be weakly cemented and relatively soft or well-cemented and hard. The degree of cementation, thickness, and intermixing with soft materials also determines the suitability of this material as a foundation-bearing layer. There can be rather extreme variations in the degree of cementation within a lens of coralline debris, and this can vary abruptly in both the horizontal and vertical directions within a deposit. Each site needs to be carefully examined for the degree of cementation, strength, and compressibility of this material. Reports surveyed for this study recommend using shallow or mat foundations for low-rise structures and piles for high-rise buildings.

Coral Ledges

Occurrence

A number of boring logs showed evidence of coral ledges that were deeper and older than the ledges defined between elevations of +20 and –30 feet. Any hard and dense coral found deeper than an elevation of –50 feet was categorized as deep coral ledge. The deep coral ledges occurred at varying depths in the subsurface rather than at consistent elevations; therefore, correlation of deep coral ledges between boreholes was not possible. Deep coral ledges were generally less than 10 feet thick and averaged about 6 feet thick, with a few exceptions. The exceptions, as indicated in the boring logs, were deep coral ledges that were as thick as 38 feet. However, no more than six references were made to deep coral over 20 feet thick. The deeper coral ledges were only present in the eastern part of the study area, where they paralleled the coast. However, it may be that deeper borings need to be made in the western part of the study area to reveal the presence of the deeper coral ledges.

Coral ledges first encountered between elevations of +22 and –30 feet are probably Waimānalo (oxygen isotope substage 5e) in age, which has been dated at ca. 124 kya (Shackleton 1987). The –30 coral ledge is defined as that hard and dense ledge first encountered between elevations of –30 and –50 feet. In the study area, it is as thin as 3 feet and as thick as 35 feet, averaging about 15 feet thick. It parallels the shoreline and is the most seaward ledge coral mapped. It is also more prevalent in the eastern part of the study area than toward the western side.

Massive ledge coral first encountered between elevations of –15 and –29 feet is classified as the –15 coral ledge. The thickness is variable, ranging from 2 to 30 feet and averaging about 12 feet. This coral ledge also parallels the coast and is located just inland of the –30 coral ledge. It is also primarily found in the eastern part of the study area.

Ferrall (1976) referred to coral found as high as +10 feet as part of the +5 ledge. Therefore, for this study, the +5 coral ledge is defined as that ledge first encountered between elevations of +10 and –10 feet. This ledge, which also parallels the shoreline, is found inland of the –15 coral ledge. The thickness is highly variable, ranging from about 1 to 42 feet and averaging 15 feet. It appears in the subsurface as a band from the eastern part of the study area clear through to the western part. In the eastern part of the study area, it is found as far *mauka* as the H-1 Freeway in some places. Toward the western side of the study area, it is located closer to the shoreline.

In the central and western parts of the study area, a coral ledge was found as high as an elevation of +22 feet. Therefore, for this study, the +20 coral ledge is defined as that ledge first encountered between elevations of +22 and +10 feet. This ledge varies from 2 to 30 feet thick and averages about 12 feet thick. It is located inland of the +5 coral ledge in the central and western parts of the study area but is not found in the eastern part of the study area. It is located as far inland as the H-1 Freeway in some areas.

Engineering Properties

The coral ledges are characterized by some of the highest blow counts of any material in the study area. Their compressive strengths and dry densities are also high and their moisture contents low. Their rock quality designations vary from 0% to 100%, indicating a wide range in in situ rock quality, but the averages fall between "poor" and "good." No consolidation values were recorded for coral ledges in the reports surveyed for this study. Maximum bearing values ranged from 3,000 to 10,000 pounds per square foot. Both Ferrall (1976) and Munro (1981) recorded bearing capacities of 6,000 to 12,000 pounds per square foot for coral ledges located in other areas on O'ahu. Allowable pile-bearing capacities found in reports used for this study ranged from 40 to 200 tons per pile. Ferrall (1976) reported the use of pile capacities between 40 and 100 tons per pile and concluded that pile capacities up to 100 tons per pile were acceptable on the coral ledges in the Waikīkī area. However, he also stated that this figure may be too high in some cases, due to excessive settlement beneath and within the coral for loads this high. Therefore, the use of pile-bearing capacities as high as 200 tons per pile found in this study may be questionable.

Although coral ledges are among the hardest and strongest of the subsurface units within the study area, there are a number of problems associated with the use of coral ledges as foundation-bearing layers. The most common are inconsistent thickness, areal extent, and hardness. Ledge coral at a site can vary from only a few feet to more than 10 feet in thickness, and it often has solution cavities that may be partially filled with soft sand. The degree of cementation and the amount of fracturing are also highly variable, both in the vertical and lateral directions. Often, the only distinction between ledge coral and coralline debris is the degree of cementation, which is reflected in blow counts. Therefore, there are probably many instances of ledge coral being misidentified as coralline debris and vice versa. However, for the purposes of this study, ledge coral is defined as that hard and dense coral characterized by blow counts of over 50 blows per foot (Dames & Moore system, 140-pound weight falling from a height of 30 inches), a rock core recovery of over 50%, and a rock quality designation of over 40%. In the consultants' reports surveyed for this study, this was the most common definition used to classify coral ledge.

Table 9 shows some core recovery and rock quality designation values that vary from those defined. This is due to the fact that some boring logs which referred to a unit as coral ledge revealed that the unit varied from hard to moderately hard to soft, depending on depth in the subsurface. Some logs indicated that the hard coral ledge graded to coralline debris and then back to hard coral ledge with an increase in depth. It is obvious that although the coral ledge is in general a hard and dense unit, there can be many irregularities in the strength of this material. Only a thorough site investigation can reveal the various irregularities so that the foundation can be properly designed.

Implications for Construction

The ease of excavation depends on the degree of cementation and fracturing of the coral ledge. In general, this material has enough in situ strength to allow excavation without bracing the sides of the excavation pit. Uncemented material may slough off into the excavation pit. If hard and well-cemented, excavation may be difficult.

One of the problems associated with using the coral ledge as a foundation-bearing layer is the presence of cavities. If the cavities are filled with soft sand, the ledge may be compressible, resulting in differential settlement of the foundation. Piles driven into these cavities may fall through and thus not bear any of the weight of the foundation. Therefore, the coral ledge may need to be probed to delineate these cavities; if present, the cavities may require infilling with concrete or cement grout prior to construction at the site. For well-cemented, dense coral ledges without cavities, settlement is generally not an issue. Dewatering of coral ledges may be difficult due to their relatively high hydraulic conductivity.

For low-rise structures, shallow foundations such as spread, mat, or continuous footings have been used on the coral ledges at or near ground surface. For high-rise buildings, end-bearing piles have been used on the coral ledges. Short piles (less than 25 feet) with low allowable bearing capacities (50 tons per pile) have been used on the +5 coral ledge.

Because of the variation in thickness and degree of cementation, many of the site reports examined recommend bypassing the upper coral ledge and using deeper coral ledges as the foundation-bearing stratum for piles. This requires predrilling through the upper coral ledge in order to place end-bearing piles on the lower ledges. The reports surveyed for this study indicated that using pile lengths in excess of 100 feet may be necessary. However, there is the possibility that piles driven to the deeper ledges would break through the coral in areas where the thickness or density is insufficient to provide support or in areas where excessive hammering is used to drive the pile. In the reports estimates of 15% to 30% were given for the number of piles that would break through the deeper ledges. If this occurs, the piles would need to be driven deeper until they achieve sufficient bearing capacity, or they could be abandoned. Recommendations for pile type include 12-inch square, 14-inch square, and 16.5-inch octagonal prestressed concrete piles.

Cinders

Occurrence

Black cinders, although widespread in the study area, are primarily located in the east-central part, between Pi‘ikoi Street on the east and Nu‘uanu Avenue on the west, within the Kaka‘ako and downtown Honolulu districts.

Cinder deposits in the study area are generally located below the fill and alluvial topsoil layer. They are also located below the lagoonal materials in regions where such sediments occur.

However, they are often found above the coral ledges. Cinders are of variable thickness, ranging from 0.5 to 55 feet, but averaging between 5 and 10 feet in the study area. The thicker deposits, which occur toward the *mauka* side of the study area, are found as reworked cinders within the old alluvial channels, especially within the HIC Channel.

Engineering Properties

There is a great range in blow counts for cinders, reflecting the degree of compaction and cementation of the deposits. In some locations, the Tantalus/Roundtop cinders are still in a loose, uncompacted condition. In other locations, the cinders have been compressed and cemented to a hard and dense state. In general, blow counts for cinders are higher than counts for fill or lagoonal deposits and approximately comparable to counts for alluvial deposits or coralline debris. Dry densities for cinders tend to be high and moisture contents low. Values for strengths vary widely, again reflecting the degree of cementation as well as intermixing with other subsurface units, especially alluvial deposits. Only one rock quality designation value was recorded for this unit; therefore, no generalizations can be made. Site reports recommend maximum allowable bearing capacities of 3,000 to 6,000 pounds per square foot for cinders. Both Ferrall (1976) and Munro (1981) reported typical bearing values of 2,500 to 6,000 pounds per square foot for cinders in other areas on O‘ahu. For clean cinders the higher values can be used. For cinders intermixed with other materials, such as alluvial silt, the lower values are suggested for use. Friction angles recorded for cinders range from 21° to 60°, averaging 38°. In general, consolidation is low for cinders. However, when uncemented and uncompacted and when intermixed with compressible materials such as unconsolidated alluvial deposits or lagoonal deposits, cinders can be expected to undergo settlement.

Implications for Construction

Ease of excavation of cinders depends on the degree of cementation. In general, this material is easy to excavate and can be a good source of clean, stable backfill. The use of cinders as a foundation-bearing layer is usually not recommended, due to the loose, uncompacted nature of much of this material. In particular, when cinders are found intermixed with alluvial deposits or lagoonal materials, consolidation and the resulting settlement of the structure must be considered. For light structures, some suggested shallow foundation types are spread or continuous wall footings, rafts, and rigid mats. One site report surveyed for this study proposed the use of 16.5-inch octagonal precast prestressed concrete piles, with an allowable bearing capacity of 100 tons per pile. These would be friction piles, as suggested for alluvial deposits, that derive their resistance from skin friction or adhesion. However, it should be noted that cinder layers are not usually used as the bearing unit for piles in the study area. For excavations requiring dewatering, this unit may cause problems, as it is permeable and therefore will be difficult to dewater.

Tuff

Occurrence

There are two main occurrences of tuff within the study area. Along the western edge, just south of the mouth of Kalihi Stream (Quads O–18 and O–19), there is a tuff that may be more than 50 feet thick. The total thickness cannot be determined as the tuff extends to the bottom of the drill holes. This tuff is first encountered between elevations of –10 and –17 feet and is located below the uppermost fill and lagoonal sediments.

The other main occurrence of tuff is leeward of the Punchbowl tuff cone. This tuff is anywhere from 1 to 45 feet thick but averages only 9 feet thick. Previous studies reported Punchbowl tuff up to 50 feet thick within the study area (Wentworth 1926). It is generally found just below the cinders. The elevation at which it occurs is highly variable, ranging from –5 feet in the northern part of the study area to –104 feet near the shoreline.

Engineering Properties

In general, tuff is a hard, competent rock, with high strength and low compressibility. Blow counts recorded for tuff are variable but tend to be high—comparable to those recorded for coral ledges. Dry densities tend to be lower and moisture contents higher for tuff than for coral ledges. The average rock quality designation was only 36%, which classifies it as "poor," although values were logged as high as 88%, which is in the category of "good." Values for compressive strength were lower than expected, but they may not be representative of the study area since only eleven values were found in the boring logs. The highest value recorded for this study was 223,200 pounds per square foot, whereas Munro (1981) reported values up to 700,000 pounds per square foot for unweathered tuff and up to 6,000 pounds per square foot for weathered tuff in the Pearl Harbor area. Compressibility is generally not a factor for tuff in an unweathered state; however, weathered tuff may be moderately compressible. As for bearing capacity, the only value recorded for tuff was 4,000 pounds per square foot. Munro (1981) reported maximum allowable bearing pressures of 8,000 to 12,000 pounds per square foot for unweathered tuff and 4,000 to 6,000 pounds per square foot for weathered tuff. It is possible that tuff in the downtown Honolulu area does not exhibit the same high strength as the tuff found by Munro in the Pearl Harbor area, which is located west of the study area. It is also conceivable that values found for the present study were actually for weathered tuff.

Implications for Construction

Ease of excavation, as well as the overall strength of the tuff, depends upon the degree of weathering and fracturing and the amount of cementation within the unit. In the unweathered state, tuff is hard and strong, making it difficult to excavate. Weathered and fractured tuff is easier to excavate but may cause problems if used as a foundation-bearing layer due its softer and weaker nature. The top few feet of a tuff unit is often highly weathered and should be bypassed as a foundation-bearing layer. Shallow spread foundations have been used in areas where tuff is at or near the surface, and piles have been used in deep areas. Open excavations generally do not need bracing, and the low permeability of tuff means that dewatering the unit is not difficult.

A detailed site investigation is necessary to reveal the quality of the tuff at a specific location. In addition, information on the degree of weathering, fracturing, and cementation, as well as total thickness of the unit and any variations in thickness at the site, is needed to determine the foundation design.

Basalt

Occurrence

Within the study area, there are at least four different basalt lava flows that date from the Honolulu Volcanic Series post-erosional or rejuvenation period. No boring logs examined for this study mentioned boreholes deep enough to reveal the much older Ko'olau basalt. Both *'a'ā* and *pāhoehoe* flows were encountered in the subsurface; however, the logs made no attempt to distinguish between the two types of flows. All four of the Honolulu Volcanic Series basalt lava flows are generally oriented perpendicular to the shoreline.

At the eastern edge of the study area (Quad D–2), a basalt is first encountered 82 to 92 feet below grade. This basalt is probably from a Rocky Hill flow event (Stearns and Vaksvik 1938). It may be present in the subsurface upgradient from this location. Deeper borings *mauka* of Quad D–2 are needed to delineate the lateral and vertical extent of the basalt.

There is another basalt encountered immediately downgradient of the Punchbowl cone. It is as thin as 2 feet in some borings and 19 feet thick or more in others. In several borings, the basalt extended to the maximum depth drilled; therefore, the total thickness could not be determined. Close to the H-1 Freeway, this basalt is first encountered as high as an elevation of +50 feet and as low as an elevation of –41 feet, probably due to the flow following irregular preexisting topography. However, it is also possible that more than one flow is represented in this area. Additional borings and petrographic studies are needed to classify the basalts here. The location of the basalt—just above the tuff or, in some instances, within the tuff—seems to indicate that the source for this flow is the Punchbowl cone. Overlying the Punchbowl tuff is a lava flow, about 15 feet thick, that was also encountered during drilling at the Board of Water Supply pumping station on Beretania Street. Therefore, it appears that the flow extends at least this far toward the coast (Stearns and Vaksvik 1935, 1938; Wentworth 1951). More borings are needed to further delineate the boundaries of this flow. Ferrall (1976) reported basalt at an elevation of –105 feet on the west side of Kewalo Basin and tentatively identified its source as the Punchbowl cone, since it was directly seaward of this cone. Stearns (1978) identified Punchbowl lava at a depth of 80 feet below ground surface at the Prince Kuhio Federal Building, located at the intersection of Punchbowl Street and Ala Moana Boulevard.

The Nu'uanu basalts are encountered at various elevations throughout much of the Kaka'ako, downtown Honolulu, and Iwilei districts, extending from about South Street west to just before the Kapālama Canal. Flows are anywhere from 2 to 40 feet thick. Because many borings were terminated once they reached a suitable foundation-bearing layer, total thickness data were not recorded in the boring logs surveyed. Near the *mauka* border of the study area, south of the H-1 Freeway, basalt is located as high as an elevation of +48 feet. Closer to the coast, there is a tendency for basalt to be found at deeper elevations. In one borehole, basalt is first encountered as deep as an elevation of −130 feet.

Borings made on the *mauka* side of the study area revealed Nu'uanu basalts below the uppermost fill and beneath thick sequences of alluvial deposits intermixed with coralline debris. Other borings in the area revealed fill, lagoonal deposits, cinders, coral ledges, and thick sequences of alluvial deposits and coralline debris overlying the basalt. One boring revealed tuff below the basalt, whereas another indicated alluvial deposits beneath the basalt. The remainder of the borings were terminated before reaching the base of the lava flow.

A fourth basalt is found at the *'ewa-mauka* edge of the study area. Borings revealed it as occurring east of Waiakamilo Road and extending to the *'ewa* border of the study area at Kalihi Stream. It appears to have advanced almost as far as Dillingham Boulevard. Deeper borings are needed to further delineate the extent of this flow. This basalt is first encountered as high as an elevation of +62 feet and as low as an elevation of +14 feet. Again, because borings were generally terminated once they encountered basalt, total thickness data were not recorded. The basalt is found below the uppermost fill and alluvial soils. There is a tendency for it to be found at higher elevations closer to the H-1 Freeway and Kalihi Stream, where ground surface elevations are higher.

Engineering Properties

Blow counts are high for basalt and are often recorded as blows per inches or fraction of a foot rather than as blows per foot, as in Tables 2 and 4. Dry densities and compressive strengths are also high. Recorded strengths for basalt are the highest of any unit in the study area. Ferrall (1976) quoted compressive strengths for dense unweathered basalt as high as 30,000 pounds per square inch (4,320,000 pounds per square foot) for the Waikīkī-Mō'ili'ili-Kaka'ako area. In this study strength values were found as high as 25,840 pounds per square inch (3,720,960 pounds per square foot), averaging over 17,000 pounds per square inch (2,456,868 pounds per square foot). Rock quality designations reported in the boring logs range from 17% to 100%, averaging 59%, which puts it in the category of "fair." However, this includes measurements taken from *'a'ā* clinker and weathered zones at the top and sides of the flow. The interior of the flow is more dense and is characterized by the higher values. Basalt is not compressible. No values for maximum allowable bearing capacities were given in the reports surveyed for this study, but Ferrall (1976) gives values of 10,000 to 30,000 pounds per square foot. Reports surveyed for this study recorded allowable pile-bearing capacities of 100 to 200 tons per pile for 16.5-inch or 18-inch octagonal piles. Ferrall (1976) also reported allowable pile capacities of up to 200 tons per pile for the Waikīkī–Mō‘ili‘ili–Kaka‘ako area.

Implications for Construction

Excavation of basalt is difficult, as it is the hardest and strongest unit found in the subsurface of the study area. It is an excellent foundation-bearing material. Shallow footings can be used in areas where the basalt is at or near ground surface. For basalt found at depth, piles are often used to support structures bearing on the basalt. Piles used in the study area range from 40 to 130 feet long. When designing, it is recommended that the possibility of the presence of compressible material below the lava be considered, as settlement could occur. Predrilling through overlying materials such as coral may be necessary when placing piles to basalt.

An adequate site investigation must be performed to determine the thickness of the lava flow in any area. The presence of weathered layers, lava tubes, abundant vesicles, and *‘a‘ā* clinker layers may decrease the strength of the basalt and should be considered when designing structures for construction on basalt.

Residual Soil or Weathered Volcanics

Occurrence

Residual soil or weathered volcanics comprise the weathered or decomposed uppermost surface of tuff and basalt deposits. This material is generally only a few feet to about 10 feet thick. It overlies unweathered tuff and basalt in the study area. It often includes weathered *‘a‘ā* clinker and mottled orange–brown clayey silt with basalt gravel and cobbles, such that it is probably an alluvial soil that formed on top of the volcanics. This unit grades down to the unweathered volcanic material with depth.

Engineering Properties

Blow counts, strengths, and dry densities for weathered volcanics tend to be comparable to or lower than those of their unweathered counterpart. The residual soils exhibit engineering characteristics similar to those of alluvium. This unit may be moderately compressible when compared to the unweathered volcanic material found below it. The scarcity of data in the boring logs for this unit, along with the mere reference to a volcanic unit encountered as basalt or tuff, without any further descriptive terms, made it difficult to distinguish between weathered and unweathered volcanics. A change in blow counts or a variation in some other engineering characteristic would be needed to make the distinction. Unfortunately, boring logs did not consistently reveal this sort of variation. The tables in this report do not include many data points for this unit. Munro (1981) reported maximum allowable bearing pressures of 4,000 to 6,000 pounds per square foot for weathered but cemented tuff in the Pearl Harbor area.

Implications for Construction

In general, weathered volcanics have characteristics similar to, but usually weaker and softer than, those of their unweathered counterparts. Therefore, excavation of this material is easier. However, its use as a foundation-bearing layer is not advised. Since this material is generally only a few feet thick and overlies denser and more competent tuff or basalt, bypassing it and utilizing the unweathered volcanic material as the foundation-bearing layer is usually not a problem.

Conclusions and Recommendations

Basalt, tuff, and coral ledges are the most competent foundation-bearing layers in the study area. The adequacy of coralline debris as a foundation-bearing unit is variable. Fill, lagoonal deposits, alluvial deposits, cinders, and residual soil or weathered volcanics can all cause problems for foundation design.

Unanticipated soil conditions are frequently encountered in the downtown Honolulu area. Each site needs to be carefully examined for heterogeneities in the subsurface materials and for variations in engineering properties within and between units. Only then can a foundation be designed to match the specifications of the building to the strengths of the subsurface materials that will support the structure.

Future investigations should include further delineation of the subsurface units. One suggestion is to obtain deeper borings in areas where only shallow subsurface information is available. The density of buildings may make additional borings difficult to obtain, however. Another suggestion is to conduct geophysical surveys to locate competent subsurface units, although this could run into the same difficulties associated with obtaining data from more borings for study. Age dating and petrographic analyses would assist in classifying the corals and volcanics in the study area.

CHAPTER 5. HYDROGEOLOGY

The purpose of this chapter is to describe and discuss the hydrogeological characteristics of the caprock units as determined from environmental reports and foundation investigation reports from geotechnical consulting firms in Honolulu. Data on depths to caprock groundwater within the study area were obtained from foundation investigation reports. The data obtained are presented in various figures and tables.

All groundwater recharge in Hawai'i comes from precipitation. On O'ahu precipitation comes primarily from orographic rain produced by nearly year-round tradewind ascent over the Ko'olau Mountains and from large winter storms. The annual rainfall for this island varies from 25 inches or less in the rain shadow on the leeward coasts to 300 inches in the Ko'olau Mountains (Giambelluca et al. 1986). The fate of this rainfall is to return to the atmosphere through evapotranspiration, to reach the ocean through surface runoff, and to recharge the groundwater. On the average, approximately one-third of the precipitation received returns to the atmosphere by evapotranspiration, another one-third goes to surface runoff, and still another one-third goes to groundwater recharge (Macdonald et al. 1983).

The watersheds on O'ahu tend to be small and steep, favoring rapid surface runoff, particularly in times of heavy rainfall during storm events. However, the soils and rocks on O'ahu and the other islands of Hawai'i typically exhibit high permeability, favoring rapid infiltration and groundwater recharge. Thus much of the rainfall recharges groundwater, and stream flow tends to be intermittent and flashy.

The high permeability of the soils and rocks in Hawai'i means that water can pass through the islands readily. Therefore, an island receiving no recharge would become saturated with saltwater to sea level (Figure 4). For an island receiving precipitation, the difference in densities between freshwater and saltwater is a controlling factor in groundwater occurrence. Because

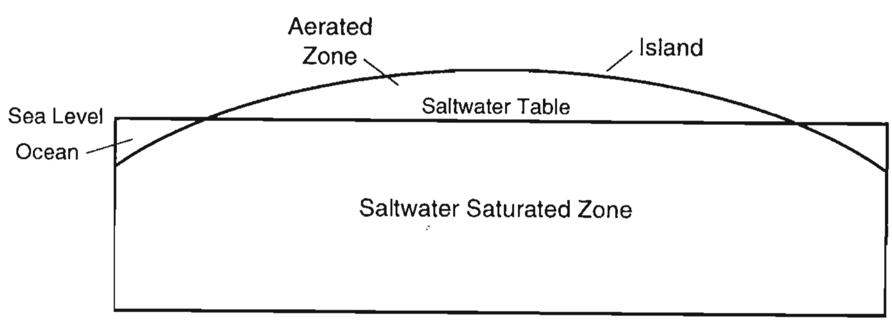


FIGURE 4. An island without rainfall, saturated up to sea level with saltwater (after Macdonald et al. 1983, p. 234)

saltwater is slightly more dense (ρ_s = 1.025 at 22°C) than freshwater (ρ_s = 1.000 at 22°C), freshwater floats on top and pushes down on the saltwater, depressing it to below sea level, thereby creating a freshwater lens. Because freshwater and saltwater are not immiscible, a mixing or transition zone of brackish water develops between the underlying saltwater and the lens of freshwater floating on top (Figure 5). This mixing zone results from the movements of the

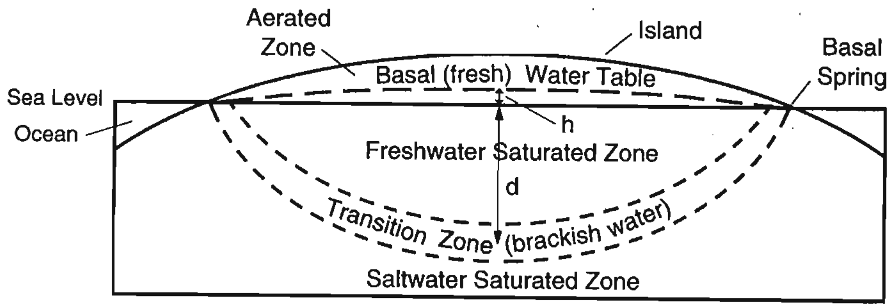


FIGURE 5. An island showing development of the freshwater lens (after Macdonald et al. 1983, p. 234)

saltwater and freshwater during tidal fluctuations and changes in groundwater recharge and discharge. If a sharp interface between freshwater and saltwater is assumed, the Ghyben–Herzberg equation given below can be used to calculate the thickness of the freshwater lens:

$$d = \frac{\rho_f}{\rho_s - \rho_f} h$$

where

d = thickness of the freshwater lens below sea level
h = thickness of the freshwater lens above sea level
ρ_s = density of saltwater
ρ_f = density of freshwater

Using the densities given above for freshwater and saltwater results in a general relationship of $d = 40h$; thus the thickness of the freshwater zone below sea level is 40 times the thickness of the freshwater zone above sea level. The Ghyben–Herzberg equation can be used to approximate the middle of the transition zone that commonly develops between the freshwater and saltwater (Macdonald et al. 1983).

The young, thinly bedded lava flows that make up the Ko'olau shield volcano are extremely permeable. Clinker layers in *'a'ā* flows, lava tubes in *pāhoehoe* flows, contraction joints formed during cooling of flows, and voids between flow layers are the major sources of permeability of these basalts. Minor features such as tree molds and gas vesicles also contribute to the porosity and permeability (Peterson 1972).

Whereas lava flows that erupt above sea level exhibit thin beds and high permeability, lava flows that erupt below sea level tend to be massive and impermeable, due to rapid chilling. Because of tectonic subsidence of the islands, permeable flows that formed above sea level are now below sea level, thus increasing the storage capacity of the aquifer. Isostatic adjustments due to the weight of the erupted lava may have caused the islands to subside more than 6,000 feet (Stearns 1985).

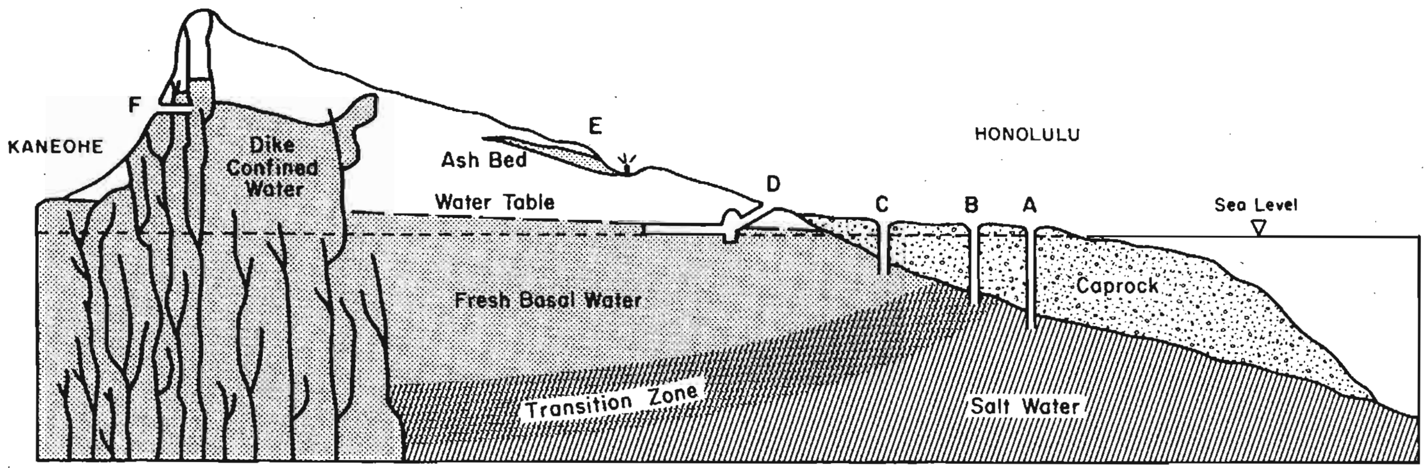
For O'ahu, the situation has been complicated by the formation of a thick wedge of sediments and volcanic deposits overlying the Ko'olau basalts. The interlayered sequences of marine and alluvial deposits and volcanics that make up the coastal plain of southern O'ahu are collectively called the caprock (Figure 6). These sequences, which may be as much as 1,200 feet thick (Stearns 1985), overlie the basalts of the Ko'olau Volcano. The primary water supply for Honolulu is the deep basal groundwater of the porous and permeable Ko'olau basalts. The younger, less-permeable materials of the caprock confine the basal water, retarding seaward movement of the groundwater to the ocean. Thus confined conditions are found near the coast where the caprock overlies the Ko'olau basalts. Extensions of the caprock deposits continue inland as valley fill and subdivide the basal aquifer (Palmer 1946).

Groundwater in the caprock is mostly unconfined, however, although locally some confinement may occur. Due to the proximity of the downtown Honolulu area to the coast, the caprock groundwater generally is brackish and nonpotable (Macdonald et al. 1983). Recharge may occur from direct precipitation, leaking water lines, irrigation return flow, lateral leakage from the inland basal aquifer, and upward leakage from the basal aquifer. Discharge may occur to streams, drainage canals, and the ocean.

Besides the basalt basal groundwater and the caprock groundwater, dike-confined and perched groundwater bodies occur on O'ahu. Both of these latter types of groundwater are found at high elevations, with dike-confined water held within compartments of permeable basalt and confined by nearly vertical impermeable dikes or a fault gouge, and with perched water found mounded on top of impermeable units such as ash beds, tuff layers, old soils, or alluvium (Stearns 1985). The caprock aquifers, which are of interest in this study, contain no significant quantities of high-level groundwater.

Methods of Investigation

The groundwater data described in this chapter come from the boring logs for foundation investigations conducted by geotechnical consulting firms in Honolulu. Since the main purpose for



A Artesian well producing salt water
B Artesian well producing brackish water
C Artesian well producing fresh water
D Maui shaft
E Perched water spring
F High level tunnel tapping dike water

FIGURE 6. Generalized groundwater occurrence in the downtown Honolulu area on O'ahu, Hawai'i (from Macdonald et al. 1983, p. 237)

borings is to examine properties of subsurface materials, these logs focus on describing the soils encountered during drilling. Usually, these logs also include information on ground surface elevation and the depth at which water is first encountered in the drill hole, along with the date, time of day of drilling, and name of the driller.

The boring logs were surveyed, and those containing data on surface elevations and depths to water were examined. Table 11 summarizes the data, giving the minimum, maximum, and average water levels by quad. The number of data points used to determine the average is also given, along with an indication of whether perched water was found within the quad. Perched water levels were not included in the caprock average water levels. Using the center point of each quad for the location corresponding to the average water level for the quad, average water levels relative to present sea level were contoured. Quads with no data points were not used in the contouring. The results are presented in Figure 7.

Because groundwater is very near to the ground surface in downtown Honolulu, most projects that involve construction below grade require dewatering of the site. Consulting firms examine the permeability of the sediments to ascertain the relative ease or difficulty with which dewatering can take place. The reports for the study area from the consulting firms were surveyed for the results of permeability tests, including both constant head and falling head laboratory permeability tests and field pump tests.

Foundation investigation reports also contain the results of consolidation tests and direct shear tests, which include void ratios. These were used to obtain porosity values using the following equation:

$$n = \frac{e}{1 + e}$$

where

n = porosity
e = void ratio

Hydraulic conductivity and porosity values for the caprock materials are summarized in Table 12.

Information on water wells was obtained from the Hawai'i Department of Land and Natural Resources' Groundwater Index database listing of wells on O'ahu. This comprehensive listing of all drilled wells on record, including some wells drilled as early as the 1880s, includes information such as well number and name, year drilled, latitude and longitude, names of the driller and the owner, major use of the well, ground elevation, well depth, water level, and chloride content of the water. It also includes information on the casing (such as diameter) and data on any tests run (such as specific capacity). The caprock may be 1,000 feet thick or more in places (Macdonald et al. 1983). However, previous studies, based on drilling records of artesian wells, have shown that the

TABLE 11. Water Level by Quadrangle, Downtown Honolulu, O'ahu, Hawai'i

Quadrangle	Water Level (ft above or below sea level)			No. of Values Reported	Perched Water
	Minimum	Maximum	Average		
A1	-1.30	3.00	1.19	13	No
A2	-0.50	1.00	0.25	2	No
A3	-0.30	0.70	0.38	5	No
A4	0.60	0.60	0.60	1	No
B1	-2.20	1.70	0.70	11	No
B2	-3.80	3.00	0.86	32	No
B3	0.10	3.00	1.32	16	No
B4	—	—	—	—	No
B5	-1.30	1.50	0.13	22	No
B6	1.50	3.50	2.17	6	No
B9	-0.90	2.00	0.28	6	No
B10	-0.90	3.20	1.15	2	No
C1	-2.10	3.00	0.81	10	No
C2	0.50	3.00	1.60	12	No
C3	-2.50	2.70	0.61	28	No
C4	-1.00	2.00	0.43	40	No
C5	-2.00	1.00	0.34	15	No
C6	—	—	—	—	No
C7	—	—	—	—	No
C8	-0.30	1.20	0.60	5	No
C9	0.10	1.90	1.03	3	No
C10	-2.30	2.50	0.29	15	No
C11	0.00	0.00	0.00	1	No
D1	2.00	2.20	2.10	2	No
D2	0.20	3.00	1.81	11	No
D3	0.20	2.00	1.21	14	No
D4	-1.50	1.50	-0.23	21	No
D5	-1.50	-0.80	-1.15	2	No
D6	0.00	4.20	1.64	10	No
D7	0.00	0.00	0.00	1	No
D8	-1.00	1.90	0.72	20	No
D9	-3.00	1.00	-0.43	17	No
D10	-3.00	4.00	0.73	32	No
D11	-0.40	0.50	0.08	8	No
D12	—	—	—	—	No
E1	2.00	5.00	3.26	8	No
E2	2.00	4.00	3.00	2	No
E3	0.00	2.00	0.80	5	No
E4	1.00	3.30	1.86	9	No
E5	2.20	3.20	2.63	3	No
E6	-1.00	4.40	1.31	27	No
E7	-2.40	2.40	0.57	26	No

TABLE 11—*Continued*

Quadrangle	Water Level (ft above or below sea level)			No. of Values Reported	Perched Water
	Minimum	Maximum	Average		
E8	-1.20	3.00	0.83	23	No
E9	-1.80	1.50	-0.04	30	No
E10	-0.80	1.00	-0.04	7	No
E11	—	—	—	—	No
E12	—	—	—	—	No
F1	—	—	—	—	No
F2	4.00	5.50	4.75	2	No
F3	—	—	—	—	No
F4	0.00	5.50	2.63	24	No
F5	1.80	3.00	2.27	3	No
F6	-1.50	4.00	1.52	40	No
F7	-1.00	3.00	1.01	43	No
F8	-0.50	3.00	0.78	44	No
F9	-1.00	4.50	0.66	32	No
F10	-0.30	3.50	0.88	13	No
G3	—	—	—	—	No
G4	—	—	—	—	No
G5	1.00	2.00	1.50	2	No
G6	0.90	2.30	1.76	14	No
G7	-1.00	4.00	1.45	28	No
G8	0.00	2.50	0.62	6	No
G9	-1.60	1.00	-0.03	29	No
G10	-1.00	1.01	0.21	14	No
G11	-1.50	1.00	-0.20	5	No
H5	—	—	—	—	No
H6	-5.00	3.00	0.25	3	No
H7	-2.50	3.00	1.17	21	No
H8	-2.00	0.70	-0.64	7	Yes
H9	-5.00	4.80	-1.02	59	No
H10	-0.90	0.60	-0.11	8	No
I6	—	—	—	—	No
I7	0.30	3.00	1.25	4	No
I8	-1.40	2.00	-0.05	12	No
I9	-5.00	1.60	-0.71	23	No
I10	-2.90	5.50	-0.06	30	No
I11	—	—	—	—	No
I12	1.00	1.00	1.00	1	No
I13	0.00	3.50	1.70	3	No
J8	-0.30	4.70	1.24	7	Yes
J9	-2.00	5.50	0.18	65	No
J10	-3.50	5.50	0.59	33	Yes
J11	-3.20	3.20	-1.13	10	No

TABLE 11—*Continued*

Quadrangle	Water Level (ft above or below sea level)			No. of Values Reported	Perched Water
	Minimum	Maximum	Average		
J12	0.00	5.30	2.64	13	No
J13	-1.70	4.00	0.45	31	No
J14	-0.80	4.00	1.63	7	No
J15	—	—	—	—	No
K8	-0.30	5.00	1.87	6	No
K9	-1.00	5.50	3.35	25	Yes
K10	-4.70	4.00	-1.01	12	Yes
K11	-2.00	1.40	-0.03	16	No
K12	0.00	3.50	1.50	12	No
K13	-1.40	3.50	1.30	19	No
K14	0.00	0.00	0.00	1	No
K15	-0.80	0.00	-0.28	6	No
K16	—	—	—	—	No
K17	2.70	2.80	2.75	2	No
K18	2.00	2.00	2.00	2	No
K19	-0.70	3.30	0.50	4	No
L8	4.50	4.50	4.50	1	No
L9	2.00	5.50	3.65	6	Yes
L10	-4.00	5.40	2.55	11	Yes
L11	-5.20	1.50	-1.78	19	No
L12	-2.00	1.10	-0.85	4	No
L13	-1.00	4.10	1.15	6	No
L14	-1.80	3.40	0.62	20	No
L15	-5.00	1.00	-0.06	8	No
L16	1.20	1.20	1.20	3	No
L19	1.60	3.60	2.85	22	No
L20	—	—	—	—	No
M9	—	—	—	—	No
M10	—	—	—	—	Yes
M11	-1.80	0.00	-0.92	5	No
M12	-1.00	0.00	-0.40	5	No
M13	-4.00	0.20	-1.17	19	No
M14	-0.80	4.50	1.31	14	No
M15	-2.00	5.00	2.73	7	No
M16	4.50	4.50	4.50	1	No
M17	—	—	—	—	No
M18	0.00	1.40	0.70	2	No
M19	0.10	4.00	1.95	12	No
M20	-2.80	0.50	-1.48	8	No
N10	—	—	—	—	No
N11	0.50	0.50	0.50	1	No
N12	-3.50	2.50	0.78	6	No

TABLE 11—*Continued*

Quadrangle	Water Level (ft above or below sea level)			No. of Values Reported	Perched Water
	Minimum	Maximum	Average		
N13	1.00	1.00	1.00	1	No
N14	0.50	1.00	0.67	3	No
N15	2.00	2.00	2.00	1	No
N16	0.00	1.50	0.75	2	No
N17	0.40	1.30	0.85	2	No
N18	0.30	2.50	1.21	19	No
N19	0.20	0.90	0.55	2	No
N20	-1.70	2.10	0.70	13	No
O12	-4.00	3.20	0.04	8	Yes
O13	-3.50	4.70	2.26	9	Yes
O14	—	—	—	—	No
O15	—	—	—	—	No
O16	1.00	3.20	2.10	2	No
O17	1.50	3.00	2.63	4	No
O18	-0.40	5.30	1.77	14	No
O19	0.30	3.50	2.25	10	No
O20	-1.50	2.20	0.99	9	No
P12	—	—	—	—	Yes
P13	—	—	—	—	Yes
P14	—	—	—	—	No
P15	—	—	—	—	No
P16	1.00	5.00	2.80	5	No
P17	0.90	1.50	1.25	4	No
P18	3.20	3.20	3.20	1	No
P19	2.50	3.90	3.06	5	No
P20	—	—	—	—	No
Q14	—	—	—	—	No
Q15	—	—	—	—	No
Q16	—	—	—	—	Yes
Q17	0.00	2.00	1.42	6	Yes
Q18	1.00	4.90	1.98	4	No
Q19	-1.00	-1.00	-1.00	1	No

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

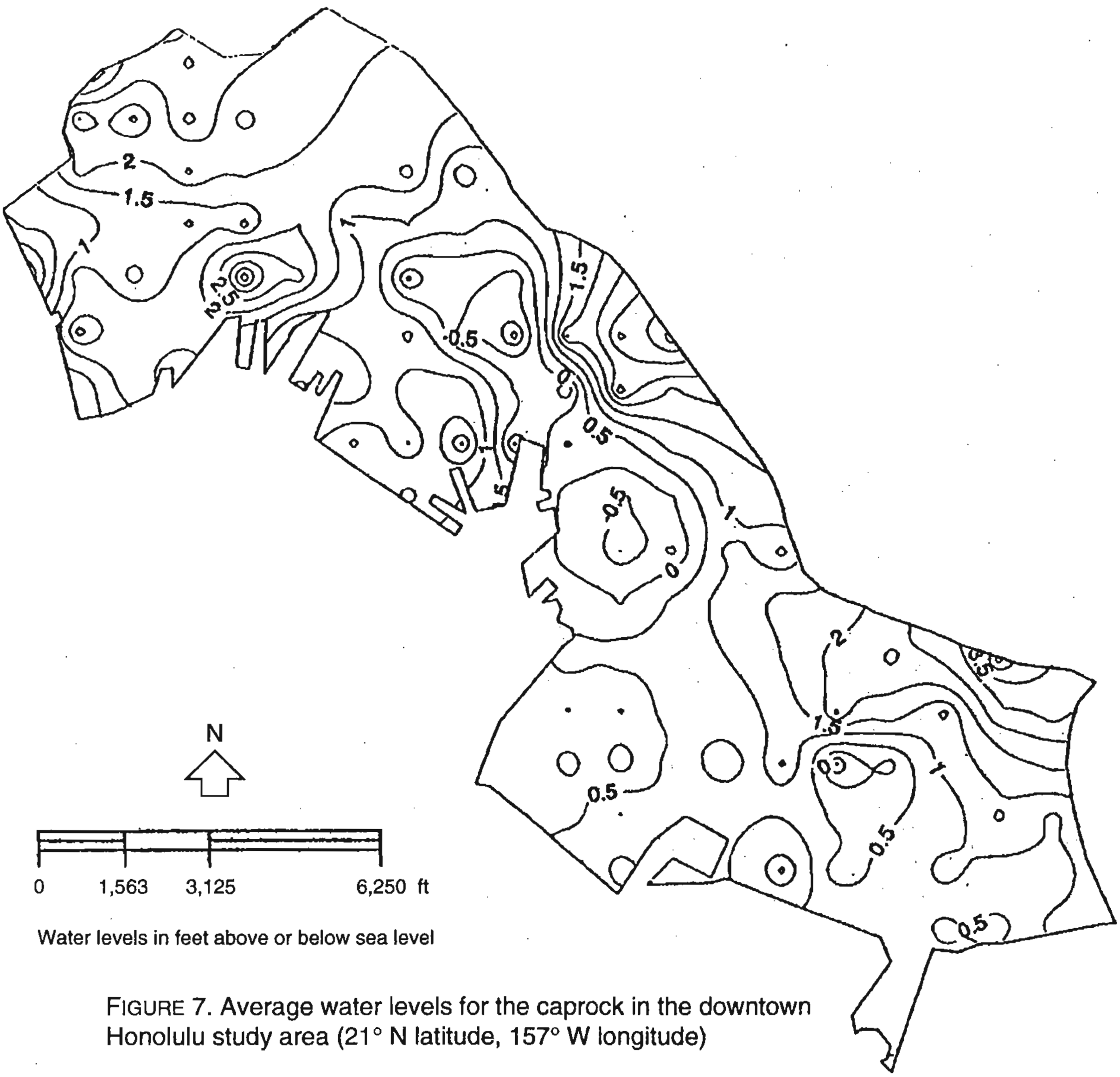


FIGURE 7. Average water levels for the caprock in the downtown Honolulu study area (21° N latitude, 157° W longitude)

TABLE 12. Hydraulic Conductivity and Porosity of Caprock Materials, Downtown Honolulu, O'ahu, Hawai'i

Material	Hydraulic Conductivity (ft/day)			No. of Values Reported	Porosity			No. of Values Reported
	Minimum	Maximum	Average		Minimum	Maximum	Average	
Fill	0.05	283.00	141.50	2	0.28	0.69	0.46	6
Lagoonal deposits (fines)	0.16	15.90	3.20	19	0.20	0.75	0.56	11
Lagoonal deposits (coarse)	0.28	2,800.00	680.40	13	—	—	—	—
Lagoonal deposits (overall)	0.16	2,800.00	247.70	32	0.20	0.75	0.56	11
Alluvial deposits	0.00283	9.60	3.00	11	0.38	0.71	0.54	24
Coralline debris	1.13	70.90	25.00	22	0.15	0.53	0.42	10
Coral ledges	1.42	173.00	43.30	30	0.15	0.45	0.35	14
Cinder deposits	4.25	401.00	77.80	10	0.46	0.52	0.50	4
Tuff	—	—	—	—	0.22	0.56	0.44	3
Weathered basalt	0.17	6.80	3.70	8	0.50	0.52	0.51	2
Overall caprock	0.00283	2,800.00	99.90	119	0.15	0.75	0.48	74

SOURCE: Site reports and boring logs from Dames & Moore, Ernest K. Hirata & Associates Inc., Geolabs Hawaii, and Hawaii Geotechnical Group Inc.

depth to the Ko'olau basalt is 300 feet or more within the study area (Wentworth 1951). Therefore, wells drilled to a depth of 250 feet or less are assumed to be within the caprock, and the initial chloride values are assumed to be indicative of caprock chloride values. Within the study area are 22 wells that are listed in the Groundwater Index database; the depth of these wells is 250 feet or less. Information on these wells, along with their initial chloride values, are presented in Table 13. The initial chloride values for these 22 wells were used to create a contour map of chloride content in the caprock. This is presented in Figure 8.

TABLE 13. Initial Chloride Content in Caprock Wells, Downtown Honolulu, O'ahu, Hawai'i

Well Number	Latitude (°N)	Longitude (°W)	Year Drilled	Surface Elevation (ft)	Well Depth (ft)	Depth to Initial Water Level (ft)	Initial Chloride Content (mg/l)
1750-10	21.292500	157.844722	1967	4.0	88	2.8	13,954
1750-11	21.292778	157.845000	1967	5.0	55	2.9	13,451
1751-01	21.297500	157.861667	1939	1.0	142	Not given	16,100
1751-03	21.295000	157.860556	1959	1.0	92	Not given	18,000
1851-41	21.313889	157.862778	1938	21.0	46	1.5	139
1851-42	21.310278	157.863889	1939	10.0	50	Not given	2,100
1851-45	21.310000	157.863889	1939	10.5	80	Not given	1,040
1851-48	21.311389	157.864444	1939	15.0	40	3.6	1,360
1851-51	21.309722	157.860556	1952	18.0	71	3.6	966
1851-55	21.312778	157.861111	1958	16.0	40	1.0	967
1851-60	21.305278	157.853333	1962	16.0	180	6.0	470
1851-61	21.311389	157.860833	1963	20.0	77	Not given	4,030
1851-62	21.303611	157.853056	1967	5.0	65	Not given	376
1852-02	21.301389	157.870000	1939	0.0	102	Not given	14,500
1951-04	21.319722	157.858056	1939	42.0	53	Not given	69
1952-23	21.321111	157.870000	1939	4.0	100	1.5	1,380
1952-24	21.319444	157.874444	1947	8.0	80	Not given	13,000
1952-25	21.319722	157.874444	1947	8.0	81	Not given	16,200
1952-30	21.320000	157.874444	1951	7.0	75	Not given	12,600
1952-32	21.318333	157.872778	1957	7.0	40	Not given	17,000
1952-33	21.318889	157.872778	1957	9.0	40	Not given	18,500
1952-35	21.325833	157.881667	1960	15.0	250	12.9	11,600

SOURCE: Groundwater Index database, State of Hawai'i Department of Land and Natural Resources.

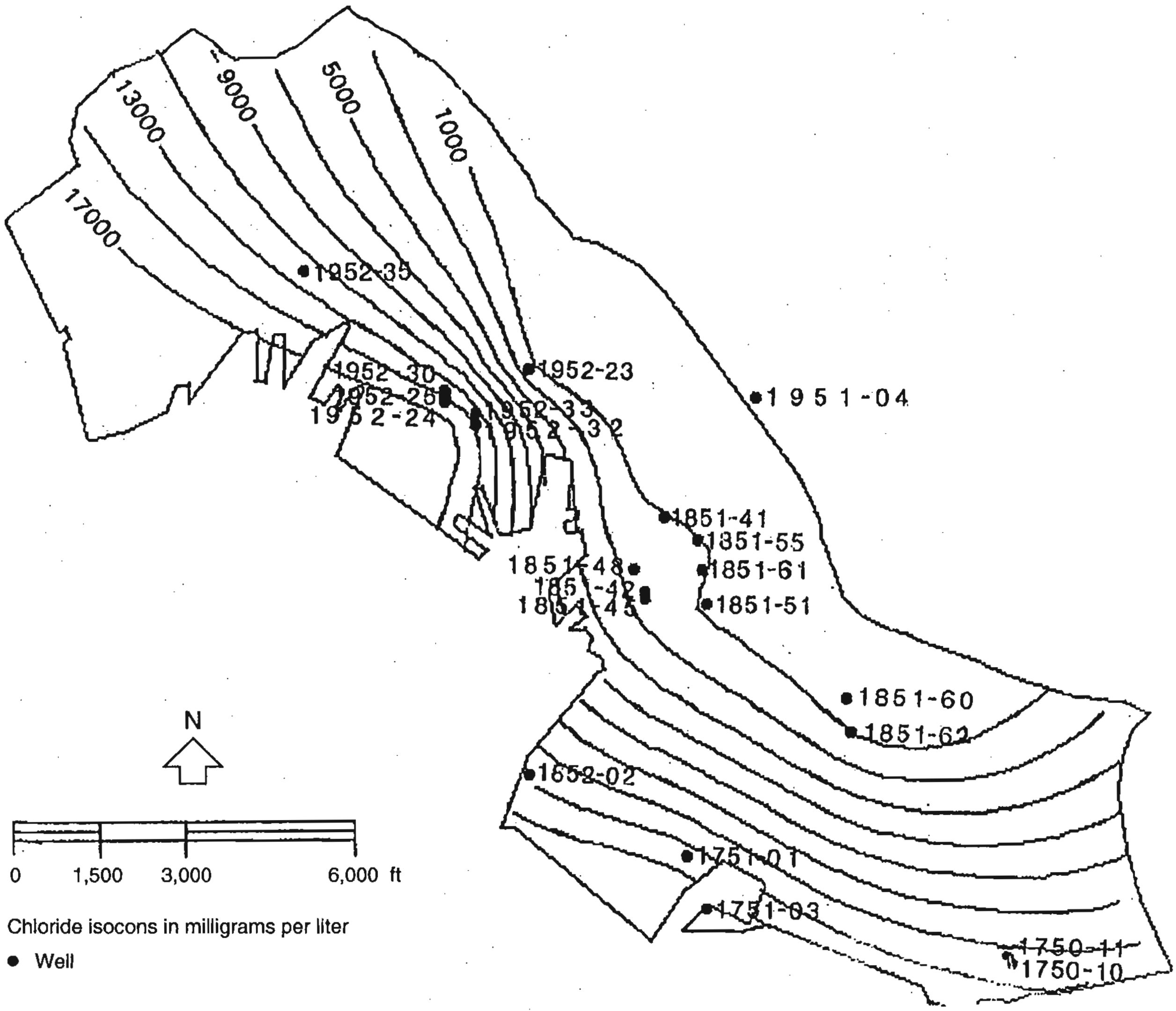


FIGURE 8. Chloride isocons for the caprock in the downtown Honolulu study area (21° N latitude, 157° W longitude)

Results

From the boring logs, water levels for the caprock aquifer were determined to range from 5.2 feet below sea level to 5.5 feet above sea level. Exceptions are values as low as 8 feet below sea level measured at sites near dewatering activities. Values as high as 24 feet above sea level reflect perched water conditions. Quads with perched water are indicated in Table 11. These quads are all located near the *mauka* edge of the study area, at the higher elevations. There are 33 instances of perched water, ranging from +6.5 feet to +24.2 feet above sea level and averaging about +11 feet above sea level. Boring logs indicating perched conditions were surveyed to determine the composition of the perching beds. These perching beds include tuff layers, weathered volcanic ash, Honolulu Volcanic Series basalt flows, and old alluvial layers, including the stiff brown silty clay referred to as adobe. There were 1,602 water levels that were neither exceptionally low due to dewatering activities nor exceptionally high due to perched conditions. The mean for these 1,602 water levels is 0.77 feet above sea level.

An examination of Figure 7 shows that, in general, groundwater levels are higher toward the *mauka* edge of the study area and lower near the *makai* edge, indicating that flow is generally from the mountains to the ocean, as expected. However, there are many exceptions to this generalization. Several groundwater sinks and mounds are present (Figure 7). The sinks may reflect areas where shallow wells were being pumped or dewatering was taking place at the time of water-level measurement. The high mounds may reflect perched water conditions not previously taken into account; leaking water mains, sewer lines, or irrigation piping; or return flow from local irrigation.

The contour map for average groundwater levels for each quad in the caprock, shown in Figure 7, indicates the variations in groundwater measurements that can occur within a relatively small area. There are a number of problems with using data from foundation investigation reports to study groundwater levels. For some quads, there were too few data points to give a representative average value. For example, if there are only two data points and one is either unusually high or unusually low, possibly due to an error in measurement, the resulting average value would not be representative of the entire quad.

Using data from the reports also presented a problem because of the wide range in dates of data collection. Reports surveyed for this study were as old as 1951 and as recent as 1992. Caprock water levels within the study area fluctuate with tides, storm surges, floods, local precipitation events, return flow from irrigation, changes in stream levels, recharge from upward leakage of the basal aquifer, and discharge to streams, canals, and the ocean. Therefore, to get an accurate comparison of water levels within the study area, measurements need to be made simultaneously and at a time when no pumping is occurring. In many cases, the multiple water levels recorded at a site were not even taken on the same day, nor were they taken at the same time of day. Many reports did not even include the time of day. A number of reports either did not include depth to water at all or only included a generalization such as "groundwater approximately three to four feet below ground surface."

Using ground surface elevation data from the boring logs also presented a problem. Ground elevations were seldom surveyed; instead, they were estimated from maps and often reported as ±5 feet or even ±10 feet or more. This could create a large error in the numbers, as ground surface elevations within the study area are generally less than 40 feet above sea level. For example, some boring logs listed elevations for a site as "100± feet," when elevations for the site as estimated from topographic maps were only about 30 feet.

Few boring logs reported water-level variations, which require that recordings be taken at different hours of the day or over the course of several days. Of the levels recorded within a single borehole, the maximum variation reported was 4.0 feet and the minimum was 0.1 foot, with a mean of 0.7 foot.

Only six reports gave groundwater gradients for the caprock, and they all described the gradients as flat, averaging only about 0.006 foot/foot.

Table 12 presents the range and average hydraulic conductivity and porosity values for the caprock units. The wide range in values indicates the heterogeneity of the caprock materials.

Hydraulic conductivities for the entire caprock varied by several orders of magnitude, from 2.83×10^{-3} feet/day to 2.80×10^{3} feet/day, with an average of 99.90 feet/day. Porosities for the caprock units varied from 0.15 to 0.75, also varying widely. The average porosity for the entire caprock was 0.48.

Table 13 gives the initial chloride content for 22 caprock wells in the downtown Honolulu area. These values, which were obtained from the Groundwater Index database, were used to create the contour map of chloride isocons presented in Figure 8. Well numbers are shown in both Table 13 and Figure 8. The values for the initial chloride content range from 69 to 18,500 mg/l of chloride, averaging 8,081 mg/l.

Discussion

Water levels reported varied from 8 feet below sea level to 24 feet above sea level, with few exceptionally low or high values reported. Most values reported were at or near sea level, with the average being just above sea level (0.77 foot). The boring logs that reported low values noted that dewatering activities were taking place at nearby construction sites, thereby lowering water levels in adjacent plots. High-level water was found at higher elevations, perched above a unit of low permeability (generally an alluvial soil or volcanic deposit). These areas of perched water were highly localized and limited in extent. It is unlikely that perched water within the study area could be developed to supply any significant amounts of water. However, areas of perched water are of interest for foundation construction purposes. A site located at a high elevation would require dewatering prior to foundation construction if substantial quantities of perched water are present.

In general, the direction of groundwater flow is from higher elevations to lower elevations, with the primary discharge area being the shoreline. Groundwater gradients for the caprock water are quite flat. Contour maps of caprock water levels recorded at low tide and again at high tide would be helpful in defining local variations in groundwater flow directions. Given the data available, it is not possible to create such maps at this time. Groundwater levels would need to be recorded for low tide and again at high tide at the same times of day and on the same day throughout the area. Even this would result only in a "snapshot" in time. The daily tidal range in Hawai'i is generally only about 1 to 2 feet (Macdonald et al. 1983). However, tides vary with the seasons, and storms and floods may influence water levels. In addition, recharge from irrigation return flow and discharge due to local pumping can alter flow patterns. The 4-foot difference in water level measured on different days within a single borehole indicates the extent of vertical variability that can occur in water levels. Table 11, which lists the range in water-level measurements by quad, and Figure 7, which shows average water levels based on measurements taken over many years, give an indication of how both spatial and temporal variabilities can occur in water levels within a small area. Because these measurements were taken over more than 40 years, current conditions are not represented in Figure 7; thus this figure should not be used to predict depths to groundwater within the study area.

Hydraulic conductivity and porosity values were extremely variable for the caprock deposits, with values for hydraulic conductivity often ranging over several orders of magnitude. The heterogeneous near-surface fill—which may include calcareous sand, mud, coral fragments, and trash such as concrete rubble and old tires—was rarely compacted when placed. Therefore, its characteristics are extremely variable from one site to another. The fine-grained lagoonal deposits, the alluvial deposits, and the highly weathered basalts all exhibit low hydraulic conductivity, roughly 3 feet/day. Older alluvial deposits, with secondary mineralization and compaction, exhibit lower hydraulic conductivity and porosity than recent alluvial deposits. This accounts for the wide range in values reported for alluvial hydraulic conductivity. No hydraulic conductivity values were reported for tuff in the reports surveyed. Wentworth (1951) reported that tuff in Honolulu exhibits low hydraulic conductivity but did not list any values.

Coralline sand and gravel (average hydraulic conductivity of 25 feet/day), coral ledges (average of 43 feet/day), and cinder deposits (average of 78 feet/day) all exhibit roughly similar hydraulic conductivity. Cementation within the coralline sand and gravel may result in lower hydraulic conductivity values. In addition, there may be more fine-grained material within these units than described in the boring logs. Secondary permeability and porosity of the coral will vary depending on formation of solution cavities and in-filling of voids by mud. The cinder deposits may also undergo secondary cementation and may contain substantial fines, which will affect its hydraulic conductivity.

An extremely wide range of hydraulic conductivity values was reported for the coarse-grained silty sand and gravel within the lagoonal deposits. Thus, even though the mean of all reported values is high (680 feet/day), it is difficult to generalize about the hydraulic conductivity of this unit. However, since most of the lagoonal or estuarine deposits are fine-grained in nature, the lower hydraulic conductivity values that characterize the fine-grained portion of the lagoonal deposits will probably govern the overall behavior of this unit in terms of hydraulic conductivity.

The total hydraulic conductivity for the caprock, based on averaging all values obtained in this study, is about 100 feet/day. However, because as much as half of the caprock may be fine-grained clay and mud (Palmer 1946), this average value for total caprock hydraulic conductivity is probably too high. Not including the relatively high conductivity values obtained for the artificial fill and the coarse-grained lagoonal deposits, the average hydraulic conductivity for the entire caprock becomes only about 27 feet/day. Wentworth (1951) and Souza and Voss (1987) reported much lower hydraulic conductivities than this study found. Based on only eight tests, Wentworth (1951) reported values ranging from 0.02 to 0.38 foot/day for various caprock materials. Souza and Voss (1987) identified a best-fit estimate of 0.15 foot/day for the caprock, based on a modeling approach.

To get a more accurate hydraulic conductivity value for the caprock using the data obtained for this study, one would need to do a weighing average, giving more weight to the greater amounts of fine-grained units. The benefit of this would be questionable, as it is difficult to measure hydraulic conductivity for such variable sediments, and values reported may not always be reliable. Often, the hydraulic conductivity of fine-grained, poorly permeable materials is not even determined because it is so low and so difficult to measure. However, the low hydraulic conductivity of these materials will control the overall conductivity of the caprock. Therefore, it is likely that the average hydraulic conductivity reported in this study is too high.

The caprock is extremely heterogeneous. Laboratory permeability tests only provide small-scale or local hydraulic conductivity values. Full-scale pump tests, run for a long duration, would more accurately determine a regional average hydraulic conductivity value for the caprock. However, pump tests, which are time-consuming and expensive, have rarely been performed in the downtown Honolulu area. The hydraulic conductivity values reported in this study are probably not representative of the overall effective hydraulic conductivity of the caprock.

The young, thinly bedded lava flows of the Hawaiian islands are in general very permeable (Macdonald et al. 1983); thus the hydraulic conductivity of the Koʻolau basalt basal aquifer can be expected to be quite high. The hydraulic conductivity of basalt aquifers in Hawai'i has been reported to be in excess of 1,000 feet/day (Mink and Lau 1990). Some values nearly as high as 5,000 feet/day (Souza and Voss 1987) have been reported. Hydraulic conductivity values reported for extremely permeable basalts range from about 1,000 feet/day to more than 30,000 feet/day (Freeze and Cherry 1979; Todd 1980). The best-fit estimate for the horizontal hydraulic conductivity of the Ko'olau basalt is about 1,500 feet/day, based on the modeling approach of Souza and Voss (1987).

Thus, the hydraulic conductivity of the Ko'olau basalt basal aquifer may be 100, 1,000, or even as much as 10,000 times higher than that of the caprock. Consequently, the caprock as a whole can be considered impermeable, even though some units within it may be quite permeable.

The variability in the hydraulic conductivity of the caprock units affects local flow patterns in the groundwater, as does fluctuations caused by tides. Therefore, although flow is generally from *mauka* to *makai* within the study area, on the small scale of one project site, flow patterns may be quite complex. This can only be revealed through an examination of monitoring wells designed as part of each site investigation. However, monitoring wells would also be needed at adjacent sites to help define local flow conditions. This would be particularly important in studies delineating contaminant migration in the subsurface. The heterogeneity of the sediments, along with local variations in water levels caused by such factors as tides and storm surges, can result in intricate flow patterns and even reversals of flow direction. The outcome may be off-site contaminants migrating on-site from unexpected directions.

The heterogeneity in the caprock sediments also affects dewatering projects. In general, the outcome of dewatering in the area is difficult to predict because flow patterns vary so greatly within the caprock. Several foundation investigation reports estimated 100 to 200 gallons/minute of flow into excavations. Some reports estimated a radius of influence of over 2,000 feet when dewatering. This can cause unexpected problems, such as consolidation and settlement of subsurface materials off-site, resulting in ground surface subsidence. The end result may be cracked foundations of structures located some distance away from the dewatering activity. The fine-grained lagoonal deposits may be especially susceptible to consolidation and subsidence with dewatering. These deposits tend to be saturated and somewhat "soupy" in nature, often consisting of a loose framework of coral rubble bound by wet mud. Removal of the water from these fine-grained layers can be difficult, but once the water is removed, the structure of the material will collapse and significant settlement will occur. The coarse-grained units are not as susceptible to consolidation, but their high hydraulic conductivity can make dewatering difficult.

Chloride values for the caprock wells (69 to 18,500 mg/l) range from that for freshwater (<250 mg/l of chloride) to that for seawater (>15,000 mg/l of chloride; true seawater has a chloride content of 18,980 mg/l) (Mink and Lau 1990). Higher salinities characterize the deep caprock wells and wells located close to the shoreline. Only two wells, both located inland and at higher elevations, had values in the freshwater range. The remainder were brackish, with the average of all values (8,081 mg/l of chloride) falling in the high-salinity category (5,000 to 15,000 mg/l of chloride). Water in the high-salinity category is not considered to have potential economic value (Mink and Lau 1990). High concentrations of carbon dioxide, bicarbonate, and calcium also characterize the caprock (Visher and Mink 1964). These constituents probably result from dissolution of the calcareous sediments of the caprock.

More data points would be needed to develop a more accurate chloride isocon map. The numbers used were initial chloride values as reported when the well was drilled. Drillers are required to report an initial chloride value for each new well drilled, but they are not required to report the depth in the borehole at which the sample was taken. Chloride content may vary with depth. Some initial chloride values probably represent the quality of the water at the water table, whereas other values may represent the quality of a mix of water pumped from the entire length of the borehole. However, the Groundwater Index database gives no indication of the depth at which the sample was taken. The wells were drilled between 1938 and 1967, thus it is not possible to check on the depths represented by the initial chloride values at this late date (K. Gooding, City and County of Honolulu Board of Water Supply, oral communication, 13 September 1995). This creates another problem with the accuracy of the chloride isocon map shown in Figure 8. In addition, because it is expected that water quality changes over time, these numbers may not be indicative of current conditions. An accurate isocon map could be created only if all measurements were made simultaneously, at a specified depth below the water table, and no pumping was occurring.

However, even if it was possible to ascertain that no pumping was taking place, and then measure chloride content all at the same time and same depth, it is likely that variations in chloride content would still be evident within the caprock due to the heterogeneities of the units. A permeable sediment may experience a greater tidal signal than an impermeable unit and thus exhibit a higher chloride content. Therefore, variations in chloride content could give an indication of the hydraulic conductivity, and even the geology, of the sediments. For example, an area exhibiting an anomolously high chloride content could be indicative of the presence of a permeable material, such as a cinder layer. However, many more values than were available for this study would be needed for such a determination.

Conclusions

Unconfined groundwater can be expected to be found within ±5 feet of sea level in the downtown Honolulu area. Exceptions would be lower water levels caused by dewatering activities and higher water levels due to perched water conditions.

The coral ledges, coralline debris, coarse-grained lagoonal deposits, and cinder deposits within the caprock all exhibit higher hydraulic conductivities than the alluvial deposits, tuff, weathered basalt, and fine-grained lagoonal deposits of the caprock. However, extremely high hydraulic conductivity characterizes the Ko'olau basalts of the basal aquifer. In comparison, the caprock as a whole can be considered an impermeable confining unit over the Ko'olau basalt basal aquifer, although individual units within the caprock may be extremely permeable.

The caprock groundwater must be taken into account when planning engineering works. In many places within the study area, the water table is located close to ground surface and will have an effect on foundation construction and possibly necessitate dewatering of the site. Because of the heterogeneity within the caprock and the extreme variability in hydraulic conductivity values, the results of this study should not be used to design dewatering schemes for excavations. Each site needs to be examined on an individual basis. A determination of the feasibility of dewatering needs to be based on the small-scale geology and hydrology of the site and surrounding sites. However, the results of this study, as presented in the geologic maps and subsurface geologic cross-sections, may be instructive. These indicate the general geology in the study area and can be used to delineate sites in need of more detailed examination.

Future research may focus on local variations in flow patterns and the effect of the tidal influence within the caprock. Those units with higher permeability may experience a greater tidal signal than units with lower permeability. Monitoring wells set in different units and to various depths could help define tidal effects due to differing hydraulic conductivities. The caprock groundwater must also be taken into account when examining contaminant transport. Contaminant plumes within the subsurface can be expected to be quite complex. Those units with higher permeability will transmit contaminants more readily than units with lower permeability. A system of monitoring wells may be useful in delineating contaminant flow in the caprock.

Caprock water quality varies from freshwater to seawater and is generally brackish. The caprock groundwater is classified as unconfined, nonpotable, not ecologically vital, moderately saline, replaceable, and highly vulnerable to contamination (Mink and Lau 1990). Developing even limited supplies will be difficult because of the heterogeneity of the caprock units. Test borings will need to be made on a site-by-site basis to determine the quantity and quality of available water. However, the brackish water of the caprock is unsuitable for drinking; thus, unless an investment is made into the expensive process of desalinization, it is unlikely to ever be used as a water supply. It may have limited use as a source of water for some industries and for air conditioner cooling and lawn irrigation.

CHAPTER 6. ENVIRONMENTAL GEOLOGY

In 1991, *Pacific Business News* published a list of sites in Hawai'i that were considered to be contaminated by leaking in-ground petroleum storage tanks (Smith 1991). Of the 267 sites on the list, 45 are within the downtown Honolulu area. Several of these sites—such as the former Aloha Motors site (now the location for the new convention center) at the corner of Kapi'olani Boulevard and Kalākaua Avenue and the new Honolulu Police Department headquarters near the intersection of Alapai Street and South Beretania Street—have had development slowed or stalled due to the time-consuming and costly tasks of site investigation and remediation.

Due to these development dilemmas and concern about the contamination issues in question, local interest in contamination problems in downtown Honolulu has been great in the last few years. Therefore, it was decided that this study would not be complete without examining environmental problems within the study area. The purpose of this chapter is to discuss contamination sites, the current state of information available, and possible future difficulties with environmental problems within the study area.

Methods of Investigation

The Hawai'i Department of Health provided four lists that comprise the major sources of information on environmental problems in the downtown Honolulu area. The leaking underground storage tank (LUST) list and the underground storage tank (UST) list were provided by DOH's Solid and Hazardous Waste Branch, as was EPA's Resource Conservation and Recovery Act (RCRA) database, which is designed to identify and track hazardous substances and wastes from the point of generation to the point of disposal. EPA's Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) list for Hawai'i sites that have been evaluated or are being evaluated as potential hazardous waste sites for the National Priorities List (Superfund list) was provided by DOH's Hazard Evaluation and Emergency Response Office. It has been estimated that 90% or more of all known contamination problems occur at sites included on these lists (S. Sklenar, Dames & Moore, personal communication, 14 May 1992; R. Seid, Hawai'i Department of Health, personal communication, 2 June 1993).

Personal interviews with DOH staff provided further information on other database listings of types of facilities that could present environmental problems. These interviews revealed that no hazardous waste sites on the National Priorities List are currently within the study area, that no sites are classified as either Open Dump or Permitted Landfills in the study area, that no RCRA major violators are listed for the area, and that no records of civil judicial actions are filed by the U.S. Department of Justice against environmental violators in the Consolidated Docket

Enforcement System database for the study area (Hawai'i Department of Health, personal communication: M. Miyasaka, 1 July 1993; C. McCabe, 22 July 1993; L. Galvez, 10 August 1993).

A desktop mapping software package, MapInfo for Windows Version 2.0 for O'ahu, was used to plot the locations of the sites from the four lists obtained from DOH.

Five tables and accompanying maps were produced to show the extent of the known, suspected, or potential contamination problems within the study area; however, only one table and one map are presented in this report. The table (presented in Appendix D) and the map (Figure 9) are composites of the individual tables and figures, with data for duplicate listings combined so that each facility is listed and plotted only once. Hence, the 606 facilities on the CERCLA (17 sites), LUST (90 sites), UST (288 sites), and RCRA (211 sites) lists have been reduced to 406 facilities. The environmental data—as well as the name, street address, and identification number of the facility at each site—are included in the table in Appendix D. In some cases, when MapInfo did not make an exact match, the nearest street number is used in the address. The facility identification number is used by DOH to locate the records in the corresponding databases and to store the reports for each site.

Results

EPA uses a ranking system to score sites according to the potential impact hazardous substances may have on human health and the environment. Any site scoring over 28.5 points is placed on the National Priorities List. Neither the draft EPA reports nor the scores are made available to the public (L. Galvez, Hawai'i Department of Health, personal communication, 10 August 1993). However, the CERCLA list is accessible, and site hazard rankings of "high priority," "low priority," or "no further remedial action [required at this time]" are reported for respective sites in the table in Appendix D.

As mentioned previously, no sites within the study area are currently on the Superfund list; however, according to the LUST list, the Symphony Park Condominium/Kapiolani Bowl site (facility ID 9-102703) received a score greater than 28.5 and was recommended for the Superfund list. The only site in the study area to receive a high-priority ranking on the CERCLA list is the Aloha Motors site at the intersection of Kapi'olani Boulevard and Kalākaua Avenue. According to DOH staff, less than 10% of the sites on the CERCLA list go on the Superfund list (L. Galvez, Hawai'i Department of Health, personal communication, 10 August 1993). Once a site is placed on the CERCLA list, it remains there, even if a recommendation is made for "no further remedial action" at some point in time. This allows EPA the option of re-examining the site at a later date if

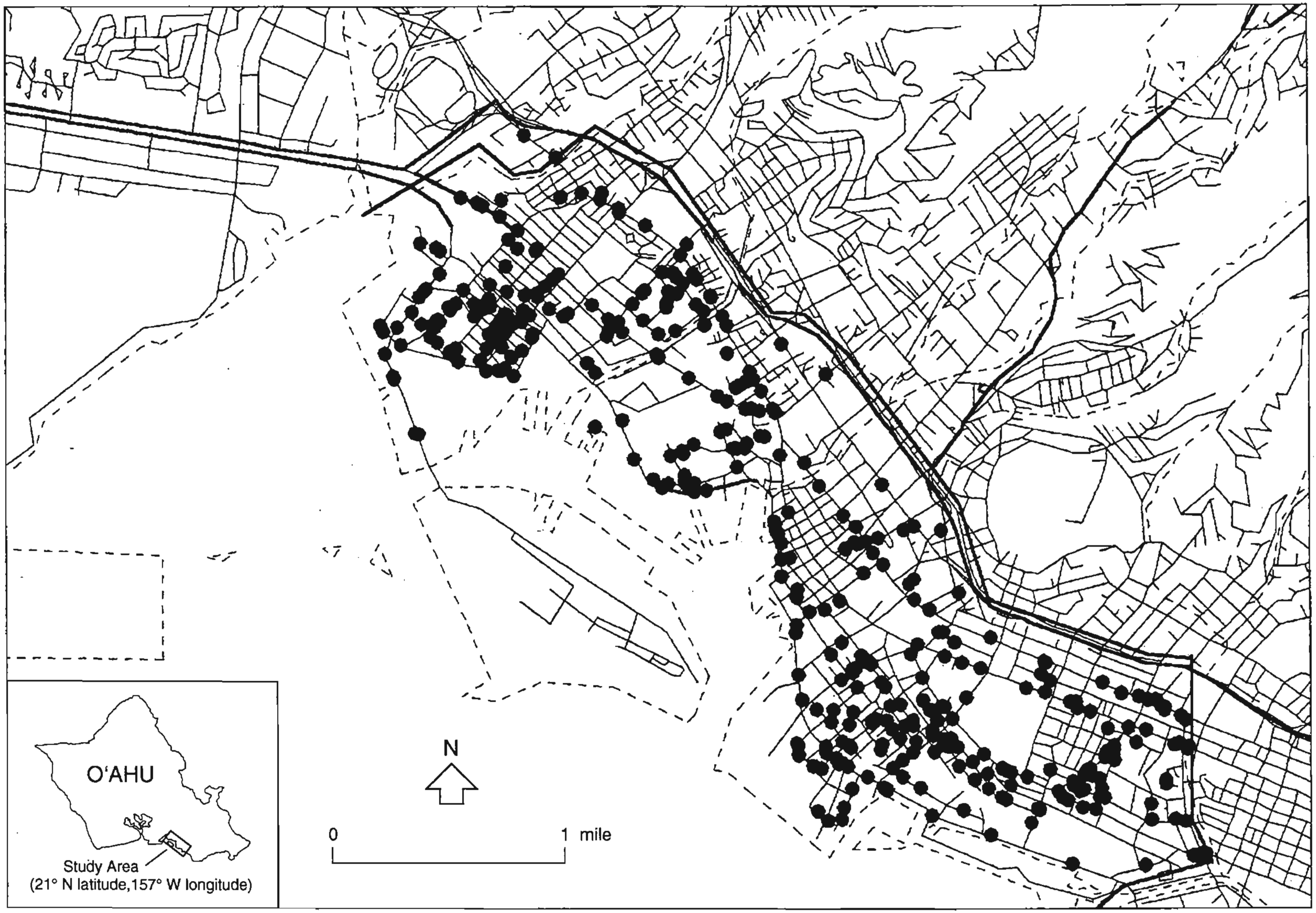


FIGURE 9. Contamination sites in the downtown Honolulu study area

new information comes to light (L. Galvez, Hawai'i Department of Health, personal communication, 25 May 1994).

The Underground Storage Tank Section of DOH's Solid and Hazardous Waste Branch also uses a site priority ranking worksheet to score and categorize all leaks. Determination is based on such factors as aquifer sensitivity, gallons of substance released, type of substance released, health and safety, time-constraints, and current extent of the contamination. The LUST hazard ranking categories are Rank 1 for high-priority sites, Rank 2 for medium-priority sites, and Rank 3 for low-priority sites. If the site has not been ranked, this is noted as "no ranking listed" in the table in Appendix D. For those sites included on both the CERCLA and LUST lists, both hazard rankings are listed.

The LUST list includes an indication of the quantity of substance released. This is listed in six categories: (1) less than 500 gallons, (2) 500 to 5,000 gallons, (3) 5,000 to 10,000 gallons, (4) 10,000 to 25,000 gallons, (5) 25,000 to 50,000 gallons, and (6) over 50,000 gallons. In many cases, the actual amount released is unknown; thus the amount listed is instead an indication of the total amount of material that can be stored on site, based on knowledge of the number and size of underground storage tanks at that location. In one case, there were no records of the number and size of storage tanks on site, so the release amount is listed as unknown.

The LUST list also includes information on the type of substance released, when known. The groupings include hazardous substances other than petroleum products; leaded gasoline; unleaded gasoline; crude oil, JP-4, or Jet B fuel; diesel, kerosene fuel, JP-5, Jet A or C fuel; heavy oil or bunker C; waste or used oil; and unknown (substances). This information is included in the table in Appendix D, which lists leaded gasoline as "Pb-gas" and unleaded gasoline as "gas." The designation "?gas" means that there was no indication in the report on file as to whether the leak was leaded or unleaded gasoline. Waste or used oil is designated as "oil." A release of a hazardous substance other than a petroleum product is indicated by "hazardous" plus the type of product, if known. For example, "hazardous-PCB" means there is a known release of hazardous polychlorinated biphenyl at that site. The LUST list for the study area did not indicate any sites with crude oil, heavy oil, bunker C, or jet fuel problems.

The LUST list also indicates the extent of the contamination. If there has been a free product release on surface waters, it is noted as "FP on sw"; if free product has been identified on groundwater, it is indicated as "FP on gw"; and if dissolved contaminants have been identified in the groundwater, the designation is "dissolved in gw." In addition, if soil contamination was identified at the site, it is designated as "soil contamination"; whereas if the extent of the contamination was not indicated, it is noted as "unknown." A site may be classified as having more than one type of media contamination. No contaminated drinking water wells were noted on the site priority-ranking worksheets. There were no notations of dissolved contaminants found in surface waters. There were 32 instances of free product identified on the groundwater, 20 of dissolved contaminants found in the groundwater, 53 of soil contamination identified at the sites, and only 1 of free product found on surface water.

The UST database contains a summary of the type of product and total tank capacity at each site. In the table in Appendix D, type of product is listed in the "tank contents" column and total capacity of all tanks at the site is listed in the "total potential contaminants on-site" column. Individual tank sizes range from 40 gallons (for storage of used oil) to 18,000 gallons (for storage of diesel fuel).

The RCRA database includes a categorization for facilities that generate hazardous material. Facilities that generate more than 1,000 kg of hazardous substances per month are classified as large-quantity generators (LQG). Small-quantity generators (SQG) deal with 100 to 1,000 kg of hazardous materials per month. Condition-exempt generators (CEG), also called limited-quantity generators, produce less than 100 kg of dangerous matter per month. Also included in the categorization are facilities that treat, store, or dispose of hazardous materials; facilities that only transport such substances; and facilities that burn, blend, or recycle hazardous materials.

Hazardous materials include pesticides, herbicides, fertilizers, PCBs, oils, lubricants, radioactive materials, solvents, acids, bases, any ignitable or reactive materials, heavy metals, and asbestos. However, it is not the type of facility or even the type of substance being generated that is important on the RCRA database; rather, it is the amount of hazardous material generated. Therefore, the RCRA database does not include a listing of the hazardous material itself, and this information is not readily available at DOH (M. Miyasaka, Hawai'i Department of Health, personal communication, 1 July 1993). Under the column heading of "total potential contaminants on-site" in the table in Appendix D, the categorizations for quantity of hazardous material generated (i.e., LQG, SQG, CEG, transporter only) are listed. In addition, if the facility is listed in the database as no longer being engaged in an activity dealing with hazardous materials, this is indicated. Of the 211 RCRA sites that lie within the downtown Honolulu area, 56% are SQGs, 27% are LQGs, approximately 8% are CEGs, less than 1% only transport hazardous substances, and 8% are considered to no longer be engaged in an activity dealing with hazardous materials.

"Storage tank status," as obtained from the UST list, is another column included in the table in Appendix D, as some tanks are considered to be permanently out of use but still in the ground, temporarily out of use, closed permanently in the ground but not removed, removed from the site, or still in use. The total number of tanks per site, as well as the most recent date for any tank removals from the site, is given in the same column in the table in Appendix D. Installation dates are given for items listed in the UST database; however, for many of the tanks, the initial date of installation is unknown. Tanks range in age from only a few years old to over 70 years old (e.g., a tank that was installed at the Dole Cannery in 1918 and has since been closed in ground). The oldest tank still listed as in use was installed in 1946. Several tanks from the 1950s are still in use. However, most of the older tanks either have been removed or closed or are considered permanently out of use. Removal of these tanks began as early as the 1960s, but most of the work of removing or closing older tanks was done in the 1980s and 1990s.

Finally, the table in Appendix D provides the site classification for each facility, based on current land use. The automotive category includes car dealerships, car rental agencies, tire shops, transmission shops, car wash shops, and automotive repair shops. The gasoline station category also includes other fueling facilities. Government sites include federal, state, and city and county land parcels. The remainder of the sites fall into the category of mixed industrial/business, which includes medical facilities, plumbing shops, machine or metal works and metal recycling shops, dry cleaning and laundry establishments, hotels, offices, and small manufacturing concerns.

In the table in Appendix D, approximately 19% of the contaminated sites within the study area are classified as automotive businesses; 14% as gasoline service stations and fuel service centers; about 7% as government operations—including a military reservation, fire stations, post offices, and public schools; and approximately 59% as mixed industrial/business establishments.

Discussion

Nearly 60% of the contaminated sites within the study area fall into the category of mixed industrial/business. Land uses in the downtown Honolulu area have included light-industrial and commercial establishments for over a century. However, tracking the type of land use back in time to determine the exact cause of the contamination can be a time-consuming task. Sources of information on past land uses include old tax records, phone books, aerial photographs, street maps, zoning maps, insurance maps, records of building permits, and visual inspections of the site. From these, a history of the site can be put together. Environmental consultants generally put together a brief history of the land use of the site when working on contamination problems, but their primary interest was in determining the extent of the contamination at the locale and the most expedient way to remediate the site. Therefore, the land use that resulted in the contamination was of minor interest to them and hence was not likely to have been included in their reports. Often, because of the many changes in land ownership and land use at a site over the years, the exact cause of the contamination cannot even be determined. In some cases, it is likely that the contaminant migrated from off-site, making a determination of the specific cause for the existence of the contamination even more difficult to ascertain. When the source of the contamination cannot be cited, a nonpoint source is assumed.

Figure 10 shows the locations of the districts (Kapālama, Iwilei, Central Downtown, Kaka‘ako, and Ala Moana) within the downtown Honolulu study area. By comparing Figure 10

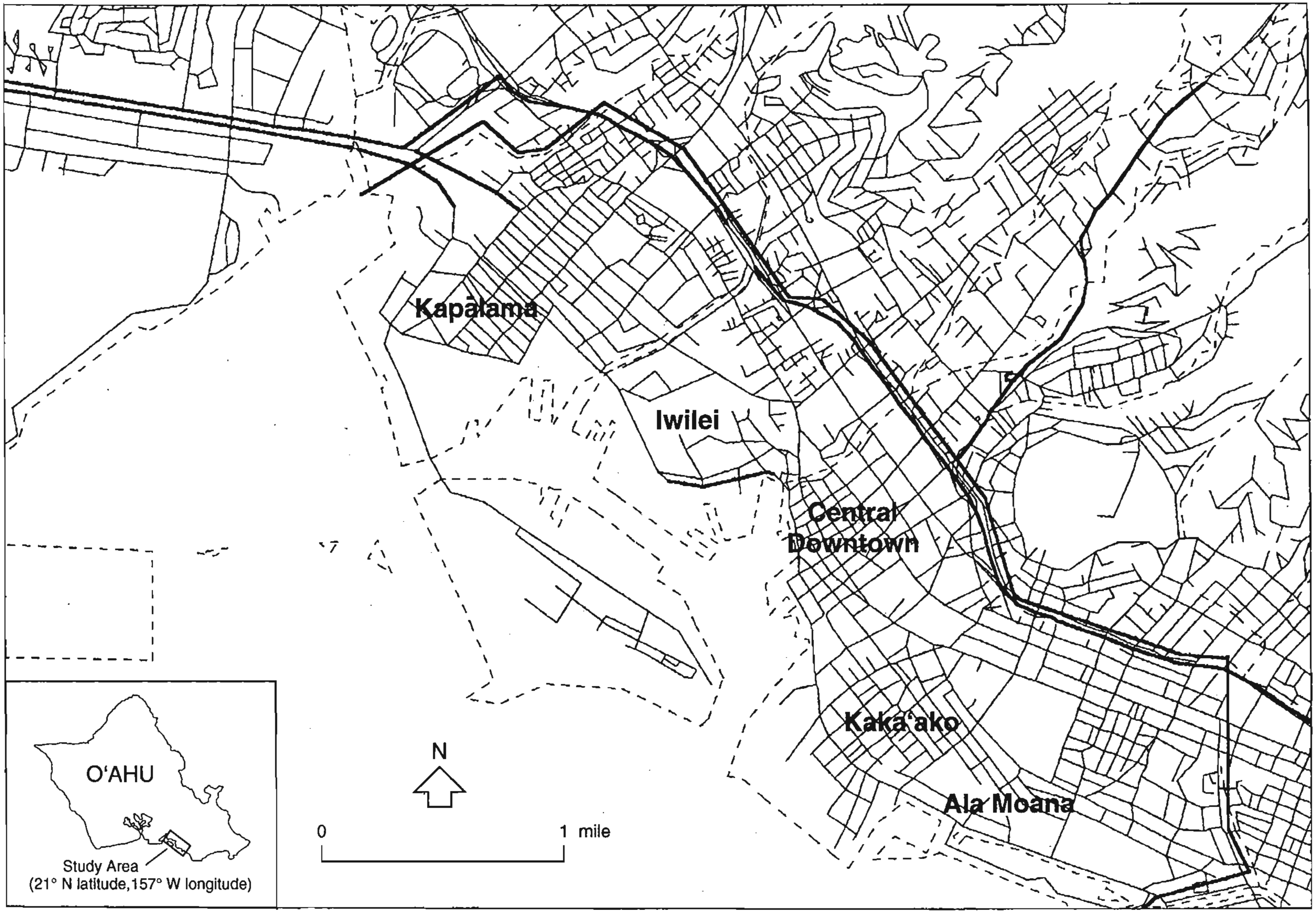


FIGURE 10. Districts within the downtown Honolulu study area

with Figure 9, which shows all the contaminated sites identified in the study area, it can be seen that Kapālama and Kaka'ako have the greatest density of contaminated sites. These districts have historically been home to many light industries and commercial businesses.

The most sizable category for type of contamination problem is that of leaking underground storage tanks. Although the RCRA database had a greater number of sites listed within the downtown Honolulu area than did the LUST database, 43% of both SQGs and LQGs on the RCRA list were in the automotive or gasoline station/fuel service center category. These businesses all rely heavily on underground storage tanks for maintaining on-site supplies of diesel fuel and gasoline and for storing waste or used oil and lubricants. Even for sites classified as mixed industrial/business or government, the primary problem is still one of leaking underground storage tanks. Diesel or gasoline storage tanks are kept on-site to fuel up delivery trucks and other company vehicles and to power emergency generators.

The LUST database includes 90 sites within the study area that are known to be contaminated by leaking underground storage tanks. The fact that a separate list is maintained of the locations of all underground storage tanks on the UST database indicates the importance of leaking underground storage tanks as a main source of contaminants in downtown Honolulu.

The UST database lists 288 locations of underground storage tanks and a total of 758 tanks. As of 1 October 1992, owners of underground storage tanks are required to register them and to pay an annual fee of $250 per tank. However, some owners do not register their tanks, unless notified of the regulation by DOH's Underground Storage Tank Section (R. Kwan, Hawai'i Department of Health, personal communication, 22 July 1993). There is the additional problem that in the past, owners were not required by law to close or remove tanks. This has resulted in some abandoned underground storage tanks remaining in the ground. Sometimes these tanks are found by accident as a site is redeveloped. Therefore, it is likely that there are more than 288 locations with underground storage tanks and more than 758 tanks within the study area.

According to the breakdown of the tanks listed in the UST database for the study area, 56% contain leaded or unleaded gasoline; 14%, diesel fuel; 14%, waste oil; 6%, other kinds of oils, including heating oils for boilers, and such substances as kerosene, methane, alcohol, and ethanol; 1%, solvents; and 8%, unknown substance.

From an analysis of the releases listed in the LUST database, 43% were either leaded or unleaded gasoline; 17%, diesel fuel; 20%, some type of oil; 15%, unknown substance; and 4%, hazardous substance other than a petroleum product.

The main type of contaminant problem therefore is petroleum hydrocarbons from leaking underground storage tanks. In addition, heavy metals, such as lead from leaded gasoline, are a concern.

The size of individual releases is also of interest. According to the LUST database, 9% of all releases was less than 500 gallons; 48%, between 500 and 5,000 gallons; 19%, between 5,000 and 10,000 gallons; 21%, between 10,000 and 25,000 gallons; and less than 3%, more than 25,000 gallons. However, in most cases the actual amount of substance released is unknown. With accurate records, one could ascertain the amount lost by leakage by subtracting the amount used to fuel vehicles from the total quantity in the tank upon filling and then comparing the resulting amount with the quantity remaining in the tank. Records, especially for older tanks, are rarely accurate enough to determine the precise amount lost by leakage, so the quantity of substance leaked from the tanks is generally an estimate. Sometimes when a tank is removed, it is found to be intact. It is then assumed that the substance surrounding the tank came from spillage during tank filling rather than from leakage of the tank itself. Often, a release is only discovered when soil staining is found or when an oily sheen is noted on the groundwater surface during construction activities at a site being redeveloped. In such cases, an accurate release amount cannot be determined.

Only six public health or nuisance complaints were noted on the LUST site priority ranking worksheets. The exact nature of the complaint was not always noted on the worksheet, but most complaints involved odors of petroleum products. Only one site, Gas Express Station #11 (LUST and UST database facility ID 9-100916), located at the corner of Auahi Street and Ward Avenue, was associated with a fire or explosion. The explosion occurred when excavations for sewer line work exposed a petroleum product floating on the groundwater surface. A leak in an unleaded gasoline line was later detected. This was the only site to be ranked as high priority.

The LUST database worksheets also included a ranking for time-constraint factors, to determine whether immediate clean-up attention is needed at the site. The three time-constraint categories are (1) the site is part of a development project, (2) the site is located in a community-sensitive area, and (3) the site is part of a pending property transaction. According to the rankings for the time-constraint factors, 15 sites were part of a development project, 28 were in community-sensitive areas, and 3 were involved in property transactions. The community-sensitive areas included schools, hospitals, beaches and parks, and historical locales such as Iolani Palace.

The most prevalent type of media contamination noted on the LUST site priority ranking worksheets is soil contamination, at 50%. Also noted were free product on groundwater, at 30%; dissolved contaminants in groundwater, at 19%; and free product on surface waters, at less than 2%. From a survey of DOH files, it was found that sorbent pads are most often used in the study area to assist in remediation of groundwater. The pads are placed in open excavations to soak up the free product, then removed to a disposal facility. Less frequently, vacuum trucks are used to pump free product from the water table. When possible, the petroleum product is recovered and recycled.

Soil contamination problems are most often addressed by either natural or enhanced bioremediation. Usually, the contaminated soil is stockpiled on-site and allowed to undergo natural or passive remediation until random sampling indicates that the contaminants have degraded to levels below those established for DOH clean-up goals. This often includes aerating and tilling the soil to augment volatilization and photochemical degradation. Enhanced bioremediation can involve the addition of microorganisms, nutrients, oxygen, water, and heat to speed up the detoxification process. In addition, contaminated soils are often removed from the site, either to be stockpiled to undergo natural bioremediation at some off-site location or to be shipped to a disposal facility. In these instances, clean fill is brought in to replace the contaminated soil removed. The amount of contaminated soil removed can vary from a few cubic yards to thousands of cubic yards.

The total scores from the LUST database for the sites that have been ranked range from 73 to 215. A high-priority or Rank 1 site has a total score range from 213 to 275 and a medium-priority or Rank 2 site from 138 to 212, whereas a low-priority or Rank 3 site has a score below 138 total points. The average for all the ranked sites within the study area was 114, which falls into the category of low priority. However, taken individually, one site fell into the category of Rank 1 (total score of 215), seven sites into Rank 2, and the rest into Rank 3. In many cases, DOH personnel included an uncertainty factor in the rankings. Ranging from ±2% to ±30% and averaging about ±10%, this uncertainty factor could result in a significant change in scores and rankings for some sites.

Conclusions

Numerous environmental contamination problems have been found within the study area, which has been characterized by light-industrial and commercial land uses for many years. Most of the problems are the result of leaking underground storage tanks. The primary type of contamination is from petroleum hydrocarbons, with heavy metals also being a concern. The main form of media contamination is that of soil contamination, with pollution of the groundwater also being a problem.

It is likely that as more sites within the downtown Honolulu area are redeveloped, more environmental problems will be found. This will be due both to the migration of contaminants in the subsurface and to the discovery of more leaking underground storage tanks and other sources of contamination. Therefore, environmental problems will continue to be a concern in the study area.

However, it is anticipated that the future of the area will remain characterized by light-industrial and commercial services, possibly with some increase in residential land use as more high-rise condominium complexes are built. The total residential population of the downtown

Honolulu neighborhoods was 58,850 in the 1980 census (U.S. Bureau of the Census 1983), whereas it was 62,842 in the 1990 census (K. Asato, Planning Department, City and County of Honolulu, personal communication, 23 February 1994), a 6.8% increase over the 10-year period. This does not account for the number of people who work within the area, commute through it, attend school there, or utilize the services and businesses there. Environmental problems that could be a health concern for humans would affect both residents of the area and the nonresidents who are regularly there for business or pleasure.

Nevertheless, in some cases the magnitude of these health concerns has probably been overdramatized. Of the ranked sites on the LUST list, most (89%) were classified as low priority on the site ranking worksheets. Most of the downtown Honolulu districts are covered in concrete—that is, with buildings, parking lots, or paved roadways. This limits the exposure pathways between the contaminants in the soil and groundwater and the people in the area. Possible places of exposure to contaminants include school playgrounds, parks, and sites of any construction activity (including roadwork) where soil is uncovered. Children, pregnant women, the elderly, and anyone with an impaired immune system are all considered at-risk populations, whether the risk is a matter of disease or endangerment from exposure to contaminants. Problems with pollutants include ignitability, corrosivity, reactivity, and toxicity; and some of the constituents of petroleum hydrocarbons, such as benzene, are considered carcinogenic. The toxicity of heavy metals, such as lead, to the central nervous system has been well-documented. Therefore, environmental problems at locations such as parks and playgrounds will continue to be a concern.

Another concern is dust blowing from construction sites. A number of complaints registered by individuals worried about contaminated soil becoming wind-borne are on file at DOH. As more sites within the downtown Honolulu area are redeveloped, this issue of wind-borne contamination will need to be addressed. Construction sites will need to provide for dust control to avoid complaints, as will sites where contaminated soil is stockpiled to undergo natural degradation of hazardous substances.

Groundwater contamination of the caprock aquifer also is of concern; however, the brackish water of the caprock aquifer is nonpotable and not likely to ever be used for drinking water, even with desalinization. The caprock groundwater in the downtown Honolulu area is very shallow, as the water table is generally within ±5 of sea level, and land elevations range from sea level to only about 40 feet above sea level at the inland edge of the study area. Because the caprock groundwater is located so close to ground surface, it has a high vulnerability to contamination.

Drinking water in Honolulu, however, comes from the confined basal aquifer, which is hundreds of feet below ground surface and thus has low vulnerability to contamination. The caprock aquifer as a whole contains many impermeable strata and has a lower hydraulic head than the basal aquifer, thus downward leaching of pollutants through the caprock and into the basal aquifer is unlikely. Caprock water could conceivably reach the basal aquifer through improperly sealed abandoned deep wells and along deep piles driven into the underlying basalt, but in general contamination of the basal groundwater from the caprock is relatively unlikely.

Migration of the contaminated caprock groundwater to surface water is possible as the caprock is hydraulically connected to the ocean. Some health risk would then exist for people who ingest fish or shellfish contaminated with the groundwater. However, the relatively low concentrations of contaminants found in the caprock groundwater suggest that this is not a major concern. Surface water contamination occurs most often here through storm runoff, sewage releases, and other surficial nonpoint sources of pollution, rather than through releases from the subsurface. Also, since water quality in Honolulu Harbor is in general poor anyway, it is not likely to be significantly impacted by leakage of contaminants from the caprock groundwater.

Although in some cases the danger to human health and the environment has probably been magnified by the media, there are undoubtedly many undiscovered or unreported cases of hazardous substance violations in the area. There are a number of factors that remain classified as unknown. These include source of contamination at some sites, total number of underground storage tanks within the area, location of some tanks, and contents of some tanks on the database listings. These unknowns should be taken into consideration and a determination made when possible. For example, geophysical surveys may reveal the presence of additional underground storage tanks within the area.

Future research into environmental problems within the area could also include in-depth tracing of historical land uses; however, this would be a time-consuming study of limited value. Of greater value would be a delineation of contaminant plumes in the subsurface. Studies undertaken by environmental consultants are very site-specific and rarely extend beyond the confines of the property in question. Environmental assessments generally include soil borings or test pits and soil sampling, although the samples are usually limited to shallow (less than 5 feet) depths. The borings are often used to create a subsurface cross-section, which is inserted into the final report; however, the cross-section will also show very shallow conditions. Only a limited number of investigations entail the installation of monitoring wells and analyses of groundwater samples. Few environmental reports include geologic maps or groundwater-level maps. Because the sites are rarely professionally surveyed, any maps included in the reports are not to scale and thus do not depict actual conditions (R. Kwan, J. Richardson, and R. Brewer, Hawai'i Department of Health, personal communication, 6 March 1996). Therefore, little work has been done to delineate contaminant plumes in the area. Those consulting reports that attempt to address the movement of contamination in the subsurface generally include maps that show contamination ending at the property boundaries. Consequently, the true extent of contaminant plumes is seldom known.

Tracing contaminant flow in the downtown Honolulu subsurface is a difficult task, given the limited amount of data available. The area suffers from widespread contamination, due to nearly a century of industrial and commercial land uses; thus contaminant plumes are likely to be quite complex. More information is needed on hydraulic conductivity values of the subsurface materials. Field or lab tests could be done to assist in determining which units are most likely to readily transmit the contamination. Perhaps a first approximation of subsurface contaminant flow could be arrived at with the assistance of computer models.

However, fractures and solution cavities in the carbonate units influence contaminant flow, and it is unlikely that small-scale mapping to reveal such details can be accomplished. In addition, local variations in groundwater flow patterns are quite complex. Although groundwater flow is in general toward the shoreline, tidal fluctuations, geological heterogeneities in subsurface sediments, and even recharge events from precipitation all influence the configurations of groundwater flow, and thus contaminant flow as well.

Noting whether there is any correlation between subsurface human-made conduits such as sewer lines and the known extent of contaminant plumes would also be useful for predicting contaminant migration. Knowledge of contamination flow in the subsurface and delineation of contaminant plumes would greatly assist in the study of environmental problems in the area and in remediation of such problems.

Nevertheless, given the rather enigmatic and elusive nature of contaminants and contaminant flow, and given the pervasiveness of contamination problems within the downtown Honolulu area, it is likely that pollution problems there will persist for decades.

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APPENDIXES

CONTENTS

Plates

APPENDIX A.
QUADRANGLE DESCRIPTIONS

The downtown Honolulu study area is divided into 157 quadrangles, each 1,000 feet by 1,000 feet. Each quad is described in detail here. The State Plane Coordinates are provided first, followed by the identification of streets, intersections, and landmarks (including parks, canals, basins, and channels) present in the quad. Detailed descriptions of the subsurface geology, as revealed in boring logs, are then presented. As the boring logs are proprietary (i.e., belonging to the client), exact locations of boreholes are not given. Instead, general locations based on subdivision of the quads into sections using major streets or intersections as dividing lines are provided.

Plates 1 through 6 in Appendix B show the division of the study area into quadrangles and the quadrangle numbering system used for this study.

Plates 1 and 2	Quads A–1 through A–4 Quads B–1 through B–10 Quads C–1 through C–11 Quads D–1 through D–12 Quads E–1 through E–12 Quads F–1 through F–10 Quads G–4 through G–11
Plates 3 and 4	Quads H–6 through H–10 Quads I–7 through I–13 Quads J–8 through J–15 Quads K–8 through K–19
Plates 5 and 6	Quads L–8 through L–20 Quads M–9 through M–20 Quads N–10 through N–20 Quads O–12 through O–20 Quads P–12 through P–19 Quads Q–14 through Q–19

Quad A–1

The coordinates for Quad A–1 are 45000 North to 46000 North and 554000 East to 555000 East (Plates 1 and 2, Appendix B). The Ala Wai Canal approximately subdivides this quad into a northern section and a southern section. Only boring logs for the northern section were examined for this study. Atkinson Drive cuts through the northwest corner of this quad.

The boring logs indicated the occurrence of 5 to 9 feet of brown clayey silt and tan silty–sandy coralline gravel, identified as artificial fill. Below this is approximately 25 feet of soft and loose lagoonal deposits, described as gray silty sand and coralline gravel, characterized by extremely low blow counts. In the northeast section of this quad, the lagoonal deposits are underlain by a lens of stiff dark-brown clayey alluvial silt of variable thickness. This lens is from 1.5 to 8 feet thick in this area, and in some places it contains small pockets of black volcanic cinders. In the north-central part of this quad, the lagoonal soils are underlain by a hard cemented coral ledge varying from less than 3 feet to 16 feet thick. Several of the boring logs describe this unit as cemented coral sand and gravel; however, the high blow counts and the continuous nature of the unit indicate that it is a coral ledge. It first appears between –27 and –35 feet; therefore, it is classified as the –30 coral ledge. The borings, which were made as deep as 225 feet, revealed coralline sand and gravel debris alternating with dark-brown clayey alluvial silts to the maximum depth drilled.

Quad A–2

The coordinates for Quad A–2 are 45000 North to 46000 North and 553000 East to 554000 East (Plates 1 and 2, Appendix B). Atkinson Drive runs through this quad in an east–west direction, Ala Moana Boulevard crosses through the southwest part, and the Ala Wai Canal ends in the Ala Wai Yacht Basin here.

There are approximately 4 to 8 feet of coral sand, gravel, and silt fill at the top of this area. Below is a layer (varying from 15 to 35 feet thick) of loose and soft gray sandy–silty clay with coral fragments and decomposed vegetation, identified as lagoonal deposits. Several borings revealed that a hard coral limestone ledge is present below the lagoonal deposits, but the ledge is not found consistently at the same elevations, nor is it of constant thickness in the section. Measurements of this ledge vary from 3 to 16 feet thick. The first appearance of this unit is at approximately –22 feet; therefore, it is tentatively identified as the –15 coral ledge. The borings were made as deep as 260 feet, revealing coralline sand and gravel debris alternating with a dark-brown alluvial silt at depths below the coral ledge.

Several boring logs noted cavities within the coralline debris, whereas others noted thin cemented lenses of coralline beach sand and well-cemented coral within the coralline sand and gravel. Well-rounded basalt gravel, coral gravel, and black cinders were noted in places within the alluvium.

Quad A–3

The coordinates for Quad A–3 are 45000 North to 46000 North and 552000 East to 553000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard crosses through the northern half of this quad, and the shoreline is located on the southern edge. This quad encompasses the easternmost section of Ala Moana Park.

Boring logs indicated the presence of 5 to 15 feet of heterogeneous fill, consisting of white silty coral sand and gravel and of brown sandy and gravelly clay with glass and other debris. Below are 13 to 17 feet of soft, compressible gray sandy silt and clay with coral fragments, identified as lagoonal deposits. A layer (approximately 10 feet thick) of coralline debris—described as loose to dense, white or gray silty–sandy coral gravel—overlies a coral ledge. The ledge, first encountered between elevations of –24 and –28.5 feet, is classified as the –15 coral ledge. It is only 3 to 8 feet thick in this area. Below is more coralline debris, consisting of loose to dense silty coral sand and gravel. These continue to the maximum depth drilled, 61.5 feet. Several borings did not reveal the –15 ledge and were not deep enough to encounter the –30 ledge. Occurrence of the –30 ledge can be anticipated here, but only additional deep drilling will verify its presence.

Quad A–4

The coordinates for Quad A–4 are 45000 North to 46000 North and 551000 East to 552000 East (Plates 1 and 2, Appendix B). This quad encompasses part of Ala Moana Park. A segment of Ala Moana Beach cuts through it on the southwest, and Ala Moana Boulevard runs through the northeast corner.

Information from only one boring log was obtained for this quad. The borehole, located in the northern midsection of the quad, is only 21 feet deep. The log indicated that the top layer is approximately 7 feet of fill, described as loose to medium-stiff brown silty–sandy gravel. Below the fill are 10 feet of soft and loose lagoonal deposits, described as gray silty coral sand and gravel. From there to the bottom of the drill hole is coralline debris, described as medium-dense white silty coral sand.

Quad B–1

The coordinates for Quad B–1 are 46000 North to 47000 North and 554000 East to 555000 East (Plates 1 and 2, Appendix B). Kalākaua Avenue cuts through the northeast corner, and the intersection of Kapi'olani Boulevard and Atkinson Drive is in the south-central part of this quad.

For the area south of the intersection, boring logs indicated the presence of about 5 feet of silty–sandy coralline gravel fill overlying about 20 feet of very loose and soft, gray silty sand and gravel lagoonal deposits. A layer (3 to 8 feet thick) of dark-brown silty alluvium mixed with black cinder sand is found beneath the lagoonal deposits. Below the alluvium are 8 or 9 feet of coralline debris, consisting of weakly cemented silty coralline sand and gravel. At about an elevation of –36 feet, a dense coral formation about 10 feet thick is encountered. This is classified as the –30 ledge. Below it is more alluvium, extending to the maximum depth drilled (55.5 feet).

North of the intersection are 4 to 9 feet of a clayey fill overlying 10 to 28 feet of loose organic gray clayey silt and silty sand with coral fragments, identified as lagoonal deposits. One boring, in the western part of this section, revealed 5 feet of dense cinder sand on top of the loose lagoonal deposits. First encountered between elevations of –13 and –26 feet is a hard white coral, probably the –15 ledge, which is as much as 27 feet thick here. However, it grades to soft coral with pockets of sand and shell fragments with depth. There is a layer (up to 20 feet thick in some locations) of mottled brown clayey silt alluvium below the coral formation. Another coral formation reported in the logs appears at about –65 feet. It extends to the maximum depth drilled, 100 feet. Described as soft clayey coral, it is probably either decomposed coral or coralline debris.

Quad B–2

The coordinates for Quad B–2 are 46000 North to 47000 North and 553000 East to 554000 East (Plates 1 and 2, Appendix B). Kapiʻolani Boulevard cuts diagonally through this quad in a northwest to southeast direction.

Boring logs indicated the presence of 4 to 9 feet of brown silty sand and gravel fill containing some boulders, bricks, and concrete rubble. Below are 15 to 30 feet of soft and loose sediments consisting of coral fragments and small shells in a gray sandy silt matrix with some organic lenses, classified as lagoonal deposits.

In the middle of this quad, the underlying sediments are interlayered alluvial deposits that consist of stiff brown clayey silt with rounded basalt gravel, and coralline debris that consists of light-colored sand, gravel, and coral fragments. The coralline debris, varying from loose to dense, is generally weakly cemented; however, there are some hard well-cemented zones, primarily at about –70, –100, –130, –145, and –170 feet. These hard zones are not laterally extensive and tend to be thin. The alluvium and coralline debris are intermixed to the total depth drilled, 203 feet. This area is probably within the Kāheka Channel, as named by Ferrall (1976). The channel cuts through the quad in a north–south direction.

Borings to the west of the channel revealed a coral ledge, first appearing at about 23 feet below sea level. It is described as a hard and massive tan algal coral. In this area, the ledge appears to be anywhere from 5 to 18 feet thick. This is classified as the –15 coral ledge. The borings also revealed coralline debris to the maximum depth drilled, 138 feet. There are several thin lenses of brown silty clay classified as alluvium, primarily at around –70 and –112 feet, and additional thin hard coral ledges at –62 and –122 feet below sea level.

Borings to the east of the channel also revealed a coral ledge, first appearing anywhere from –16 to –23 feet below ground surface. This is identified as the –15 coral ledge. Beneath is coralline debris, interlayered with some thin alluvial lenses of brown clayey silt, to the maximum depth drilled, 195 feet.

Quad B–3

The coordinates for Quad B–3 are 46000 North to 47000 North and 552000 East to 553000 East (Plates 1 and 2, Appendix B). Kapi'olani Boulevard cuts through the northeast corner. The eastern part of Ala Moana Shopping Center is here.

In the southern part of this quad, 6 to 10 feet of sand and gravel fill overlie lagoonal deposits of variable thickness consisting of gray clay with sandy silt and coral fragments. Boring logs indicated the presence of anywhere from 16 to 34 feet of these soft and compressible low-energy deposits. A ledge coral is first encountered at –18.5 to –27 feet. It is classified as the –15 coral ledge. Borings show this ledge to be 5 to 10 feet thick in this area. Below is sand and gravel coralline debris. One boring log described almost 25 feet of dark-brown silty alluvium, mixed with black cinder sand, overlying the coral ledge. The maximum depth drilled is 117 feet.

In the northern half of this quad approximately 5 feet of brown clayey silt fill overlie 10 to 20 feet of soft and loose gray silty coralline sand and gravel lagoonal deposits. Below that is a great deal of variability, as indicated in the boring logs. A thin layer (5 to 10 feet) of brown silty alluvium overlies coralline debris in several borings. A few borings revealed the presence of a coral ledge first appearing at 15 to 25 feet below ground surface; however, this ledge is not continuous through this area. It is classified as the –15 coral ledge. There is primarily coralline debris below, to the maximum depth drilled (210 feet). A number of borings revealed thin lenses of brown sandy–silty alluvium at elevations of –60 and –90 feet. Another coral ledge appears between 130 and 145 feet below sea level and a thin (only 5 feet thick) competent coral at 170 feet below sea level, but these do not appear to be continuous as their presence is not indicated in all boring logs. Two borings revealed lithified sandstone, possibly beachrock, at 70 feet and 110 feet below gradient, but this layer is also not continuous. Several borings indicated the presence of decomposed tuff with dark-brown cinder sand between 165 and 170 feet below sea level.

Quad B–4

The coordinates for Quad B–4 are 46000 North to 47000 North and 551000 East to 552000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard crosses through the southwest corner of this quad, and Pi'ikoi Street cuts through the northwest corner. This quad encompasses the western side of Ala Moana Shopping center. No borings are located within this quad.

Quad B–5

The coordinates for Quad B–5 are 46000 North to 47000 North and 550000 East to 551000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard approximately subdivides this quad into a northeast section and a southwest section. Ala Moana Park is located south of the boulevard.

Borings in the southern section of this quad revealed 3 to 10 feet of medium-dense fill, composed of brown clayey silt and white silty coralline sand and gravel. Beneath is a layer (23 to 30 feet thick) of soft, loose, and wet lagoonal deposits that consist of gray silt with some coral sand and gravel. Below is a layer of coralline debris of variable thickness. It is described as dense white silty coral sand and gravel, and, according to a number of logs, it includes dense black cinders. This layer varies from negligible to as much as 15 feet thick. First encountered between elevations of –30 and –41 feet is a very dense coral limestone of variable thickness, anywhere from 11 to 35 feet thick. However, it grades to medium-dense with depth, probably indicating coralline debris rather than coral ledge at depth. This is classified as the –30 ledge. Coralline debris intermixed with brown alluvial silty clay is found beneath the coral ledge to the maximum depth drilled (241.5 feet). Several additional coral ledges or hard well-cemented zones of coralline debris are also present, primarily at –82 and –104 feet, but these are not found in all borings and thus are not continuous in this area.

Borings in the northernmost part of the quad indicated the presence of 4 to 20 feet of fill, consisting of brown clayey silt and white coralline sand and gravel, with basalt gravel and cobbles, and miscellaneous debris. Beneath are soft and loose lagoonal deposits, 10 to 30 feet thick. These are described as gray silts and silty sand with some clayey coral gravel. Black cinder sand is also present within the lagoonal deposits, according to several logs, but the cinder layer is only about 2 feet thick. The top surface of a tan–white algal coral limestone is encountered between –24 and –29 feet. This is categorized as the –15 ledge, which is only 2 to 12 feet thick here. Below is coralline debris, composed of white or tan sand and gravel with shells, intermixed with some alluvium, described as brown silty clay with weathered basaltic fragments. The coralline debris, varying from loose to very dense and well-cemented, extends to the maximum depth drilled, 210.5 feet. Several boring logs noted a 10-foot-thick layer of hard coral at about –160 feet, but this layer was not encountered in all borings.

Quad B–6

The coordinates for Quad B–6 are 46000 North to 47000 North and 549000 East to 550000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard crosses through the northern part of this quad, and the shoreline is on the southern edge. Between them is Ala Moana Park.

Boring logs indicated the presence of about 10 feet of a silty sand and coral gravel fill, overlying loose lagoonal deposits interlayered with loose to medium-dense coralline debris to the maximum depth drilled, only 36.5 feet. Any ledge coral in this area would thus have to be encountered below –36 feet, in which case it would be categorized as the –30 ledge. Blow counts for the coralline debris encountered were quite low (20 per foot or less); therefore, another possibility is that ledge coral in this area is just weakly cemented and thus cannot be identified as coral ledge, which is characterized by high blow counts and continuity.

Quad B–7

The coordinates for Quad B–7 are 46000 North to 47000 North and 548000 East to 549000 East (Plates 1 and 2, Appendix B). The shoreline is in the southern half of this quad, and part of Kewalo Basin is in the western area. This quad encompasses the westernmost segment of Ala Moana Park. No borings are located within this quad.

Quad B–8

The coordinates for Quad B–8 are 46000 North to 47000 North and 547000 East to 548000 East (Plates 1 and 2, Appendix B). This quad encompasses Kewalo Basin, and the shoreline is located in the southern part of the quad. No borings are located within this quad.

Quad B–9

The coordinates for Quad B–9 are 46000 North to 47000 North and 546000 East to 547000 East (Plates 1 and 2, Appendix B). Part of the new Kaka'ako Waterfront Park is in this quad. The entrance to Kewalo Basin is in the southeast part of this quad.

Borings in the western part of this quad revealed about 15 feet of human-placed fill, consisting of silty sand, boulders, and wood and glass rubble. Underlying this are a few feet of a soft dark-gray organic sandy silt, black mud, and decayed wood, identified as a marsh deposit within the low-energy lagoonal deposits. This layer is not mentioned in some of the boring logs. Below is a deposit of light-gray sandy and silty coralline debris, varying from very soft to dense. At about 30 feet below sea level, a competent coral ledge is encountered. It extends downward to at least –54 feet, the maximum depth drilled. This coral layer is classified as the –30 coral ledge.

Borings taken from the central part of this quad indicated the presence of 5 to 10 feet of artificial fill overlying about 20 feet of a loose to dense, white to light-gray silty–sandy coral gravel—possibly more fill. Beneath is 5 to 20 feet of soft and loose gray silty sand, gravel, and shell fragments—classified as lagoonal deposits. This overlies loose to dense silty–sandy gravel and shell fragments, as well as several layers of hard jointed white coral. The first hard coral ledge appears at about 35 or 40 feet below ground surface, another at around 60 feet below ground surface, and a third at about 95 feet below ground surface. The uppermost ledge is probably a continuation of the –30 coral ledge. None of these coral ledges is continuous throughout the quad.

Quad B–10

The coordinates for Quad B–10 are 46000 North to 47000 North and 545000 East to 546000 East (Plates 1 and 2, Appendix B). The shoreline is along the northeast corner of this quad. Part of the new Kaka'ako Waterfront Park is here.

Information for this quad was obtained from only two boring logs. Both indicated the presence of 20 feet of artificial fill that consists of clay, silt, gravel, boulders, rubber, and glass that overlie medium-dense coral sand and shells to the total depth penetrated, 32 feet.

Quad C–1

The coordinates for Quad C–1 are 47000 North to 48000 North and 554000 East to 555000 East (Plates 1 and 2, Appendix B). Makiki Stream runs in a north–south direction through the eastern part of this quad, as does Kalākaua Avenue.

A number of borings were made in the Kalākaua Circle housing area. In the boring logs about 5 feet of a soft to stiff red–brown clayey or sandy silt are identified as fill. Beneath are lagoonal deposits, consisting of soft and loose dark-gray sandy silts and coral sand. These deposits are described as slightly organic, containing some fragments of decayed wood in addition to some shells. They are of variable thickness, anywhere from 10 to 30 feet thick, in this area. Below are alluvial deposits to the maximum depth drilled, 200 feet below ground surface. These are described in the logs as mottled orange–brown sandy silts, silty clays, and clayey silts, with weathered brown to black volcanic cinders, and some coral fragments and shells. These alluvial sediments are within the Kāheka Channel.

Quad C–2

The coordinates for Quad C–2 are 47000 North to 48000 North and 553000 East to 554000 East (Plates 1 and 2, Appendix B). Ke'eaumoku Street passes through the northwest corner of this quad.

Borings in the northeast corner of this quad revealed 5 to 9 feet of brown silty sand and gravel fill with some cobbles and boulders. Below are slightly organic lagoonal deposits consisting of soft and loose gray silty sand and sandy silt with coral fragments and shells. These deposits are of variable thickness, between 14 and 28 feet. Beneath are alluvial deposits to the maximum depth drilled, 162 feet. The alluvium is a stiff brown clayey silt, sandy silt, or silty sand, with some gravel and weathered volcanic cinders and with minor amounts of coral sand and gravel. This area is within the Kāheka Channel.

Borings in the southern part of this quad indicated similar conditions. Approximately 5 feet of fill overlie lagoonal deposits, which in turn overlie alluvial deposits, consisting primarily of sandy and clayey silts, with volcanic sand and gravel and coralline sand and gravel. The alluvial sediments and coralline debris extend to the maximum depth drilled, 200 feet. This area is also part of the Kāheka Channel.

Borings in the western part of this quad revealed 5 feet of fill over 15 to 20 feet of lagoonal deposits. A hard tan–white fractured algal coral appears at about the –20-foot elevation, making it part of the –15 coral ledge. The coral, which is 5 to 10 feet thick in this area, is underlain by coralline debris with some layers of alluvium. Another hard but fractured coral ledge appears at about 140 feet below ground surface and extends to the maximum depth drilled, 151 feet.

Quad C–3

The coordinates for Quad C–3 are 47000 North to 48000 North and 552000 East to 553000 East (Plates 1 and 2, Appendix B). Ke'eaumoku Street passes through the southeast corner of this quad, Sheridan Street cuts through the northwest corner, and Kapi'olani Boulevard crosses through in a northwest to southeast direction.

Borings in the southern part of this quad indicated the presence of approximately 5 feet of fill, consisting of clayey and sandy silt, silty coral sand, and volcanic cinders. Below are 12 to 26 feet of very soft and very loose lagoonal deposits, composed of clayey silt, coral sand, and coral fragments. A dense coral is first encountered at –15 to –20 feet. The coral, which is 5 to 10 feet thick in this area, is probably the –15 coral ledge. Another hard and dense coral is encountered at –33 or –37 feet. This is probably the –30 coral ledge. Thus, in this area, the –15 ledge appears to overlie the –30 ledge. Some boring logs indicated the presence of a stiff brown silt with white finger coral, which is either coralline debris or alluvium, between these two ledges. From the bottom of the coral to the maximum depth drilled (200 feet), coralline debris alternates with brown alluvial silt. Additional dense coral ledges are found at –90 feet and at –150 feet, but these are not found in all borings. An alluvial deposit is found fairly consistently at –115 feet.

Borings in the northern part of this quad revealed 3 to 8 feet of brown clayey silt fill with gravel, cobbles, and pieces of concrete. This overlies 10 to 20 feet of soft and loose lagoonal deposits, consisting of an organic gray to black clayey silt, with shells, decomposed wood, and coralline sand and gravel. First appearing at an elevation of –6 to –13 feet is a hard, slightly fractured tan to white algal coral, with some small solution cavities. This is tentatively categorized as the +5 coral ledge. It is only 2 to 10 feet thick here. Beneath is coralline debris, varying in density and consisting of coralline sand and gravel with some clayey silt, alternating with layers of stiff yellow–brown clayey silt, identified as alluvium. The alluvial layers vary from 1 to 25 feet thick. Another hard coral ledge, about 10 feet thick, appears at about 60 feet below the ground surface in some borings. In others, a hard coralline sandstone appears at about –100 or –190 feet. These deeper ledges are not found in all borings and thus are not continuous in this area. The maximum depth drilled is 205 feet.

In three borings in the northeast part of this quad, the shallower coral ledge was absent. These borings revealed the presence of fill and lagoonal deposits overlying alluvial deposits and coralline debris to the maximum depth drilled (180 feet). A moderately fractured coral of variable hardness and cementation is first encountered at about –37 or –40 feet. Its thickness ranges from 18 to 28 feet. Hard coralline sandstones of variable thickness are located at greater depths; however, these are not found in all borings and thus are not continuous in this area. In most of the borings, a brown clayey silt is found at about –90 feet. Some boring logs describe this as an alluvial silt, whereas other logs refer to it as a weathered tuff. The absence of the shallow coral ledge and the presence of large amounts of alluvial silts indicate that a stream channel formerly flowed through this area. The deeper coral ledges could be used for foundation-bearing purposes.

Quad C–4

The coordinates for Quad C–4 are 47000 North to 48000 North and 551000 East to 552000 East (Plates 1 and 2, Appendix B). Pi'ikoi Street divides this quad into approximately equal eastern and western sections. Kapi'olani Boulevard crosses through this quad in a northwest to southeast direction, and the intersection of Sheridan Street with Kapi'olani Boulevard is within this quad.

Borings in the northeast corner of this quad—bordered by Sheridan Street, Kapi'olani Boulevard, and Pi'ikoi Street—revealed 4 to 5 feet of brown silty sand and coral fill. Beneath are 9 to 16 feet of soft and loose dark-gray organic sandy clay, with some coral fragments and shells, classified as lagoonal deposits. A dense tan to white algal coral first appears between –9.5 and –13.5 feet. This is tentatively identified as the +5 coral ledge. The ledge, which appears to be between 5 to 14 feet thick, contains some cavities. The coral grades into underlying coralline debris, which is a less dense and hard tannish-white sandy silt and clayey sand with coral fragments. This extends to the maximum depth drilled, 112 feet. A hard coral ledge, anywhere from a few feet to as much as 25 feet thick, also appears at around –35 feet in several borings. A number of borings revealed hard coral ledge at various elevations, such as at about –70 and –85 feet, but the degree of hardness is not consistent among borings, and classification as coral ledge may depend on the degree of cementation. The +5 coral ledge was missing in only one boring, which revealed brown cinders and mottled orange–brown clayey sand and sandy clay, probably alluvium, below the lagoonal deposits but above a soft coral present at –35 feet. A shallow alluvial channel may have eroded away the +5 coral ledge in the vicinity of this boring.

Borings located in the northwest part of this quad, in the corner formed by Pi'ikoi Street and Kapi'olani Boulevard, revealed similar conditions. One boring in this area extends to –150 feet, revealing several deep alluvial lenses alternating with coral and coralline debris. The alluvium is described as stiff mottled orange–brown sandy–clayey silt, 5 to 10 feet thick. Another dense and hard coral is found at –103 feet; it extends to the maximum depth drilled. Variability in this coral was indicated by descriptions that varied between soft and hard coral, differences in blow counts, and the presence of several cavities.

Borings located in the southeast corner of this quad indicated the presence of approximately 5 feet of fill overlying 15 to 20 feet of soft lagoonal deposits. Beneath is a hard algal coral of variable thickness that is first encountered between elevations of –15 and –21 feet. This is probably the –15 coral ledge, which ranges from about 5 to 25 feet thick, averaging 10 feet thick. In the thicker sections, this coral varied from hard to medium to soft, indicating a great variability in its strength in this area. Beneath the –15 ledge, conditions are complex. The deposits consist mainly of coralline debris, coral, coralline sandstone, and alluvium. Hard coral lenses, with a thickness of generally less than 10 feet, occur at –30, –79, –90, –120, –160, and –200 feet. These ledges are not found in all borings; therefore, it is likely that they are not continuous in the area. At about 110 feet below ground surface, coral gravel with brown clayey silt is found. This material extends to as much as 157 feet below grade. It may be the remnants of an ancient alluvial channel that crossed through here. A brown cemented volcanic cinder sand at approximately 170 feet below ground surface is described in some boring logs. This may be a tuff deposit that is less than 10 feet thick. Another layer of volcanic cinder sand, also less than 10 feet thick, is found at 210 feet below grade in one boring. Below this, coralline debris extends to the maximum depth drilled, 231 feet.

A number of borings are located south of Kapi‘olani Boulevard, along both sides of Pi‘ikoi Street. These revealed 3 to 5 feet of fill, described as tan to brown silty sand and sandy silt with coral fragments. Beneath are lagoonal deposits, 15 to 23 feet thick, consisting of soft and loose, highly compressible, gray organic sandy–clayey silt with shells and coral fragments. First appearing at –14.5 to –21.5 feet is a medium-hard to hard tan coral, classified as the –15 coral ledge. This is between 13 and 23 feet thick in this area. Below, to the maximum depth drilled here (150.5 feet), are mixed alluvial deposits and coralline debris. These are stiff tan to mottled brown silty sand and silty clays with coral fragments.

Quad C–5

The coordinates for Quad C–5 are 47000 North to 48000 North and 550000 East to 551000 East (Plates 1 and 2, Appendix B). The intersection of Pensacola Street with Kapi‘olani Boulevard is located in the northeast corner of this quad.

Borings in the southeast corner of this quad indicated the presence of 4 to 10 feet of fill composed of brown silty and sandy gravel and cobbles. Below are lagoonal deposits, described as soft and very loose gray silty–clayey coralline sand and gravel. Two boring logs describe a 1- to 5-foot-thick layer of black volcanic cinders at the base of the lagoonal deposits. Below, with a first appearance ranging from –19 to –29 feet below sea level, is a hard and dense tan–white coral limestone, tentatively identified as the –15 coral ledge. This is anywhere from 2 to 10 feet thick in this area. Beneath is coralline debris, described as calcareous sand and gravel with shells, coral fragments, and cavities. This debris is locally cemented to very hard and dense. In several borings, hard cemented sand layers are found at 75 and 100 feet below ground surface. Several boring logs describe hard coral limestones at –39, –60, –100, and –160 feet, but these are not identified in all logs. Some logs describe only coralline debris at these depths; therefore, it would appear that the identification as hard coral limestone depends upon the degree of cementation. The hard coral limestones are between 5 and 15 feet thick. Coral and coralline debris extend to the maximum depth drilled, 200 feet.

In the northwest part of this quad, 3 to 4 feet of fill, composed of medium-dense tan to brown sandy silt with coral fragments, overlie 11 to 25 feet of soft and loose organic lagoonal deposits, consisting of gray silty sand and coral fragments. At an elevation of –21 to –25 feet, a dense and hard coral ledge is encountered. This is probably the –15 coral ledge. This ledge appears to be at least 9 feet thick in this area, but borings are shallow here (35 feet) so the total thickness is not known. Two boring logs describe black cinder sand with mottled gray–brown alluvial silt, which indicates the presence of an alluvial channel crossing through here. This channel has apparently eroded through the coral ledge at some locations within this area.

Borings in the northeast corner of this quad revealed 5 to 10 feet of brown silty sand and coral gravel fill. About 15 feet of soft gray clayey sand and coral fragments, classified as lagoonal deposits, are beneath the fill. A dense tan–white coral, which first appears between elevations of –15 and –19 feet, is tentatively identified as the –15 coral ledge. This is only 5 to 10 feet thick in this area, then it grades down into a less hard and dense coralline sand and gravel. Another hard coral ledge is found at an elevation of –36 feet in two borings. One boring revealed 4 feet of dense black volcanic cinders between the two coral limestones. This may be an area where the –15 ledge overlies the –30 ledge.

Quad C–6

The coordinates for Quad C–6 are 47000 North to 48000 North and 549000 East to 550000 East (Plates 1 and 2, Appendix B). No borings are located within this quad.

Quad C–7

The coordinates for Quad C–7 are 47000 North to 48000 North and 548000 East to 549000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard crosses through the southern part of this quad, running in a northwest to southeast direction. The eastern corner of Kewalo Basin is in the southwest part of the quad.

The only boring located in Quad C–7 is found in the northwest corner on the border with Quad C–8. It revealed about 4 feet of brown silty sand and coral fragments, identified as fill, overlying about 25 feet of lagoonal deposits, consisting of loose and soft gray clay, sand, and coral fragments. Below, at an elevation of about –24 feet, is a dense sandy white coral. This is classified as the –15 coral ledge. The dense coral alternates with medium-dense coralline debris to the maximum depth drilled, 51 feet.

Quad C–8

The coordinates for Quad C–8 are 47000 North to 48000 North and 547000 East to 548000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard crosses through this quad, running in a northwest to southeast direction, and the intersection of Ward Avenue with Ala Moana Boulevard is within this quad. The western part of Kewalo Basin is located in the southeast corner.

A number of borings were done in the northeast corner of this quad. They indicated the presence of 4 to 5 feet of brown silty sand and coral fragments (fill) overlying 24 to 35 feet of soft and loose lagoonal deposits that consist of gray clayey sand and coral fragments with some shells. In most of the borings, a hard coral ledge first appears at –23 or –24 feet. This is tentatively identified as the –15 ledge. This ledge is inconsistent in this area, being anywhere from 2 to 20 feet thick and alternating at depth with less dense and hard coralline debris that consists of white clayey sand and coral. The coralline debris extends to the maximum depth drilled, 76 feet. In one boring, the first appearance of a hard coral ledge is not until –46 feet. Between the lagoonal deposits and this coral is medium-dense coralline debris. Therefore, it appears that the coral ledge may depend upon cementation to give it strength in this area.

Quad C–9

The coordinates for Quad C–9 are 47000 North to 48000 North and 546000 East to 547000 East (Plates 1 and 2, Appendix B).

One boring, located in the approximate center of the quad, showed 5 feet of light-brown sand and clay fill, over 17 feet of soft and loose gray silty sand with coral fragments and pockets of clay. Beneath, at an elevation of –17 feet, is dense coral, which may be the –15 coral ledge. However, this coral is only 2 feet thick here. Below is apparently coralline debris, which is described in the boring log as soft sand. Blow counts are low (less than 10 per foot) for this sand unit, until about 41 feet below ground surface, when blow counts increase to over 100 per foot, indicating the presence of either a coral ledge or well-cemented coralline debris. The log for this boring ends the description at –42 feet; therefore, it is not possible to make an accurate determination of this unit. It is likely that the thin coral ledge at –17 feet is actually a pocket of hard coralline debris and that the first appearance of a coral ledge is at 41 feet below grade, or at an elevation of –36 feet, making this the –30 ledge.

The only boring located in the southwest corner of this quad is only 32 feet in depth. It revealed about 7 feet of fill over very loose lagoonal deposits to the maximum depth drilled.

Borings in the northwest corner indicated about 5 feet of fill over about 42 feet of lagoonal deposits that consist of soft and loose gray silty sand with coral fragments and clay. At an elevation of –44 feet a hard coral, tentatively identified as the –30 ledge, is encountered. The maximum depth drilled is 50 feet; therefore, it is not possible to determine the total thickness of the ledge here.

Quad C–10

The coordinates for Quad C–10 are 47000 North to 48000 North and 545000 East to 546000 East (Plates 1 and 2, Appendix B). The shoreline cuts through the southwest corner of this quad.

In the southern part of this quad, the ground surface has been built up with as much as 26 feet of heterogeneous fill—composed of brown clayey silt, sand, and gravel, with metal, ashes, wood, and glass. Below, first appearing between –5 and –8 feet, is a coral limestone, possibly part of the modern coral formation. About 18 feet thick, this limestone overlies 2 feet of black cinder sand, which in turn overlies coralline debris. The maximum depth drilled here is only 32 feet; therefore, it is likely that drilling did not get down to the –30 coral ledge.

Two borings in the northwest section of this quad revealed 7 to 10 feet of brown silty sand, gravel, boulders, and glass (classified as fill) overlying a white sandy coral limestone. The limestone first appears between –10 and –12 feet. It is possible that this is the –15 coral ledge, but more likely it is part of the modern coral reef development. The maximum depth drilled is –27 feet; therefore, it is likely that the –30 coral ledge was not encountered.

The 12 borings in the northeast corner of this quad revealed anywhere from 5 to 14 feet of brown clayey–silty sand and coral fragments, classified as fill. Below is loose and soft gray sandy silt, with coral fragments and shells, identified as lagoonal deposits. These are of variable thickness, from 21 to 44 feet thick. Beneath, first appearing between elevations of –37 and –47 feet, is a medium-hard fractured coral with coral fragments, probably the –30 coral ledge. Two of the borings in the far northeast corner indicated several thin lenses (1.5 to 4 feet) of black cinder sand interrupted by 9 feet of brown sandy silt. This is possibly an alluvial silt with fluvially reworked cinders. These deposits first appear at about –40 feet, and coral then appears at about –50 feet. A stream may have crossed through this area and eroded the top of the –30 coral ledge in this small area. The coral ledge continues to as deep as 81 feet below grade, the maximum depth drilled.

Quad C–11

The coordinates for Quad C–11 are 47000 North to 48000 North and 544000 East to 545000 East (Plates 1 and 2, Appendix B). The shoreline subdivides this quad into a northeast section and a southwest section.

One boring is located on the shoreline. It indicated the presence of 8 feet of fill, consisting of brown silty gravel and sand with boulders. Underneath is about 8 feet of soft and loose gray silty sand and gravel, categorized as lagoonal deposits. Below is a hard white coral limestone. Presumably this coral belongs to the modern reef.

One boring in the northeast corner of the quad, on the border with Quad D–11, revealed 8 feet of brown silty sand, gravel, cobbles, and boulder fill, overlying about 5 feet of gray sand and gravel, classified as lagoonal deposits. Beneath is a hard white coral, which is tentatively identified as modern reef coral.

Neither of these borings were deeper than 21 feet; therefore, they do not give an indication of the presence or absence of the –30 coral ledge in this area. It is presumed to be present, but only additional drilling will verify its presence in this area.

Quad D–1

The coordinates for Quad D–1 are 48000 North to 49000 North and 554000 East to 555000 East (Plates 1 and 2, Appendix B). Kalākaua Avenue crosses through the eastern part of this quad, running in a north–south direction, and King Street crosses through the quad diagonally from northwest to southeast. The intersection of Kalākaua Avenue with King Street is located within this quad.

All borings are located in the southwest part of this quad, in the area west of Kalākaua Avenue and south of King Street. Borings revealed 5 feet of a brown sandy–clayey silt fill over 12 to 15 feet of soft and loose slightly organic gray clayey silt and silty sand with some coral gravel and shell fragments, classified as lagoonal deposits. From here to the maximum depth drilled (125.5 feet), a stiff mottled orange–brown sandy silt or clayey silt alluvium with weathered volcanic cinders is encountered. Some zones of tan cemented coralline sand with coral fragments in a silty matrix were noted within the alluvial deposits. This area is within the Kāheka Channel.

Quad D–2

The coordinates for Quad C–2 are 48000 North to 49000 North and 553000 East to 554000 East (Plates 1 and 2, Appendix B). King Street cuts through the northeast corner of this quad, and Ke‘eaumoku Street and Sheridan Street cross through the western part of the quad in a general northeast to southwest direction.

Borings in the eastern part of this quad indicated the presence of a layer (2 to 5 feet thick) of brown silty sand fill, with gravel, cobbles, and boulders, overlying stiff brown clayey alluvial silts with weathered gravel. Some boring logs describe loose black organic silts at the top of the brown alluvial silts, probably indicating the presence of lagoonal deposits overlying the alluvial silts. These marsh or lagoonal deposits are 8 to 10 feet thick in several borings. A hard, vesicular, fractured basalt is found 82 or 92 feet below grade. It is as much as 16 feet thick and is underlain by stiff alluvial silts. In the deepest boring (–130.5 feet), the basalt is underlain by a soft tan coral that is 16 feet thick. Beneath the coral is a silty clay alluvium that extends to the bottom of the borehole. According to Stearns and Vaksvik (1938), drilling for a well near the corner of King Street and Kalākaua Avenue revealed rock, interpreted to be post-erosional Rocky Hill basalt, between 97 and 107 feet below grade. Thus the basalt found in the borings for this study could belong to a Rocky Hill flow event.

Borings in the northwest corner showed 1 to 6 feet of a brown silty clay or sandy clay fill with cobbles. Below are lagoonal and alluvial deposits, described as mottled gray–brown sandy silts and clayey silts that are slightly organic and stiff. A medium-dense to dense tan coral is encountered between elevations of –2 and –8 feet. It extends to the maximum depth drilled in this area, 30 feet. This coral is most likely part of the +5 coral ledge.

Quad D–3

The coordinates for Quad D–3 are 48000 North to 49000 North and 552000 East to 553000 East (Plates 1 and 2, Appendix B). Sheridan Street crosses through the southeast part of this quad, and Pi‘ikoi Street cuts through the northwest corner.

One boring in the northeast corner indicated similar conditions to that found in the northwest corner of Quad D–2. Two feet of silty clay fill overlie 17 feet of gray organic silt and mottled brown stiff sandy silt, probably lagoonal deposits and alluvium. At an elevation of –7 feet, a dense tan coral is encountered. This is presumably the +5 coral ledge, which extends to the maximum depth drilled, 29.5 feet.

Borings in the east-central part of the quad showed 3 to 5 feet of fill, composed of stiff brown silty clay with sand. Below are 3 to 5 feet of lagoonal deposits, described as loose gray silty sand. At an elevation of –2 or –3 feet, a hard white coral, classified as the +5 ledge, is encountered. This continues to the maximum depth drilled here, only 16 feet.

A number of borings are located in the southeast corner of this quad. They revealed 3 to 8 feet of fill, consisting of brown sandy–clayey silt with gravel, cobbles, and boulders. Below, 4 to 9 feet of lagoonal deposits—described as soft and loose, slightly organic black clayey silt with some shells—are encountered. First encountered between elevations of –2 and –7 feet is a hard, slightly fractured white algal coral, with some small solution cavities. This is categorized as the +5 coral ledge, and it is anywhere from 4 to 40 feet thick here. Beneath this coral, conditions are variable. Layers of silty coralline sand and gravel alternate with stiff brown alluvial silts to the maximum depth drilled, 106.5 feet.

Quad D–4

The coordinates for Quad D–4 are 48000 North to 49000 North and 551000 East to 552000 East (Plates 1 and 2, Appendix B). Pi‘ikoi Street crosses through the eastern part of this quad, running from southwest to northeast, and Pensacola Street crosses through the western part, also running from southwest to northeast.

Borings in the northwest part of the quad indicated the presence of 5 feet of heterogeneous fill, consisting of clay, silt, sand, gravel, cobbles, and organic debris. This overlies 5 feet of soft and loose gray organic sandy silts with occasional layers of peat, classified as lagoonal deposits. First appearing at an elevation of –4 to –6 feet is a hard and dense coral that is slightly fractured. Categorized as the +5 ledge, it extends to the maximum depth drilled here, 40.5 feet.

Borings in the east-central part of the quad, located along Pi'ikoi Street, revealed 4 to 5 feet of a brown clayey silt fill with some sand and gravel. Only 3 or 4 feet of lagoonal deposits are encountered below the fill. These deposits are described as soft and loose, gray to black silty clay and coralline sand. At an elevation of –2 feet, a hard coral appears in the borings. The logs describe this coral as open-structured, slightly fractured, and well-cemented, with pockets and lenses of coralline sand and gravel. This coral extends to 41 feet; however, its strength appears variable due to the pockets of loose coralline debris within the denser +5 ledge coral. One boring extended to 42 feet. The log for this boring revealed a stiff brown clayey silt alluvium in the last foot of the borehole.

Borings in the southwest corner, located between Pi'ikoi Street and Pensacola Street as well as west of Pensacola Street, revealed 4 to 9 feet of fill, which is primarily brown silty–sandy gravel, with cobbles as well as glass and metal debris. Lagoonal deposits that are 6 to 15 feet thick are found below. These are described as soft and loose, gray to black organic clayey silts and silty sand with shells, peat, wood, and coral fragments. First encountered between elevations of –8 and –13 feet is a hard and dense, slightly fractured, and well-cemented white algal coral. This is probably the +5 coral ledge, which is between 5 and 13 feet thick here. Conditions beneath this ledge coral were variable. The logs revealed the presence of coralline debris (mostly silty–sandy coralline gravel), with some lenses of stiff brown alluvial silts containing some black volcanic cinder sand. Some boring logs noted additional hard coral ledges around elevations of –35, –80, and –120 feet, but these are not found consistently in the area. In addition, the thickness of these deeper ledges is quite variable, ranging from 3 to 37 feet. The maximum depth drilled here is 156.5 feet.

Quad D–5

The coordinates for Quad D–5 are 48000 North to 49000 North and 550000 East to 551000 East (Plates 1 and 2, Appendix B). Kapi'olani Boulevard crosses through the southwest corner of this quad.

One boring from the northeast corner revealed 5 feet of fill, described as brown clayey silt and silty clay with sand, on top of 5 feet of lagoonal deposits that consist of loose gray silty sand

and clay. A dense tan coral first encountered at an elevation of –3 feet extends to the maximum depth drilled, 20 feet. This is classified as the +5 coral ledge.

Two borings in the southeast corner indicated 4 to 5 feet of brown silty sand with coral fragments, classified as fill. Below are about 13 feet of soft and loose lagoonal deposits, described as slightly organic gray clayey silt and silty sand with coral fragments. At about an elevation of –10 feet, a hard white coral that is 7 to 8 feet thick is encountered. Coralline debris, described as tan silty–sandy coralline gravel with coral fragments, is then found to the maximum depth drilled here, 100.5 feet. Two additional hard and dense coral layers are found at elevations of –35 and –75 feet. The intermediate-level coral is between 18 and 28 feet thick and contains numerous small solution cavities. The lower-level coral is only 8 feet thick. The uppermost-level coral presumably belongs to the +5 coral ledge.

Quad D–6

The coordinates for Quad D–6 are 48000 North to 49000 North and 549000 East to 550000 East (Plates 1 and 2, Appendix B). Kapi'olani Boulevard cuts through the northeast corner of this quad, and Ward Avenue crosses through the northwest corner.

The three borings located in the southeast corner of this quad revealed 3 to 5 feet of brown silty sand with coral fragments, identified as fill. Beneath are lagoonal deposits—described as slightly organic loose gray silty sand and silty clays with coral fragments—between 16 and 24 feet thick. In one of the borings, a tan coral that is slightly fractured is encountered at –15.5 feet. This tan coral extends to the bottom of the borehole at 49 feet below grade. Descriptions of this coral varied from hard to moderately hard to soft. It is classified as the –15 ledge. The second boring revealed 12 feet of gray silty clay and 8 feet of black cemented cinders beneath the lagoonal deposits, with coralline debris encountered at an elevation of –41 feet and extending to the maximum depth drilled, 56 feet. This area may be within an alluvial channel. The third boring in this area was too shallow to delineate either the alluvial channel or the –15 coral ledge.

Borings located in or near the center of this quad showed 4 to 6 feet of fill—consisting of brown clayey silt and sand, with gravel, cobbles, scrap metal, and concrete fragments—overlying 7 to 8 feet of lagoonal deposits composed of loose gray silty sand with coral fragments. At about an elevation of –7 feet, a hard tan coral, probably the +5 coral ledge, is encountered. This extends to the maximum depth drilled, 19 feet.

Borings in the northwest corner of the quad indicated the presence of 4 to 6 feet of fill, consisting of brown silty gravel, clayey silt, and silty sand with coral fragments. This overlies 7 to 12 feet of loose slightly organic gray silty sand with coral fragments, classified as lagoonal deposits. From this depth to the bottom of the drill holes at 51.5 feet below grade, alluvial sediments alternate with coralline debris. The alluvium consists of stiff brown clayey silt intermixed with white to brown silty–sandy coralline gravel with some coral fragments. This is probably part of the HIC Channel, first named by Ferrall (1976) for the Honolulu International Center, now called Blaisdell Center.

Borings in the northeast corner of this quad showed 3 to 5 feet of fill, consisting of coral fragments, cobbles, and boulders, in a medium-stiff gray clayey silt matrix. Below are 8 to 10 feet of lagoonal deposits, described as soft and loose slightly organic gray clayey silts and silty sand with shells and coral fragments. At an elevation of –5 or –6 feet, a dense tan coral is encountered. This is reported to be as much as 40.5 feet thick. The coral is described in boring logs as moderately hard to hard with some pockets of soft sand. This is probably the +5 coral ledge. It overlies an alluvial deposit consisting of stiff mottled brown silty clay that extends to the maximum depth drilled, 55.5 feet.

Quad D–7

The coordinates for Quad D–7 are 48000 North to 49000 North and 548000 East to 549000 East (Plates 1 and 2, Appendix B). Ward Avenue crosses through this quad, approximately dividing it into a southeast section and a northwest section.

The only boring for this quad is located on the western edge, just north of Ward Avenue. The boring indicated the presence of 6 feet of fill, consisting of brown clayey silt, sand, and gravel. The fill overlies 14 feet of lagoonal deposits, which are described as very loose gray silty sand with some coral gravel and shell fragments. At an elevation of –15 feet, a dense tan to white coral is encountered; it extends to the maximum depth drilled, 30 feet. This is classified as the –15 coral ledge.

Quad D–8

The coordinates for Quad D–8 are 48000 North to 49000 North and 547000 East to 548000 East (Plates 1 and 2, Appendix B). Ward Avenue cuts through the southeast corner, and Ala Moana Boulevard just touches the southwest corner.

Borings in the southeast corner showed 5 to 6 feet of brown clayey silt fill, with some sand and gravel. Beneath are 14 to 18 feet of soft and loose lagoonal deposits, primarily gray silty sand with some gravel and shell fragments. At an elevation of –15 or –18 feet, a dense tan coral is encountered; it extends to the maximum depth drilled here, 30 feet. This is categorized as the –15 coral ledge.

Borings in the southwest corner indicated the presence of approximately 5 feet of fill, consisting of silty sand and coral fragments with some cobbles and boulders, overlying about 20 feet of lagoonal deposits that are composed of soft and loose gray silty sand with some gravel and coral fragments. First encountered between elevations of –16 and –20 feet is a hard white cemented coral, probably the –15 coral ledge. This is anywhere from 10 to 25 feet thick here;

however, its strength appears to be quite variable, as the logs describe it as highly weathered and fractured and as open-structured with cavities filled by soft sand and silts. Below, to the maximum depth drilled (55.5 feet), are coralline sand and gravel with some shells, categorized as coralline debris.

Borings in the far northern part of the quad showed 2 to 3 feet of fill, composed of clayey silt and silty sand with coral fragments, overlying 10 to 15 feet of soft and loose lagoonal deposits, primarily gray organic clayey–silty sand and coral fragments. A hard tan coral is first encountered at an elevation of –8 to –10 feet; it extends to the maximum depth drilled in this area, 28 feet. This is probably the +5 coral ledge.

Borings in the middle section of this quad showed 3 to 5 feet of a brown silty sand fill, overlying 10 to 16 feet of loose and soft gray lagoonal clays, silts, and sand, with coral fragments. A dense white coral is first encountered between elevations of –13.5 and –15.5 feet; it extends to the maximum depth drilled, 25 feet. This is most likely the –15 coral ledge. This area marks the boundary between the –15 coral ledge and the +5 coral ledge and delineates the northernmost extent of the –15 ledge.

Quad D–9

The coordinates for Quad D–9 are 48000 North to 49000 North and 546000 East to 547000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard crosses through this quad, running in a northwest to southeast direction, and approximately subdivides it into a northeast section and a southwest section.

In the northeast section of the quad, borings revealed 2.5 to 7 feet of fill, described as tan silty sand and sandy clay with coral gravel and basalt boulders. Below are 17 to 25 feet of gray lagoonal deposits, described as soft and loose clayey and silty sand and gravel. Between elevations of –15 and –24 feet is a hard white reef coral, probably the –15 ledge. This continues to the maximum depth drilled here, 33 feet.

In the southwest section of the quad, borings showed 3 to 6 feet of fill, primarily silty sand and gravel with cobbles and coral fragments. Conditions beneath the fill are variable. Soft and loose lagoonal deposits, intermixed with coralline debris, are reported as anywhere from 25 to 40 feet thick. These consist mainly of gray clayey coral and sandy clay with shells and coral fragments. Several boring logs describe pockets or ledges of dense coral within the lagoonal deposits, but these coral formations are more likely dense, well-cemented coralline debris since the low blow counts and lack of continuity are not indicative of the presence of ledge coral. Five boring logs did record the first appearance of a dense coral at an elevation of –29 to –38 feet. This coral, which is between 5 and 11.5 feet thick, is probably the –30 ledge. Below, more coralline debris with some decomposed clayey coral is found to the maximum depth drilled, 60 feet.

Conditions within this quad seem to indicate that Ala Moana Boulevard approximates the dividing line between the –30 and the –15 coral ledges in this area, with the –15 ledge found northeast of Ala Moana Boulevard and the –30 ledge found southwest of the boulevard.

Quad D–10

The coordinates for Quad D–10 are 48000 North to 49000 North and 545000 East to 546000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard cuts through the northeast corner of this quad, and South Street crosses through the northwest part, running in a southwest to northeast direction.

Borings in the northeast corner and middle of this quad seem to indicate that the –15 coral ledge extends into this quad. Between 2 and 4 feet of fill—consisting of silt, sand, and gravel, with coral fragments—overlie soft and loose lagoonal deposits. The lagoonal deposits, which are between 17 and 26 feet thick in this area, are described as gray to black sandy silts and clayey silts, with some coral gravel and coral fragments. First encountered between –14 and –25.5 feet is a hard white limestone, with some small voids, classified as the –15 coral ledge. This coral formation is anywhere from 6 to 18 feet thick here, and it is underlain by coralline debris, consisting of silty coral sand and gravel. Only one boring extended to any great depth (105 feet); it revealed coralline debris to the maximum depth drilled, with several thin hard yellow–gray coral ledges at –50 feet and –82 feet. Without additional deep borings it is not possible to determine if these deeper ledges are continuous or not.

Borings in the northern part of this quad that do not show evidence of the –15 coral ledge do, however, show evidence of the –30 coral ledge. Between 3 and 9 feet of fill—composed of brown to black clay, silt, sand, and gravel, with concrete fragments—overlie soft and loose lagoonal deposits and coralline debris. These are anywhere from 23 to 38 feet thick and consist of gray clayey–gravelly sand with some coral fragments and coralline sand and gravel. First encountered between elevations of –29 and –37.5 feet is a hard and massive white coral–algal reef limestone, with some small voids, categorized as the –30 coral ledge. The ledge is between 17.5 and 26.5 feet thick here. However, because the maximum depth drilled is only 60 feet, the total thickness of the ledge here cannot be determined.

Borings in the southwest corner indicated the presence of between 3 and 5 feet of fill, described as reddish-brown to black silty sand and gravel with coral fragments. Beneath are lagoonal deposits of variable thickness, anywhere from 3 to 17 feet thick. These consist of loose gray to black clayey–gravelly coral sand and silts. Several boring logs describe a coral limestone, 3 to 11 feet thick, first encountered between elevations of –1 and –4 feet. This may be part of the recent or modern reef. The logs then indicated the presence of between 13 and 23 feet of coralline debris, described as silty sand with coral fragments and shells. Only two borings in this area were drilled deep enough to encounter the –30 coral ledge, which occurs between elevations of –33 and –33.5 feet. Thickness for the coral in this area could not be determined, as the borings only went as deep as 40 feet here. The remainder of the borings showed coralline debris—consisting of silty sand and sandy gravel, coral fragments, and shells—to the maximum depth drilled, 122 feet.

Borings in the southeast corner of the quad also showed evidence of the –30 coral ledge. Between 2 and 9 feet of fill, described as brown clayey silt and silty sand with coral fragments, overlie thick gray lagoonal deposits. Described as soft and loose clayey sand, sandy clays, and silty sand with gravel and shells, these deposits are 30 to 48 feet thick. First appearing between elevations of –29 and –49 feet is a hard white coral, probably the –30 coral ledge. This ledge is 8 to 15 feet thick. Another coral appears at an elevation of –66 feet. This coral is up to 38 feet thick, but the variability in blow counts reported for this coral indicates that the strength is not consistent. Several boring logs indicated the presence of a thin layer of alluvium overlying the upper coral ledge. This alluvium consists of dark-brown clayey silt and black cinder sand. In addition, two boring logs indicated the presence of coral at +1 and –1 feet, but the coral is only 1 to 3 feet thick here. This is younger coral, presumably belonging to the modern reef. The remainder of the boring logs indicated the occurrence of coralline debris, described as clayey sand and coral gravel, to the maximum depth drilled, 128 feet.

Quad D–11

The coordinates for Quad D–11 are 48000 North to 49000 North and 544000 East to 545000 East (Plates 1 and 2, Appendix B). The shoreline cuts through the northwest and southwest corners of this quad.

Logs for a number of borings made in the central and west-central part of this quad indicated the presence of 8 to 14 feet of fill that consists primarily of coral sand and gravel and basalt boulders. Below are 5 to 20 feet of loose gray silty sand and sandy silt with coral and shell fragments, classified as lagoonal deposits. A dense white coral, 9 to 13 feet thick, first appears at an elevation of –10 to –13 feet in a number of borings. Another hard coral, 3 to 8 feet thick, appears at elevations between –29 and –34 feet. A third dense coral is found at about –45 feet. The remainder of the boring logs revealed coralline debris between the coral occurrences and from the third coral occurrence to the maximum depth drilled, 60 feet. This coralline debris consists of loose to dense, gray to white coral gravel and silty sand. The uppermost coral may belong to the modern reef, whereas the intermediate-level and lowermost corals may be part of the –30 coral ledge.

Three borings located in the southeast corner of this quad indicated the presence of 7 to 10 feet of fill, consisting of brown sand, gravel, cobbles, and boulders, in a clay and clayey silt matrix, with some debris such as wood fragments and bricks. A lagoonal deposit of variable thickness (5 to 20 feet), described as a gray or black silty gravelly–clayey sand with coral fragments, is encountered beneath the fill. First encountered between –6 and –12 feet is a moderately hard tan to white coral–algal ledge, 5 to 9 feet thick, probably modern reef coral. Beneath is coralline debris to the maximum depth drilled, only 39 feet in this area.

Quad D–12

The coordinates for Quad D–12 are 48000 North to 49000 North and 543000 East to 544000 East (Plates 1 and 2, Appendix B). The shoreline is located along the eastern part of this quad.

All borings in this quad are located offshore. The first sediments encountered are loose and soft black muds and gray sandy silts, with some gravel and shell fragments, of variable thickness (between 10 and 39 feet thick). At an elevation of about –46 feet, a hard white ledge coral, with some large cavities, is encountered. Below are loose to dense coral sand and gravel, with hard and dense coral ledges again encountered at elevations of about –65 and –100 feet. The uppermost coral ledge, which is about 10 feet thick, is presumably part of the –30 coral ledge. The intermediate-level coral is anywhere from 5 to 15 feet thick, whereas the lower-level coral appears to be at least 18 feet thick. The lowermost coral ledge extends to the maximum depth drilled, 124 feet.

Quad E–1

The coordinates for Quad E–1 are 49000 North to 50000 North and 554000 East to 555000 East (Plates 1 and 2, Appendix B). The intersection of Kalākaua Avenue with Beretania Street is located in the southeast part of this quad.

All borings, located in southwest corner of this quad, indicated the presence of alluvial deposits to the maximum depth drilled, 55 feet. These are described as stiff mottled orange–brown clayey silts, sandy silts, and silty fine sand, with some weathered volcanic cinders. These are probably slopewash deposits, resulting from erosion in the upper valleys washing sediments down over large alluvial fans spread over this area. Rocky Hill basalt may be present below the alluvial deposits, but deeper borings are needed for verification.

Quad E–2

The coordinates for Quad E–2 are 49000 North to 50000 North and 553000 East to 554000 East (Plates 1 and 2, Appendix B). Both King Street and Beretania Street cross through this quad in a northwest to southeast direction. Ke'eaumoku Street passes through the eastern part of this quad, running in a northeast to southwest direction. The intersection of Sheridan Street with King Street is in the southwest part of this quad.

All borings in this quad revealed alluvial deposits to the maximum depth drilled (29.5 feet). Several borings indicated the presence of 1 to 2 feet of fill, consisting of grayish-brown silty sand and silty clays with some coral fragments and concrete rubble, over the alluvial deposits. The alluvium is described as stiff mottled orange–brown clayey silts and silty clays, mixed with brown cinders and some weathered gravel. Deeper borings are needed to prove the presence of basalt below the alluvium here.

Quad E–3

The coordinates for Quad E–3 are 49000 North to 50000 North and 552000 East to 553000 East (Plates 1 and 2, Appendix B). Beretania Street cuts through the northeast corner of the quad. King Street runs through the middle section of this quad, in a northwest to southeast direction. Piʻikoi Street cuts through the western half of the quad, running in a southwest to northeast direction.

All borings are located in the northwest section of this quad. Borings indicated the presence of 2 to 9 feet of fill and alluvium over 4 to 9 feet of loose to medium-dense black cinders. The fill consists of brown silty–sandy coralline gravel, and the alluvial soils are stiff mottled brown clayey silts and silty clays. Beneath the cinders is coralline debris, composed of dense tan silty–sandy coralline gravel, to the maximum depth drilled here, 19.5 feet. Borings were made too shallow to reveal the presence of any basalt that might be present at greater depth.

Quad E–4

The coordinates for Quad E–4 are 49000 North to 50000 North and 551000 East to 552000 East (Plates 1 and 2, Appendix B). The intersection of King Street with Pensacola Street is in the northern half of this quad.

Borings in the southwest corner revealed 4 to 5.5 feet of fill, consisting of brown silts and clays with some coral sand and gravel. Below are 3 to 6 feet of soft and loose lagoonal deposits, composed of organic gray silty clays, with some sand. First encountered at an elevation of –2 to –4.5 feet is a hard and dense coral formation, probably the +5 coral ledge. This coral extends to the maximum depth drilled, 21.5 feet.

Borings in the central part of the quad indicated the presence of 2.5 to 3.5 feet of fill, consisting of brown clayey silt and silty sand and gravel. Below is a 3-foot-thick layer of dense black cinders. First encountered between elevations of +1 and +0.5 foot is a hard tan coral with some cavities filled with silty sand, classified as the +5 ledge. This continues to the maximum depth drilled, 25 feet.

Borings north of King Street revealed 1 to 3 feet of fill, composed of brown silty–sandy gravel. Beneath are 2 to 7 feet of alluvial soils, described as stiff mottled yellow–brown clayey and sandy silts with some cinders and gravel. Continuing down, 5 to 10 feet of loose to dense, gray to black volcanic cinders are found over coralline debris and coral. The hard and dense tan coral, with pockets of sand, is first encountered between elevations of +0.5 and –3 feet. It is categorized as the +5 coral ledge. Coralline debris, consisting of brown sand and silts with some coral gravel and coral fragments, is found beneath the ledge coral. Three boring logs noted a 2- to 4-foot-thick bed of partly decomposed red–brown tuff over the coral ledge. Two other boring logs noted 5 feet of coralline debris on top of the coral ledge. The ledge is 15 to 20 feet thick here. One boring went deep enough to encounter dark-gray vesicular basalt at an elevation of –28 feet. This extends to the maximum depth drilled, 49 feet.

Quad E–5

The coordinates for Quad E–5 are 49000 North to 50000 North and 550000 East to 551000 East (Plates 1 and 2, Appendix B). King Street cuts through the northeast corner of the quad.

All borings within this quad showed similar subsurface conditions. The topmost layer consists of 1 to 6 feet of fill, composed of stiff brown to gray clayey silt and sand with some cobbles and boulders. Beneath are 3 to 10 feet of soft and loose lagoonal deposits, described as dark-gray moist organic silty sand and clayey silts with some coral fragments. Several boring logs noted the presence of 5.5 to 7.5 feet of loose to firm, gray to black wet cinders at the base of the lagoonal deposits. First encountered between elevations of +1.5 and –6 feet is a dense tan coral, classified as the +5 coral ledge. This coral is quite thick, as much as 40 feet, in this area. Only one boring revealed anything below the coral ledge; it revealed a stiff brown alluvial silty clay that extends to the maximum depth drilled, 76 feet.

Quad E–6

The coordinates for Quad E–6 are 49000 North to 50000 North and 549000 East to 550000 East (Plates 1 and 2, Appendix B). Ward Avenue crosses through the quad in a northeast to southwest direction, and Kapi‘olani Boulevard cuts through in a northwest to southeast direction.

Conditions in the southeast corner of this quad are identical with those described for Quad E–5, but the subsurface geology in the southwest corner is very different. There, 2.5 to 5.5 feet of fill—consisting of brown to gray silt, sand, gravel, and coral fragments—overlie 10 feet of soft and loose gray lagoonal deposits—composed of silts and sand with coral fragments and traces of organics. From here to the maximum depth drilled (51.5 feet) are alluvial sediments intermixed with coralline debris. The alluvium is a stiff brown clayey and sandy silt with some coral fragments. The coralline debris varies from white to brown and is mainly silty–sandy coralline gravel with some fragments of decomposed coral. It is likely that this area is within the HIC Channel.

Borings in the northwest section of this quad indicated two differing conditions. Borings south of Kapi‘olani Boulevard revealed 6 or 7 feet of fill, described as stiff brown silty sand with both coralline and basaltic gravel, and fragments of red bricks. Below are 3 to 9 feet of soft and loose slightly organic wet greenish-gray silty–sandy clays, with some coralline gravel and black volcanic cinder sand. These are categorized as lagoonal deposits. First appearing between elevations of –3 and –9 feet is a hard moderately cemented and fractured white to brown coral, classified as the +5 ledge. This is 5 to 10 feet thick here. From the coral ledge to the maximum depth drilled (171.5 feet), the subsurface is dominated by coralline debris intermixed with alluvial sediments. These primarily consist of white to brown silty–sandy coralline gravel and brown clayey silts. Additional hard coral ledges are found at elevations of –29, –40, –54, and –77 feet, but these are only 4 or 5 feet thick and are not found in all borings so are not continuous in this area.

Borings north of Kapi'olani Boulevard indicated the presence of the HIC Channel here. On top are 5 to 6 feet of poorly compacted fill, consisting of a mixture of brown silt, sand, gravel, and cobbles, with some black cinders and debris such as concrete rubble, glass shards, and pieces of red brick. Beneath are 2 to 15 feet of soft and loose saturated lagoonal deposits, comprised of organic greenish-gray sandy–clayey silts, with some gravel, cinders, coral fragments, and shells. A thick (up to 25 feet) layer of loose to dense black volcanic cinder sand, intermixed with some brown alluvial silt, is below the lagoonal deposits. From here to the maximum depth drilled (165.6 feet), alluvial deposits intermixed with coralline debris are dominant. The alluvium is comprised of a stiff mottled brown sandy–clayey silt with some subrounded coralline and basaltic gravel. The coralline debris primarily consists of white to brown silty–sandy coralline gravel, with some shell fragments. This varies from loose to dense, depending upon the degree of cementation. A number of hard and strong, moderately fractured coral ledges, with numerous small cavities, are present. Several boring logs noted these ledges at around –28, –49, –62, –68, –79, –94, and –130 feet. These ledges are of variable thickness, from 2 to 30 feet thick; however, they are not found in all boring logs so are not continuous in this area.

Quad E–7

The coordinates for Quad E–7 are 49000 North to 50000 North and 548000 East to 549000 East (Plates 1 and 2, Appendix B). Kapi'olani Boulevard cuts through the northeast corner of the quad.

With the exception of borings located in the north and northeast parts of this quad, all borings revealed similar subsurface conditions. The topmost layer is comprised of fill and alluvial soil, 2 to 7.5 feet thick, and is primarily a brown sandy silt, with coral gravel, black cinders, and debris such as red bricks and metal fragments. Beneath are 5 to 10 feet of soft and loose saturated lagoonal deposits, described in boring logs as organic blue–gray to green–gray sandy clays and clayey sand, with some coral fragments and shells. At the base of the lagoonal deposits is a layer (1 to 5 feet thick) of dense black volcanic cinders. First encountered between elevations of –3 and –10 feet is a hard, moderately fractured and weathered tan coral–algal reef with some pockets of dense sand. This is categorized as the +5 coral ledge. Varying from 5 to 30 feet thick, this ledge averages about 10 feet thick in this area. Below, to the maximum depth drilled (81.5 feet), is coralline debris, consisting of white to brown partially cemented silty coralline sand and gravel. Some boring logs describe additional coral ledges, notably at –19, –31, and –43 feet, but these are generally only a few feet thick and are not found consistently at the same elevations. It is possible that these are dense and well-cemented layers of coralline debris rather than coral ledges.

Borings in the north and northeast corner of this quad revealed variable conditions. It appears that an alluvial channel, probably the HIC Channel, crossed through this area. At the top of the borings is a layer (1 to 7.5 feet thick) of brown fill and soil, described as silty–sandy gravel with some black cinder sand and debris such as wood and glass fragments. Below are 10 to 17 feet of soft and loose lagoonal deposits, reported in the logs as moist gray silty sand and silty clays with some coralline gravel. A layer of 5 to 15 feet of dense brown to black volcanic cinders is beneath the lagoonal deposits. From here to the maximum depth drilled (201.5 feet) is coralline debris interlayered with alluvium. The alluvium is primarily a stiff dark-brown clayey silt, with some subrounded gravel, shells, and coral fragments. It is interbedded with black volcanic cinder sand and weakly cemented tuff. The coralline debris is composed of tan silty beach sand and white to brown silty–clayey coralline sand and gravel. Several hard coral ledges—primarily at around –14, –20, –30, –52, –71, and –92 feet—are noted in the boring logs. However, these were not found in all logs; therefore, it is likely that they are not continuous the area. In addition, these ledges tend to be quite thin, generally less than 5 feet, although there are three instances of hard coral being reported as 20 to 30 feet thick in this area. Additional drilling could determine whether any of these ledges are widespread and thick enough for foundation-bearing purposes.

Quad E–8

The coordinates for Quad E–8 are 49000 North to 50000 North and 547000 East to 548000 East (Plates 1 and 2, Appendix B).

Borings in the western part of the quad showed 3 to 6 feet of fill, described as medium-dense brown clayey silt and silty sand with gravel, cobbles, and coral fragments. Beneath is a layer (6 to 11 feet thick) of loose gray lagoonal deposits, consisting of organic sandy silts and silty sand with coral fragments. In one boring only, a 0.5-foot-thick layer of black volcanic cinder sand is found at the bottom of the lagoonal deposits. First encountered at an elevation of –5.6 to –10 feet is a hard tan coral, which extends to the maximum depth drilled here, 30 feet. This is probably the +5 coral ledge.

Borings in the northern part of this quad indicated the presence of 3.5 to 6.5 feet of fill, consisting of brown clayey–sandy gravel and gravelly sand with coral fragments, glass, and wood debris. This overlies 4 to 5.5 feet of soft and loose slightly organic gray lagoonal clays with some sand and coral fragments. Beneath is a 1.5- to 5.5-foot layer of medium-dense black volcanic cinder sand. First appearing at an elevation of –2.8 to –5.5 feet is a dense cream-colored coral–

algal reef, described as containing many *puka* or voids that are either empty or filled with soft sand. This reef, which is about 13 feet thick in this area, is classified as the +5 coral ledge. From here to the maximum depth drilled (139 feet), coralline debris dominates the subsurface materials. It primarily consists of medium-dense coralline sand and gravel, with some coral fragments and shells. Several additional hard and dense coral layers are present, but they are typically thin (4 to 6 feet) and not continuous in the area. Also, some lenses of brown clayey silt, probably alluvial silt, are present within the coralline debris. In addition, at an elevation of –81 feet, there is a 1- to 2.5-foot-thick layer of hard dark-brown tuff.

Three borings located in the easternmost part of this quad indicated the presence of 2 to 4 feet of fill, described as brown sandy silt and silty sand with gravel and coral fragments. Below are 4 to 6 feet of soft and loose lagoonal deposits, consisting of gray clayey–silty sand with some gravel and coral fragments. The first appearance of a hard tan to white coral is between elevations of –2 and –5 feet. This is at least 12 feet thick in this area; the total thickness for this coral could not be determined because the borings only went as deep as 20 feet. This coral is categorized as the +5 ledge.

Borings in the southernmost part of the quad showed 2 to 8 feet of medium-dense brown silty–sandy fill, with some coral fragments. Beneath are 3.5 to 12 feet of soft and loose lagoonal deposits, consisting of saturated organic gray clayey–silty sand, with some gravel and coral fragments. From here to the maximum depth drilled (23 feet) is a hard tannish-white coral with some small cavities. The first appearance of this coral ledge is between elevations of –3.5 and –8 feet. It is categorized as the +5 coral ledge.

Quad E–9

The coordinates for Quad E–9 are 49000 North to 50000 North and 546000 East to 547000 East (Plates 1 and 2, Appendix B). South Street passes through the northwest corner of the quad.

Borings northwest of South Street indicated the presence of 5 to 7 feet of fill—composed of medium-dense silty sand and gravel, with some red bricks and fragments of wood—overlying 12 to 22 feet of loose lagoonal deposits. The lagoonal deposits are primarily soft gray clayey and silty sand and gravel, with some thin lenses of denser coralline debris, mainly coralline gravel. Within the lagoonal deposits is a layer (between 5 and 16 feet thick) of dense black volcanic cinder sand found at an elevation of about –4 feet. First encountered at an elevation of –14 to –22 feet is a hard white coral, tentatively identified as the –15 ledge. It is as much as 20 feet thick in this area. Beneath is mostly coralline debris, consisting of coralline sand and gravel with shells. Only one boring extended to any great depth (103 feet). This boring revealed another hard coral ledge at –35 feet and a hard and strong, slightly weathered and fractured basalt beginning at about –92 feet and extending to the bottom of the borehole. This may be an area where the –15 coral ledge overlies the –30 coral ledge. The basalt is possibly from a Punchbowl lava flow.

Nineteen borings are located south of South Street in the northwest part of the quad. These showed 3 to 11 feet of fill, consisting of brown silty–sandy coralline gravel, with occasional basalt gravel, boulders, and concrete rubble. In several borings, the bottom 1 to 3 feet of fill consists of black volcanic cinders. Beneath the fill are 4 to 18 feet of soft and loose saturated lagoonal deposits. These are described as gray clayey silts and silty–sandy gravel with some shell fragments. Conditions below the lagoonal deposits are quite variable, but primarily thick sequences (as much as 73 feet) of coralline debris are present. These are tan silty coralline sand and gravel, varying from loose to medium-dense, with numerous cavities. In a number of borings, a 1- to 5-foot-thick layer of dense black cinder sand is encountered around an elevation of –15 feet; this layer probably originates from Tantalus/Roundtop fire-fountaining eruptions. Several borings revealed a layer (1 to 6 feet thick) of hard brown silts or siltstones within the coralline debris. These may be tuff deposits; however, they are not found in all borings and thus are not continuous in the area. A slightly fractured hard tan algal coral with some cavities is first encountered anywhere from –15 to –28 feet; it ranges from 3 to 23 feet thick in this locale. This coral is classified as the –15 ledge. Additional coral ledges are encountered between –33 and –47 feet, at –82 feet, at about –105 feet, and at –114 feet. The deeper ledges, which are not found at the same elevations in all borings, are generally rather thin (about 6 feet). The coral found between –33 and –47 feet may belong to the –30 ledge, and the –15 ledge may overlie the –30 ledge in this area. Borings in this area are quite deep, as much as 132 feet. Found at an elevation of around –90 feet is a hard gray basalt that is moderately weathered and fractured, possibly originating from a Punchbowl lava flow. The basalt is up to 14 feet thick. It overlies a highly fractured hard brown tuff, 1 to 5 feet thick. Below, more coralline debris and the thin coral ledges mentioned above extend to the maximum depth drilled.

Four borings in the eastern part of the quad revealed 3.5 to 5 feet of fill, described as medium-dense brown silty sand with gravel, cobbles, and coral fragments. Beneath is a layer (7 to 8.5 feet thick) of loose gray lagoonal deposits, consisting of organic sandy silts and silty sand with coral fragments. First encountered at an elevation of –6.8 to –8 feet is a hard tan coral, which extends to the maximum depth drilled here, 30 feet. This is probably the +5 coral ledge.

Quad E–10

The coordinates for Quad E–10 are 49000 North to 50000 North and 545000 East to 546000 East (Plates 1 and 2, Appendix B). The intersection of South Street with Ala Moana Boulevard is located in the eastern half of the quad. All borings are located in the eastern part of the quad.

Borings in the southeast corner indicated the presence of 3 to 4 feet of fill, consisting of brown clayey silt with sand and gravel. Below are 27 to 28 feet of soft and loose lagoonal deposits, described as gray clayey silts with coralline sand and gravel. About 6 feet of gray to white silty coralline sand and gravel are beneath. At an elevation of –24 to –26 feet, a hard white coral ledge is found; it is at least 19 feet thick. This is tentatively identified as the –15 coral ledge. The maximum boring depth here is 50 feet. One exception to these findings involves a boring located near the intersection of South Street with Ala Moana Boulevard. This boring did not encounter the coral ledge; instead, it encountered a layer of dense black volcanic cinder sand at an elevation of –29 feet. This boring is only 36.5 feet deep. It is possible that a small alluvial channel eroded the coral ledge here. Additional borings are needed to determine whether any ledge coral is present in this location.

Borings in the northeast section of the quad, above the intersection of South Street with Ala Moana Boulevard, revealed 5 to 6 feet of fill, composed of brown silty sand and gravel. This overlies 15 to 26 feet of gray lagoonal deposits, described as soft and loose clayey sand and gravel, with some thin lenses of dense black volcanic cinders. Below are 4 to 10 feet of dense tan coralline sand and gravel, probably coralline debris. First appearing at an elevation of –30 to –31 feet is a hard, very dense tan coral, with some pockets of soft coralline sand. This is tentatively identified as the –30 coral ledge, and it probably extends to the maximum depth drilled here (55 feet). Within the coral ledge is a less-dense layer of silty coralline sand and gravel. This is either a lens of coralline debris within the ledge or a less well-cemented layer of ledge coral.

Quad E–11

The coordinates for Quad E–11 are 49000 North to 50000 North and 544000 East to 545000 East (Plates 1 and 2, Appendix B). The shoreline divides this quad into a southeast section and a northwest section. No borings are located within this quad.

Quad E–12

The coordinates for Quad E–12 are 49000 North to 50000 North and 543000 East to 544000 East (Plates 1 and 2, Appendix B).

Three borings in this quad are located offshore. These borings, drilled in 7 to 44 feet of water, indicated the presence of a layer (anywhere from 17 to 87 feet thick) of loose gray silts and sand, with some coral fragments. A hard and dense white coral with large cavities, which first appears at an elevation of –50 feet, is as much as 30 feet thick. This is tentatively classified as the –30 coral ledge. Additional coral ledges appear at –62 and –77 feet and are 3 to 8 feet thick. The remainder of the deposits described in the logs include more loose gray silts, sand, and coral fragments, to the maximum depth drilled, 131 feet. A comparison of data in boring logs for Quad

D–12 with those for this quad reveals that the coral layers below the –30 ledge are not found consistently at the same elevations, nor are they of constant thickness in the area.

Quad F–1

The coordinates for Quad F–1 are 50000 North to 51000 North and 554000 East to 555000 East (Plates 1 and 2, Appendix B). The H-1 Freeway splits this quad into a northern section, which is outside of the study area, and a southern section, which is inside the study area. The H-1 Freeway overpass at Ke‘eaumoku Street is in the western part of the quad.

The two borings in this quad are located in the southeast corner, and both are only 20 feet deep. They showed 1 to 2.5 feet of fill, consisting of brown clayey silt with sand and gravel, over alluvial soils, composed of mottled brown silty sand and clayey silts with weathered cinders.

Quad F–2

The coordinates for Quad F–2 are 50000 North to 51000 North and 553000 East to 554000 East (Plates 1 and 2, Appendix B). The H-1 Freeway cuts this quad into a northern section and a southern section. Ke‘eaumoku Street cuts through the southeast corner of the quad.

The maximum depth drilled here is 45 feet. All sediments described are alluvial soils and volcanic cinders. The alluvium consists of stiff mottled brown silty clays and clayey silts, with sand, gravel, and weathered cinders. Layers of medium-dense brown to gray cinders, as thick as 5 feet, are located within the alluvium. The uppermost foot, which is composed of a loose clayey silt soil, is probably fill. The presence of basalt can be anticipated, but deeper borings are needed for verification.

Quad F–3

The coordinates for Quad F–3 are 50000 North to 51000 North and 552000 East to 553000 East (Plates 1 and 2, Appendix B). The H-1 Freeway passes through the northeast corner of the quad, Beretania Street cuts across the southwest corner, Pi‘ikoi Street crosses through the eastern half in a northeast to southwest direction, and Pensacola Street cuts through the northwest corner.

All borings are located in the northern part of the quad, with several actually outside of the study area. The maximum depth drilled is only 15 feet. Subsurface conditions are similar to that described for Quad F–2. There is variable fill in this area, as evidenced by descriptions in borings logs of pieces of concrete as deep as 14.5 feet. All sediments are described as dark-brown clayey silt and sand with cinders, gravel, and coral fragments. In some borings the cinder layers are as thick as 7 feet.

Quad F–4

The coordinates for Quad F–4 are 50000 North to 51000 North and 551000 East to 552000 East (Plates 1 and 2, Appendix B). Beretania Street divides the quad into a northern section and a southern section, and Pensacola Street crosses through the eastern section of the quad.

Borings south of Beretania Street revealed 2 to 6 feet of fill and alluvial soils, described as loose to stiff brown and mottled yellow–brown sandy silts, with some gravel and cinders. Below are 5 to 10 feet of brown to black weathered volcanic cinders, composed of loose to medium-dense, fine to coarse sand. Several borings showed 2 to 4 feet of decomposed red–brown tuff beneath the cinder layer. Under the tuff is a 19- to 31-foot-thick hard tan coral ledge that is first encountered between +8 and –3 feet. This is classified as the +5 ledge. Deposits beneath the +5 ledge are variable. Several borings indicated the presence of 4 to 9 feet of coralline debris, consisting of coralline sand and gravel, with clayey silt. This is also described as coralline rubblestone and siltstone. A 3- to 5-foot-thick layer of yellow–brown stiff clayey silt, with some coral fragments, is also indicated in some borings. This may be an alluvial deposit; however, it is categorized as decomposed volcanic tuff in several boring logs and thus may be Punchbowl tuff. Two boring logs describe another hard coral layer at an elevation of –24 feet. It is 16 feet thick and contains basalt and tuff inclusions. The deepest borings revealed vesicular basalt, which first appears between –28 and –41 feet and which extends to the maximum depth drilled (60.5 feet). This material is labeled Ko'olau basalt in one set of boring logs, but this is highly unlikely, as Ko'olau basalt is generally found hundreds of feet below the caprock sediments in the Honolulu coastal plain area. More likely, this material originated from a Punchbowl lava flow.

Borings north of Beretania Street indicated the presence of 3 to 9 feet of fill and recent alluvium, consisting of stiff mottled gray–brown clay, silt, and fine sand, with some coralline gravel. Below are 5 to 15 feet of brown to black, medium-dense to dense, volcanic cinders. A hard tan coral, with pockets of soft silty sand, is first encountered between +8 and –10 feet; this is classified as the +5 coral ledge. This ledge is anywhere from 14 to 28 feet thick, although it grades to soft coral in some locales. Several boring logs indicated the presence of layers of coralline debris and alluvium or weathered tuff with additional thin coral ledges. The deeper coral ledges are only a few feet thick and are not found consistently at the same elevations. The coralline debris consists of silty coralline sand and gravel with some shells. The distinction between alluvium and weathered tuff in the logs is not obvious, except in two cases. One boring log describes a deposit at an elevation of –11 feet as fractured; therefore, it is likely to be tuff. Another log describes a thin lens above the +5 coral ledge as containing coral fragments, cinders, and basaltic gravel; therefore, it is likely to be alluvium. The rest of the sediments are described as brown silty clays, clayey silts, silty sand, and sandy silts. The maximum depth drilled is 76.5 feet. No basalt was encountered.

Quad F–5

The coordinates for Quad F–5 are 50000 North to 51000 North and 550000 East to 551000 East (Plates 1 and 2, Appendix B). Beretania Street cuts across the northeast corner, King Street cuts through the southwest corner, and Ward Avenue passes through the western half of the quad running in a northeast to southwest direction.

All borings within this quad revealed similar subsurface conditions. The top sediments are comprised of 1.5 to 6 feet of fill and recent alluvium, described as loose to medium-dense red–brown clayey silt and silty sand with coral fragments. Below are medium-dense gray to black cinders, 7.5 to 11 feet thick. Two borings indicated the occurrence of 1.5 to 3 feet of stiff mottled brown sandy silt below the cinders. A dense white to tan coral is first encountered between +7 and +3.5 feet; this is categorized as the +5 coral ledge. This coral grades down to soft uncemented coral and coralline debris intermixed with alluvium and additional thin but dense coral ledges. The coral ledges vary from 2 to 10 feet thick in thickness. The rest of the deposits are stiff brown silty sand and sandy silts, with gravel and coral fragments, probably alluvium with some coralline debris. The maximum depth drilled in this area is 56 feet.

Quad F–6

The coordinates for Quad F–6 are 50000 North to 51000 North and 549000 East to 550000 East (Plates 1 and 2, Appendix B). Ward Avenue cuts through the southeast corner of the quad, and King Street divides the quad into a northern section and a southern section.

Subsurface conditions in the northern section of the quad are similar to those in Quad F–5. Borings revealed 1 to 8 feet of fill and alluvial soils, described as loose to medium-dense, brown to mottled gray–brown silty sand and sandy silts with some coralline and basaltic gravel. Beneath are 4 to 13 feet of loose to medium-dense black volcanic cinder sand. First encountered between elevations of –1.3 and –7 feet is a dense white algal–coral reef, with pockets of soft sand; this is classified as the +5 coral ledge. This grades down into tan silty and clayey sand with coral, probably decomposed coral. This decomposed coral is interlayered with several thin lenses of alluvium, described as stiff mottled orange–brown clayey silt and silty sand with some basaltic gravel. The maximum depth drilled is 67 feet.

Borings in the southeast corner of the quad revealed similar subsurface conditions to that described above for the northern section of the quad. The upper 1.5 to 8 feet of sediments are composed of medium-dense brown sandy silt and silty sand, with some gravel; these are classified as fill and alluvial soils. Below are 2 to 12 feet of medium-dense to dense black volcanic cinder sand. First encountered between elevations of +3 and –4.9 feet is a dense white coral, categorized as the +5 ledge. This grades down to soft to medium-dense coral with silty sand. Borings also revealed cavities and some coral fragments and clayey coral, probably coralline debris and decomposed coral. This material extends to the maximum depth drilled, 105 feet.

Three borings in the southwest part of the quad revealed similar subsurface conditions to those in the southeast corner of the quad. One exception is the presence of 2.5 to 6 feet of lagoonal deposits above the +5 coral ledge. These lagoonal deposits consist of soft, slightly organic gray clayey silts and clayey–sandy silts. The +5 coral ledge is found at an elevation of about –5 feet in this area. The maximum depth drilled is 25 feet.

The remainder of the borings in the southwest corner of the quad indicated that this area is within the HIC alluvial channel. Fill and alluvial soils, 5 to 11 feet thick, consist of brown clayey silt with sand and gravel, as well as miscellaneous debris such as bricks and broken glass. As little as 1 foot and as much as 20 feet of medium-dense black volcanic cinders intermixed with soft and loose organic lagoonal deposits are found beneath the top soil and fill layer. The lagoonal deposits are primarily gray–green clayey silts and silty clays. Below is alluvium mixed with coralline debris and black volcanic cinders. The alluvium is stiff brown to yellow–brown silt, and the coralline debris is coralline sand and gravel with some shells. There are several thin but hard coral ledges or layers of well-cemented coralline debris, but these are not found in all borings or at the same depths in the borings. These hard layers are typically less than 10 feet thick and often only 1 or 2 feet thick. The alluvium, intermixed with coralline debris and volcanic cinders, extends to the maximum depth drilled here, 165 feet.

Quad F–7

The coordinates for Quad F–7 are 50000 North to 51000 North and 548000 East to 549000 East (Plates 1 and 2, Appendix B). The intersection of King Street, Kapi‘olani Boulevard, and South Street is in the northern part of the quad.

Borings in the southwest, northwest, and northeast corners and in the eastern part of this quad indicated that similar subsurface conditions exist throughout these areas. At the top of the section is a layer (1.5 to 10.5 feet thick) of human-placed fill and alluvial soil, consisting of medium-dense gray to brown clayey silt and silty sand and gravel, with some cobbles and boulders. Beneath is a layer (2 to 10 feet thick) of soft and loose lagoonal deposits. Although missing in several borings, where present, these deposits appear as slightly organic gray to black silts and clays, with some gravel and shells. Below is a 1.5- to 7.5-foot-thick layer of dense black volcanic cinder sand, where present. First encountered between elevations of +4.5 and –7.7 feet is a hard coral–algal reef that is as much as 34 feet thick here. Another hard coral, which is about 6 feet thick, is encountered at an elevation of about –40 feet, but it is not found in all borings. The upper coral, categorized as the +5 ledge, grades into coralline debris, which consists of clayey and silty coralline sand and gravel. The degree of weathering, fracturing, and cementation in the coral ledges and coralline debris is highly variable. The coralline material extends to the maximum depth drilled (101.5 feet), with the exception of a 3- to 4-foot-thick layer of hard tuff, described as mudrock in several boring logs, at an elevation of about –60 feet.

Borings in the southeast corner and western part of the quad indicated different subsurface conditions from those in the other parts of the quad. These areas appear to be within the HIC Channel. At the top of the section is a layer (2.5 to 8 feet thick) of fill, consisting of brown clayey silt and silty sand with gravel and cobbles. Below is a layer (3 to 14 feet thick) of soft and loose gray–green to black lagoonal deposits. These are organic fine-grained materials such as clays, silts, and sand, with some gravel and shell fragments. A layer (2 to 5 feet thick) of stiff brown clayey–silty sand, probably alluvium, is beneath the lagoonal deposits. As much as 33 feet of dense cemented black volcanic cinder sand are found below the alluvium. From the cinder layer to the maximum depth drilled (120 feet), stiff mottled brown clayey silts, identified as alluvium, are found alternating with coralline deposits. The coralline sediments are primarily silty coralline sand and gravel (coralline debris) with some thin coral ledges. The coral ledges are not found in all the borings or at the same depths within the borings. The ledges are generally less than 10 feet thick and vary in strength from hard and strong to soft and weak. Three borings revealed a layer of hard and strong, slightly weathered, and highly fractured tuff at an elevation of about –58 feet. This tuff is between 2 and 5 feet thick in this area. It may be Punchbowl tuff.

Quad F–8

The coordinates for Quad F–8 are 50000 North to 51000 North and 547000 East to 548000 East (Plates 1 and 2, Appendix B). South Street subdivides this quad into a northern section and a southern section.

Borings in this quad revealed anywhere from 1 to 10 feet of heterogeneous fill. The fill is gray to brown clayey–silty sand and gravel, with debris including basalt boulders, bits of glass, nails, bricks, and concrete rubble. Most borings revealed soft and loose lagoonal deposits below the fill. The lagoonal deposits, are organic gray clayey silts and sandy clays with some shell fragments. First encountered between elevations of +5 and –10.8 feet is a massive coral–algal reef, classified as the +5 ledge. Above the coral ledge is a layer (1.5 to 6 feet thick) of dense black volcanic cinders. The coral ledge appears to be quite thick here, as much as 30 feet; however, its strength varies greatly. Borings indicated that the coral grades down to coralline debris, mainly silty coralline sand and gravel. Both the ledge coral and the coralline debris vary from loose to medium-dense to dense, with some cavities that are either empty or filled with soft clay or clayey sand. The degree of cementation, weathering, and fracturing appears to be highly variable within the ledge coral and the coralline debris. Several hard and strong coral ledges are present within the thick sequences of coralline debris, but they are not found consistently at the same elevations.

There are also several thin lenses (generally less than 5 feet thick) of dark-brown silty alluvium within the coralline debris. The coralline debris extends to the maximum depth drilled here (151.5 feet), with the exception of a 5-foot-thick layer of weathered dark-brown tuff located at an elevation of about –72 feet.

Quad F–9

The coordinates for Quad F–9 are 50000 North to 51000 North and 546000 East to 547000 East (Plates 1 and 2, Appendix B). South Street crosses through the southeastern section of the quad.

Borings in the western part of the quad indicated the occurrence at ground surface of 2.5 to 6.5 feet of fill, consisting of loose to dense tan silty coral sand and gravel, with some coral fragments and cinders. Below are 2.5 to 11.5 feet of soft and loose gray lagoonal deposits, composed of silty coral sand with some gravel and some clay. Below the lagoonal deposits is a layer (2 to 7 feet thick) of dense black volcanic cinders. A hard tan coral first appears between elevations of –4 and –12 feet; this is categorized as the +5 ledge. The coral ledge is between 19 and 35 feet thick here; however, it contains pockets of uncemented silty sand with shell fragments, has cavities, and grades from well-cemented to weakly cemented in some areas. Therefore, although the ledge is quite thick in this area, its strength is variable. Beneath the coral ledge is coralline debris, primarily silty coral sand and gravel, varying from weakly cemented to dense. The coralline debris is up to 53 feet thick here. Two borings were made deep enough to encounter basalt at an elevation of about –82 feet. The basalt—which is described as gray, very dense, and massive—extends to the maximum depth drilled, 100 feet. It may be part of the Punchbowl or Nu'uanu lava flow.

Borings in the eastern section of the quad showed slight variations from borings in the western part of the quad. In the east, at the top of the section is a layer (1.5 to 8 feet thick) of fill, composed of loose to medium-dense grayish-brown silty sand and clayey silt, with some gravel, cobbles, boulders, and concrete rubble. Several borings revealed soft and loose lagoonal deposits, 3 to 13 feet thick, below the fill. The lagoonal deposits consist of organic gray to black silty–sandy coral gravel with some shells. The lagoonal sequences are missing in a number of borings. Dense dark-brown to black volcanic cinder sand is present in most borings. The cinders are between 1.5 and 7.5 feet thick. First encountered between elevations of +5.5 and –10.5 feet is a hard tannish-white fractured coral, classified as the +5 ledge. The coral ledge is as much as 40 feet thick; however, its strength is variable, as it grades from soft to medium-dense to dense and contains pockets of soft silty sand. Below is coralline debris, described as dense tan silty sand with coral fragments. The debris extends to the maximum depth drilled, 50.5 feet. Borings made in the eastern section of the quad are apparently not deep enough to have encountered basalt.

Based on information for nearby borings (i.e., those located in the northwest part of Quad E–9 and the southeast part of Quad F–10), it is probable that the –15 coral ledge is located in the southwest part of Quad F–9. However, since no borings are located there, this has not been confirmed.

Quad F–10

The coordinates for Quad F–10 are 50000 North to 51000 North and 545000 East to 546000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard runs in a north to south direction through the eastern half of the quad. The shoreline is located in the western half of the quad.

The southern edge of this quad seems to mark the boundary between the –30 coral ledge and the –15 coral ledge, as there are no borings in this quad that only indicate the presence of the deeper ledge. The dividing line between the –15 coral ledge and the +5 coral ledge is also within this quad. Borings south of this division indicated the occurrence of 5 to 11 feet of fill, composed of tan to brown clayey–silty sand and gravel, on top of 6.5 to 12 feet of soft and loose lagoonal deposits, described as saturated gray clay with some silty sand and gravel. Below is a 4- to 10-foot-thick layer of dense black volcanic cinder sand. First appearing between elevations of –14.5 and –18 feet is a hard and dense white coral, categorized as the –15 coral ledge. This ledge is 20 to 22 feet thick in this area. Beneath is coralline debris, composed primarily of medium-dense white silty gravel. Only one boring extends to any great depth; it revealed another hard coral ledge (28 feet thick) at an elevation of –48 feet. This coral is tentatively classified as the –30 ledge. Therefore, in this area the –15 ledge may overlie the –30 ledge. A moderately weathered, slightly fractured, hard, and strong dark-gray basalt appears at an elevation of –91 feet and extends to the bottom of the drill hole at 107.5 feet. This is part of a Nuʻuanu lava flow or, possibly, a Punchbowl lava flow.

Subsurface conditions north of the dividing line between the –15 coral ledge and the +5 coral ledge are the same as that described for the western side of Quad F–9.

Quad G–4

The coordinates for Quad G–4 are 51000 North to 52000 North and 551000 East to 552000 East (Plates 1 and 2, Appendix B). The H-1 Freeway divides the quad into a southwest section (included in this study) and a northeast section (outside the boundaries of this study).

Only one boring is located in the study area within this quad. It revealed 7 feet of alluvial soil, described as firm brown clayey silt, on top of 14 feet of dense black volcanic cinders. A 7-foot layer of stiff yellow–brown silty clay alluvium is located beneath the cinder layer. Below the lower alluvium is a hard tan coral, probably the +5 ledge. Drilling ended 1 foot into the coral for this borehole, which is just 29.2 feet deep.

Quad G–5

The coordinates for Quad G–5 are 51000 North to 52000 North and 550000 East to 551000 East (Plates 1 and 2, Appendix B). The H-1 Freeway passes through the northern part of the quad, Ward Avenue divides the quad into an eastern section and a western section, and Beretania Street cuts through the southwest corner.

Only the area south of the freeway falls within the study area. East of Ward Avenue and south of the freeway, borings revealed 2.5 to 6 feet of fill and alluvial slopewash deposits. These consist of brown clayey silt with gravel, cobbles, and coral fragments in the uppermost reaches and stiff brown sandy silt and silty clay below. An 11- to 16-foot-thick layer of loose to medium-dense black cinder sand is beneath the silty alluvium and fill. Below the cinder sand is a lens (13 to 15 feet thick) of weathered tuff, described as hard brown clayey–sandy silt or decomposed rock. Several boring logs mention a dense white coral, with some silty sand pockets, encountered at elevations of +3 and +8 feet. This is probably an extension of the +5 coral ledge. Borings that did not encounter the ledge coral indicated the presence of coralline debris, consisting of white to tan sandy coral fragments with clayey coral sand. The coral and coralline debris layers are between 5 and 11 feet thick. Below is a thick lens (36 feet) of very coarse and angular white to brown dense tuff sand, with some black cinders. This grades down to decomposed tuff, described in boring logs as hard brown silty clay, which extends to the maximum depth drilled, 79.8 feet. This is probably Punchbowl tuff.

Borings made west of Ward Avenue and south of the H-1 Freeway revealed 4 to 12.5 feet of fill and alluvial soils, composed of stiff brown clayey silts and sandy silts with some cinders. Beneath are 12.5 to 20 feet of dense black volcanic cinders. In some borings, the cinders grade down to a stiff brown sandy–clayey silt mixed with cinders, possibly alluvium with cinders or ash and cinders. Below the cinder layer, conditions are variable. One boring indicated the occurrence of 2 feet of alluvium (stiff brown clay, sand, gravel, and coral fragments) on top of 19.5 feet of basalt (dense blue lava rock and clinkers), which in turn is on top of brown tuff or cemented ash. One boring on the western edge of the quad indicated the presence of a 5-foot-thick coral ledge at an elevation of +1.5 feet; this is probably the +5 coral ledge. Several borings revealed a hard cemented orange–brown tuff containing coral fragments; this tuff occurs between elevations of +34 and +13 feet and is anywhere from 6 to 24 feet thick. Some boring logs refer to this tuff as sandstone. This tuff overlies a hard brown to black clayey silt and weathered rock, most likely decomposed tuff. Beneath is hard black fractured basalt, which is first encountered between elevations of +10 and –1 feet and which extends to the maximum depth drilled, –48.5 feet. The tuff and basalt may have originated from Punchbowl eruptions.

Quad G–6

The coordinates for Quad G–6 are 51000 North to 52000 North and 549000 East to 550000 East (Plates 1 and 2, Appendix B). Running in a northwest to southeast direction, Beretania Street divides the quad into a northeast section and a southwest section.

In the southwest section of the quad, borings revealed 0.5 to 3.5 feet of fill and alluvial topsoil, consisting of gray to brown clayey silt and silty sand, with some coralline sand and gravel and coral fragments in the uppermost layers. Below is a layer (4 to 9.5 feet thick) of medium-dense black volcanic cinders with some brown sandy silt. First encountered between elevations of +3.7 and +9.5 feet is a dense white to brown coral, with some pockets of sand. Classified as the +5 ledge, this coral is anywhere from 8.5 to 23.5 feet thick here. Below, extending to the maximum depth drilled (50 feet), is alluvium, described as stiff mottled brown clayey–sandy silt, with some shells, coral fragments, and basaltic gravel and cobbles.

Two borings in the far northeast corner of the quad revealed 3.5 to 7.5 feet of fill and alluvial soil on top of 8 to 9 feet of cinders. The uppermost deposits are brown clayey–silty sand and gravel, with some concrete rubble. The cinder sand is black and medium-dense. Below, a brown weathered mudrock, identified as tuff, extends to the maximum depth drilled, only 15 feet here.

The remainder of the borings in the northeast section revealed 1 to 5 feet of fill and alluvial topsoil, composed of stiff brown sandy silt and silty sand and gravel, on top of 8 to 13 feet of dark-gray medium-dense volcanic cinder sand. First encountered between elevations of +17.5 and +11.2 feet is a medium-hard to hard tan to white coral, categorized as the +20 ledge. The coral extends to the maximum depth drilled, 28.5 feet.

Quad G–7

The coordinates for Quad G–7 are 51000 North to 52000 North and 548000 East to 549000 East (Plates 1 and 2, Appendix B). Beretania Street cuts through the northeast corner, and King Street cuts through the southwest corner of this quad.

Borings northeast of Beretania Street revealed 2 to 8 feet of fill and alluvial slopewash deposits, described as soft to stiff, tan to brown clayey silts, silty sand, and sandy silts with some gravel. Beneath is a layer (6 to 12 feet thick) of loose brown to black silty cinder sand. First encountered between elevations of +7 and –13 feet is a slightly fractured hard white to tan coral formation, with voids. This is classified as the +5 ledge. The coral grades down to medium-dense coralline debris, described as cemented coral fragments with sand. In several borings, medium-dense coralline debris, between 1 and 10 feet thick, overlies the hard coral ledge. One boring encountered hard black basalt at an elevation of –22 feet; another encountered highly weathered dense tan tuff, around 15 feet thick, at an elevation of about –33 feet. Below is more coralline debris, extending to the maximum depth drilled, 61.5 feet.

Borings in the southeast corner revealed 1.5 to 6 feet of fill, composed of soft to stiff, gray to brown clayey silt and silty sand, with some gravel and boulders. Underneath are 6 to 9 feet of loose to dense black volcanic cinders. First encountered between elevations of +4.5 and –10 feet is a hard tan laminated coral, categorized as the +5 ledge. This grades down to coralline debris, characterized by very loose to very dense coral fragments and coral sand. The coralline formations are as much as 28 feet thick and are underlain by alluvium interlayered with more coralline debris. The alluvium is a hard brown sandy silt and sandy clay, with some weathered cinders and basalt gravel that is referred to in several boring logs as stream gravel. The coralline debris consists of medium-dense brown silty–sandy coralline gravel with coral fragments. The alluvium intermixed with coralline debris extends to the maximum depth drilled, 121.3 feet.

Borings in the westernmost part of the quad indicated similar conditions to those in the southeast corner. At ground surface is a layer of 3 to 13 feet of fill and alluvial soils, consisting of clayey silt, silty clay, and silty sand, with coral sand and gravel and coral fragments. Beneath are 2 to 7 feet of loose to medium-dense, brown to black silty volcanic cinders. A layer, 2 to 3 feet thick, of dense brown silty sand is found at the base of the cinders in several borings. This may be a consolidated ash deposit or tuff. One boring log refers to it as mudrock. Appearing between elevations of +1 and –5 feet is a dense tan coral, categorized as the +5 ledge. This grades down to coralline debris, described as medium-dense silty sand with coral fragments and shells. In several borings, a medium-dense layer of coralline debris, 1 to 7 feet thick, is found overlying the denser coral ledge. The coral formations are as much as 25 feet thick and are underlain by alluvium (stiff brown sandy silt with gravel) intermixed with coralline debris (medium-dense tan sand with coral fragments and some clay), which extends to the maximum depth drilled, 41.5 feet.

Borings in the southwest corner and central part of the quad revealed the presence of an alluvial channel. There are 5 to 18 feet of fill and slopewash deposits, consisting of medium-stiff brown clays, silts, and sand, with some shells, boulders, and decomposed coral. One boring log describes a lens of clayey silt as mudrock, which could be an indication of the presence of a tuff deposit within the uppermost sediments. Below are loose to dense, gray to black silty cinder sand, as thick as 55 feet. Underneath are alluvial sediments intermixed with coralline debris. The alluvium is primarily a stiff brown silt, with some sand, rounded basalt gravel (called stream gravel in one boring log), and weathered cinders. The coralline debris consists of medium-dense white cemented silty coral sand and gravel with coral fragments. These alluvial deposits, combined with coralline debris, extend to the maximum depth drilled, 155 feet. This area is apparently within the HIC Channel.

Quad G–8

The coordinates for Quad G–8 are 51000 North to 52000 North and 547000 East to 548000 East (Plates 1 and 2, Appendix B). King Street subdivides this quad into a northeast section and a southwest section.

All borings within this quad revealed similar subsurface conditions. Fill and alluvial soils, 2.5 to 5.5 feet thick, are composed of stiff brown silts and sand with some gravel. Beneath are 2 to 8 feet of ash and cinders, described as loose to dense, brown to black sand with some silt. First encountered between elevations of +7.9 and +1.5 feet is a soft to hard, moderately to severely fractured tannish-white coral formation, with pockets of sand and gravel. The coral formation, categorized as the +5 ledge, is 6 to 20 feet thick here. It grades down to coralline debris—described as medium-dense tannish-white silt, sand, and gravel—which extends to the maximum depth drilled, 31.3 feet.

Quad G–9

The coordinates for quad G–9 are 51000 North to 52000 North and 546000 East to 547000 East (Plates 1 and 2, Appendix B). King Street cuts through the northeast corner of the quad.

Borings within this quad revealed 2.5 to 10 feet of heterogeneous fill—composed of loose to stiff brown clay, silt, sand, gravel, and some boulders, with pieces of tuff, coral fragments, and shells and with miscellaneous trash such as charcoal, glass shards, and metal debris. Underneath are 1.5 to 9 feet of loose to dense, brown to black silty cinders. Several borings made in the westernmost section of the quad revealed 1 to 5 feet of organic marsh or lagoonal deposits beneath the fill and above the cinders. These lagoonal deposits are described as loose gray clayey–silty sand and gravel, with soft black peat and decaying vegetation such as stems, roots, and leaves. First encountered between elevations of +7.5 and –11 feet is a hard tan reef limestone, with pockets of silty sand. This is categorized as the +5 coral ledge. It grades down to coralline debris, consisting of weakly cemented to dense silty coral sand and gravel. Typically, the upper 3 to 10 feet of the coral ledge are also weakly cemented in this region. The coralline formations in this area are quite thick, up to 81 feet. Below are alluvial sediments mixed with more coralline debris, extending to the maximum depth drilled (111.5 feet). The alluvium is a stiff mottled orange–brown clayey–sandy silt. Only one boring found a moderately fractured dark-gray basalt at an elevation of –81 feet.

Quad G–10

The coordinates for Quad G–10 are 51000 North to 52000 North and 545000 East to 546000 East (Plates 1 and 2, Appendix B). Ala Moana Boulevard runs north to south through the eastern half of the quad, and the shoreline is located in the western half. All borings in this quad are located in the eastern part.

Borings indicated 4 to 10 feet of loose heterogeneous fill, consisting of brown clay, silt, sand, basalt gravel, coral gravel, cinders, and boulders. Also included in the fill is rubbish, primarily fragments of glass and some charcoal ashes. Below are medium-dense black silty cinders, anywhere from 1 to 8 feet thick. A number of borings, mainly located in the southeast section of the quad, revealed 2 to 6 feet of soft and loose lagoonal deposits below the fill and above the cinders. These consist of gray silty–sandy clays with some gravel and decaying vegetation. First appearing between elevations of –2 and –11 feet is a hard tannish-white coral with pockets of soft silty sand. Categorized as the +5 ledge, it grades down to decomposed coral and coralline debris, primarily silty coralline sand and gravel with shells and fragments of finger coral. The coralline debris contains several thin lenses of brown clayey–silty alluvium. The coralline formations extend to the maximum depth drilled here, 80 feet. The uppermost few feet of the coral ledge in this area are weakly cemented, a description that is similar to that for the coral ledge in Quad G–9.

Quad G–11

The coordinates for Quad G–11 are 51000 North to 52000 North and 544000 East to 545000 East (Plates 1 and 2, Appendix B). The shoreline is located in the northeast corner of this quad.

The southernmost boring in the quad showed 7 feet of fill, consisting of medium-dense light-brown silty sand and coral fragments, on top of 16 feet of loose dark-gray lagoonal deposits, composed of silty sand with coral fragments and shells. At an elevation of –15 feet is a tannish-white coral. Extending to the maximum depth drilled (59.9 feet), this coral varies from dense to medium-dense to soft. It is tentatively classified as the –15 ledge.

The remainder of the borings in the quad indicated the presence of 5 to 8 feet of fill, described as medium-dense to dense, tan to brown silty sand with coral and some clay. This fill overlies 6 to 8 feet of loose dark-gray lagoonal deposits, also described as silty sand, with coral fragments and shells. First encountered between elevations of –3 and –8 feet is a dense white coral limestone that is moderately fractured and highly weathered. It grades down to a soft clayey sand with coral, which in turn grades down to a dense tan coral with some sand and clay and a medium-dense clayey sand with coral fragments. These deposits extend to the maximum depth drilled, 58 feet. The uppermost hard coral, which is 9.5 to 15 feet thick, is probably the +5 ledge. It grades down to coralline debris of variable hardness. It is likely that the dividing line between the –15 ledge and the +5 ledge runs through this quad. Alternatively, the uppermost coral may belong to the recent or modern reef.

Quad H–6

The coordinates for Quad H–6 are 52000 North to 53000 North and 549000 East to 550000 East (Plates 3 and 4, Appendix B). The H-1 Freeway splits this quad into an eastern section and a western section. All borings are located in the western section.

Borings in the southern part of this quad revealed a layer of fill and slopewash deposits, composed of soft to stiff brown clayey silt with sand and gravel. This layer is of variable thickness (up to 11.5 feet). Beneath is a layer of volcanic cinders, described as dense gray to black cemented silty sand. This second layer is also of variable thickness (as much as 15 feet). Below are thick sequences of volcanic deposits, primarily tuff, described as dense gray to red–brown to yellow–brown bedded, welded, fractured, and weathered tuff with silty sand and secondary calcite cementation. Several borings revealed a layer (up to 17 feet thick) of black cemented cinders within the tuff. A number of borings revealed a layer of very hard gray basalt, described as vesicular, fractured, and "fresh," with clinkers, within the tuff. The basalt, which is between 5 and 19 feet thick, first appears between elevations of +50 and +22 feet. The volcanic sequences of tuff, with cinders and basalt, are as much as 73 feet thick. Beneath is coralline debris—consisting of white to gray, poorly cemented coralline silt, sand, and gravel—extending to the maximum depth drilled, 102.5 feet. The uppermost cinders are part of the blanket of Tantalus/Roundtop cinders covering the entire area, whereas the tuff is from the Punchbowl eruption. The location of the basalt within the tuff indicates that the source of the lava flow is Punchbowl. There is no evidence of the presence of coral ledges here.

Borings in the central and northern parts of the quad revealed 3 to 14 feet of fill and slopewash alluvial sediments, consisting of stiff dark-brown sandy–clayey silt with some weathered coral and basalt gravel and with debris such as bricks, charcoal, glass, metal, and decayed wood. Below are 4.5 to 22 feet of medium-dense silty volcanic cinders which are dark-brown and weathered in the upper layers and black and less weathered toward the bottom. Underneath are alluvial sediments intermixed with some coralline debris. The alluvium is composed of stiff brown clayey–sandy silts, with rounded and weathered basalt gravel, cobbles, and boulders. The coralline debris is composed of coralline sand and gravel with coral shells and coral fragments. These alluvial sediments intermixed with coralline debris are between 8 and 22 feet thick. Three borings revealed a thin layer (2 to 3 feet) of hard gray vesicular basalt below the alluvium and coralline debris and on top of the Punchbowl tuff. The tuff, which is as much as 33 feet thick, is described in the boring logs as tuff breccia and hard brown tuff that is well-cemented but fractured. Two borings extend deep enough to encounter a weakly cemented white coral limestone at an elevation of about –12 feet. This extends to the maximum depth drilled, 71.5 feet.

Quad H–7

The coordinates for Quad H–7 are 52000 North to 53000 North and 548000 East to 549000 East (Plates 3 and 4, Appendix B). Beretania Street cuts through the southwest corner of the quad.

Borings in the southern part of this quad indicated the presence of 1 to 7 feet of fill and alluvial soils, composed of loose to medium-dense brown silty sand and gravel. Below are 3 to 10 feet of very loose to medium-dense, brown to black volcanic cinders. First encountered between elevations of +8.6 and –6 feet is a hard tan coral formation that is fractured and contains voids. This is classified as the +5 ledge. It grades down to dense coralline debris, consisting of cemented silty coral sand and gravel with shells. Only one boring was made deep enough to reveal a 45-foot-thick layer of dense tan weathered tuff at an elevation of –28 feet. Below, alluvium (brown clayey silt) and coralline debris (cemented coral fragments and coral sand) extend to the maximum depth drilled, 110 feet.

Borings in the east-central part of the quad indicated similar conditions as in the southern part. On top are 2 to 7 feet of fill and alluvial slopewash sediments, consisting of stiff brown clayey silts with coralline and basaltic gravel. Below is a layer of dense cinders of variable thickness, 4 to 24 feet. These are weathered brown silty sand in the uppermost reaches of the layer and unweathered black coarse sand toward the bottom. First appearing between elevations of +15 and +10 feet is a tannish-white algal coral formation with lenses of coralline silty sand, categorized as the +20 ledge. The coral grades down to coralline debris, which is composed of white cemented coral sand with shells and coral fragments. In several boring logs this coralline debris is noted as containing black cinder sand, but it may be cinders that fell into the hole from above as it was being drilled. One boring revealed gray vesicular basalt that is only about 1 foot thick at an elevation of –9 feet. Several borings revealed a layer of brown cemented fractured tuff and tuff breccia at an elevation of –5 feet. This layer is only about 5 feet thick, and the tuff is probably from a Punchbowl eruption. It overlies coralline debris, described as medium-dense white to gray silty coralline sand and gravel, which extends to the maximum depth drilled, 51.5 feet.

Borings in the northeast corner and central part of the quad showed a different situation. On top are 2 to 29 feet of fill and alluvial soils, consisting of soft to stiff gray–brown clayey–silty sand and gravel with fragments of coral, basalt, and tuff. Beneath is a thick layer (up to 31 feet) of volcanic cinders. Toward the top, the cinders are weathered brown silty sand, whereas toward the bottom they are unweathered black sand. Underneath, to the maximum depth drilled (84 feet), are alluvial deposits intermixed with coralline debris. The alluvial deposits consist of dense brown clayey silt with some gravel and boulders. The coralline debris is medium-dense cemented silty coral sand with shells and coral fragments. This area is probably the northern extension of the HIC Channel.

Quad H–8

The coordinates for Quad H–8 are 52000 North to 53000 North and 547000 East to 548000 East (Plates 3 and 4, Appendix B). Beretania Street passes through the northeast corner of this quad.

Most borings in this quad indicated the presence of 1 to 6 feet of fill, composed of soft to stiff, tan to brown clayey–silty sand and gravel, with some coral fragments and concrete and metal debris. Below are 3 to 9 feet of medium-dense, fine to coarse, brown to black volcanic cinders. Several borings also indicated the presence of a 2- to 10-foot-thick layer of hard brown sandstone, cemented ash, or mudrock (possibly Punchbowl tuff) below the cinders. Below is a thin layer (1 to 5 feet) of alluvium—described as brown clayey silt with sand and rounded gravel—and decomposed coral and coral sand. First encountered between elevations of +9 and +4 feet is a hard tannish-white coral with pockets of coral sand, classified as the +5 ledge. Two borings in the northwestern corner first encountered coral at elevations of +15 and +14 feet, respectively, indicating the presence of the +20 coral ledge. The hard coral ledges, which are 5 to 15 feet thick, both grade down to coralline debris, consisting of poorly cemented coral fragments, clayey–silty coral sand and gravel, and shells. The coralline debris is as much as 40 feet thick. Beneath are alluvial deposits, primarily stiff brown clayey silts with some sand and rounded basalt gravel. This extends to the maximum depth drilled, 91.5 feet.

Three boring logs did not indicate the presence of the coral ledge or the coralline debris; rather, they describe alluvium below the fill and cinders. This alluvium appears to define a channel running through the northwest corner of this quad.

Quad H–9

The coordinates for Quad H–9 are 52000 North to 53000 North and 546000 East to 547000 East (Plates 3 and 4, Appendix B). King Street divides this quad into a northeast section and a southwest section.

Four borings in the northeast corner of the quad revealed about 4 feet of sandy silt and coralline rubble (fill) on top of about 6 feet of loose black cinders. First encountered at an elevation of +13 to +10 feet is cemented tan algal coral, classified as the +20 ledge. This coral is between 15 and 28 feet thick here. Beneath are thick sequences of coralline debris, consisting of loose to dense silty coralline sand and gravel with numerous shells. These are up to 25 feet thick and are underlain with alluvial deposits, described as stiff dark-brown silty clay with well-rounded basaltic gravel. At an elevation of −110 feet, a hard dark-gray basalt is encountered; it extends to the maximum depth drilled, −122 feet. This may be part of a Nuʻuanu lava flow.

The remainder of the borings northeast of King Street showed 2 to 7 feet of heterogeneous fill, composed of clayey–silty sand and gravel with debris including bricks, metal, glass, wood, and concrete rubble. Beneath are 1 to 7.5 feet of loose to dense black cinder sand and cemented ash or mudrock. Underneath is a layer (1 to 10 feet thick) of decomposed coral and coralline debris with alluvium, described as stiff brown clayey–silty sand and decomposed coral with silty–sandy coralline gravel and shells. First encountered between elevations of +8 and –5 feet is a dense tan algal coral with pockets of soft silty sand. This is categorized as the +5 ledge. It is 5 to 25 feet thick here and grades down to coralline debris, which is described as loose to dense silty coralline sand and gravel with coral fragments and shells. The coralline debris grades siltier with depth, becoming interlayered with alluvium and thin lenses of hard coral. The alluvium is stiff mottled brown clayey silt with some shells, cobbles, and rounded basaltic gravel. Two borings revealed basalt below the alluvium, at elevations of –41 and –55 feet; however, since no other borings in the vicinity revealed basalt at this shallow depth, it may be that basalt boulders within the alluvium were encountered rather than basalt that is part of a lava flow. Six borings were made deep enough to reveal decomposed basalt or residual soil, described as stiff mottled brown clayey silt with weathered basaltic gravel, on top of a hard, vesicular, and slightly fractured dark-gray basalt encountered between elevations of –95 and –122 feet. The vesicular basalt extends to the maximum depth drilled, 144.5 feet. It is probably part of a Nu‘uanu lava flow.

Southwest of King Street, borings indicated the presence of 3 to 12 feet of soft to medium-dense fill, composed of brown silty sand, sandy silt, and clayey silt, with coral fragments, cobbles, boulders, and debris including decaying vegetation. Below are 1 to 12 feet of black volcanic cinder sand. First encountered between elevations of –1.4 and –10 feet is a hard cemented tan to gray coralline limestone with cavities. This is classified as the +5 ledge. It is 10 to 25 feet thick in this area and in some instances is overlain by a layer (about 3 feet thick) of weakly cemented coral and clayey decomposed coral and coralline debris. The coral ledge grades down to coralline debris, exhibiting weaker cementation and consisting of silty coralline sand and gravel. The coralline debris, which is about 40 feet thick, becomes more silty with depth, grading to brown sandy–silty alluvium. At an elevation of about –90 feet, a hard, moderately weathered and fractured dark-gray basalt is encountered. It extends to the maximum depth drilled, 99.5 feet.

A channel runs through this quad, apparently a continuation of the channel mentioned in the description for Quad H–8. As it approximately parallels Alakea Street, it is being referred to as the Alakea Channel. Borings in the vicinity of this channel showed 2 to 10 feet of fill, composed of stiff brown clayey–sandy silt, with gravel, cobbles, boulders, and debris such as wood fragments and concrete rubble. Below are 1 to 12 feet of loose to medium-dense black silty volcanic cinders. Underneath are alluvial channel deposits, consisting of mottled gray–brown clayey–silty sand and sandy silts, with rounded gravel, cobbles, boulders, weathered cinders, and some coral fragments and shells. The notations in the boring logs of thin basalt at various elevations (–50, –60, –67, and –76 feet) are most likely an indication of the presence of basalt boulders within the alluvium. A hard, vesicular, slightly weathered, and moderately fractured dark-gray basalt, also called blue rock in some boring logs, is encountered between elevations of –101 and –112 feet. It extends to the maximum depth drilled, 132 feet. It is probably part of a Nu‘uanu lava flow.

Quad H–10

The coordinates for Quad H–10 are 52000 North to 53000 North and 545000 East to 546000 East (Plates 3 and 4, Appendix B). Ala Moana Boulevard separates this quad into an eastern section and a western section. All borings are located in the eastern section.

Borings indicated the presence of 4 to 10 feet of fill, composed of firm brown silty–clayey sand with coral fragments, gravel, cobbles, and boulders. Below are 1.5 to 8 feet of medium-dense to dense black volcanic cinders. First encountered between elevations of –0.4 and –9 feet is a hard tan coral with silty sand. This is categorized as the +5 ledge. It is between 6 and 15 feet thick and grades down to coralline debris. The coralline debris is described as clayey and silty coral sand with coral fragments and shells and some cavities. In some cases, only the much higher blow counts distinguish the coral ledge from the coralline debris. At depth, the coralline debris is intermixed with alluvial deposits, consisting of stiff mottled brown sandy silt and clay, with some gravel, black cinders, shells, and coral fragments. A hard basalt, described as fractured blue lava rock, first appears between elevations of –106 and –123 feet and continues to the maximum depth drilled, 140 feet. This basalt may be from a Nu‘uanu lava flow. Two borings in the southeast corner did not reveal the presence of the coral ledge; rather, they revealed the occurrence of alluvium and coralline debris, under the topmost layers of fill and cinders, extending to the basalt. This is probably a continuation of the Alakea Channel, which is also mentioned in the descriptions for Quads H–8 and H–9.

Quad I–7

The coordinates for Quad I–7 are 53000 North to 54000 North and 548000 East to 549000 East (Plates 3 and 4, Appendix B).

Borings in the eastern part of this quad showed 2 to 10 feet of fill, consisting of medium-stiff brown clayey silt with sand and gravel, as well as debris such as nails, wood, glass, and ceramic fragments. Beneath, alluvial soils extend to the maximum depth drilled here, only 25 feet. The alluvium is composed of stiff mottled brown clayey silt, sandy silt, and sandy clay, with weathered cinders.

Borings in the western part of the quad indicated the presence of 1.5 to 3.5 feet of fill or alluvial soil, composed of firm brown sandy silt with some gravel. One boring log noted that this uppermost deposit is derived from volcanic ash; therefore, it could be a residual soil deposit. Below are 3 to 5.5 feet of medium-dense to dense slightly cemented black volcanic cinders. Underneath is a thick layer (up to 15 feet) of partly cemented stiff brown sandy–clayey silt with some gravel, cobbles, and boulders. One boring log calls this deposit weathered volcanic tuff, but it may be alluvium. Below is coralline debris (described as tan silty coral sand with shells), grading down to more alluvium (described as stiff red–brown clayey silt). The maximum depth drilled is 52 feet.

It is anticipated that basalt would be encountered at depth within this quad, but deeper borings are needed for verification.

Quad I–8

The coordinates for Quad I–8 are 53000 North to 54000 North and 547000 East to 548000 East (Plates 3 and 4, Appendix B). Beretania Street divides this quad into a large northeast section and a smaller southwest section.

Only one boring is located in the southeastern corner of the quad. It indicated the presence of 5 feet of fill (stiff brown clayey silt) on top of volcanic cinders (dense black silty sand). Beneath are alluvial deposits (dense brown sandy silt with gravel) intermixed with coralline debris (dense tan clayey silt with coral fragments). At sea level, a dense tan coral with silty sand is encountered. The log for this boring ends with descriptions for only the first 2 feet into the coral, so the thickness of the coral could not be determined. This coral is tentatively classified as the +5 ledge.

Borings in the central and southwestern parts of the quad indicated the presence of 4 to 6 feet of fill, consisting of soft to firm, gray to brown clayey–silty sand and gravel with coral and tuff fragments. Below is a thin layer (only 2 to 3 feet thick) of loose to medium-dense black volcanic cinders. First encountered between elevations of +20 and +13 feet is a hard white algal coral, with pockets of sand. This is classified as the +20 ledge. This ledge, which is weak or weathered in the top few feet, grades down to coralline debris, described as moderately hard cemented coralline sand and gravel with shells. The hard coral ledge is a few feet to more than 10 feet thick, whereas the coralline debris is as much as 40 feet thick here. Below are alluvial sediments or decomposed volcanics, described as dense brown sandy silts with rounded basalt river gravel, basalt cobbles and boulders in an orange–brown clay matrix, and reddish-brown weathered tuff fragments. It is likely that these thick layers (about 60 feet) of deposits are composed of intermixed alluvial sediments and decomposed volcanics. Between elevations of –90 and –116 feet, a hard vesicular fractured basalt first appears; it continues to the maximum depth drilled (150 feet).

Borings in the northwest corner of the quad indicated the presence of fill of variable thickness (between 2 and 18 feet). This fill is composed of brown silty coralline sand and gravel with some basalt gravel. Below are about 50 feet of loose to medium-stiff, brown to gray to black clayey–sandy silt with gravel and boulders. Several boring logs refer to this as volcanic ash alluvium. Underneath are an additional 60 feet of stiff mottled reddish-brown sandy–clayey silt with gravel and boulders, again categorized as alluvium. First appearing between elevations of –88 and

−115 feet is a hard vesicular basalt with pockets of clayey silt; it extends to the maximum depth drilled, 160 feet. The basalt is probably part of a Nu'uanu lava flow. There are no coral deposits in this corner of the quad.

Quad I–9

The coordinates for Quad I–9 are 53000 North to 54000 North and 546000 East to 547000 East (Plates 3 and 4, Appendix B). Beretania Street cuts through the northeast corner of the quad, King Street through the southwest corner, and Nu'uanu Avenue through the northwest section.

Borings in the northeast corner of the quad revealed 2 to 6 feet of fill, consisting of brown clayey–silty coralline sand and gravel and basaltic sand and gravel. One boring revealed a 2-foot-thick layer of medium-dense black volcanic cinder sand at the bottom of the fill. Beneath are 14 to 20 feet of coralline debris, composed of silty coral sand and gravel, with some boulders. Blow counts were too low to classify this as ledge coral in this vicinity; however, it may actually be weakly cemented ledge coral or highly weathered coral over coralline debris. Underneath is a thick sequence (up to 110 feet) of volcanic ash alluvium and alluvium—described as loose to medium-dense dark-brown silty sand with gravel, cobbles, boulders, and occasional shells—over stiff brown clayey–silty sand and gravel. First encountered between elevations of −88 and −114 feet is a hard vesicular basalt with pockets of brown clayey silt; it continues to the maximum depth drilled, 154 feet.

The remainder of the borings within this quad indicated the presence of a coral ledge. On top are 1 to 10 feet of fill—consisting of brown clayey–silty sand with gravel and coral fragments—and debris including bricks, glass, concrete, and metal rubbish. Below, most borings indicated the presence of 1 to 5 feet of loose to medium-dense, brown to black volcanic cinder sand. First encountered between elevations of +19 and +9 feet is a dense white algal coral that is moderately fractured but hard. This is categorized as the +20 ledge coral. The top foot of this ledge tends to be weathered or decomposed. This hard coral, which is 3 to 25 feet thick, grades down to weakly cemented silty coralline sand and gravel with some shells. This coralline debris is between 5 and 22 feet thick. Below is alluvium, described as hard brown sandy–clayey silt, with rounded basalt gravel and cobbles, and river-washed tuff and basalt fragments and boulders, in an orange–brown clay matrix. Within the alluvium are thin lenses of coralline debris, primarily silty–sandy coralline gravel. The alluvium intermixed with coralline debris is as much as 100 feet thick. A weathered layer of *'a'ā* clinker, as much as 10 feet thick, is present below the alluvium and coralline debris. Between elevations of −88 and −120 feet is a hard vesicular gray basalt, which extends to the maximum depth drilled, 155.5 feet. The basalt is probably part of a Nu'uanu lava flow. Several borings indicated the presence of a lens (averaging about 10 feet thick) of alluvium within the basalt. It consists of basalt cobbles and gravel in a soft brown clay matrix.

Quad I–10

The coordinates for Quad I–10 are 53000 North to 54000 North and 545000 East to 546000 East (Plates 3 and 4, Appendix B). The intersection of King Street with Nu'uanu Avenue is located in the eastern half of the quad. Ala Moana Boulevard crosses through the western half, running in a north–south direction.

Borings east of King Street and south of Nu'uanu Avenue revealed 3.5 to 9 feet of fill, consisting of brown clayey silt with sand, gravel, cobbles, and debris such as concrete and glass fragments and bricks. Beneath is a layer (up to 4.5 feet thick) of medium-dense to dense black volcanic cinders. First encountered between elevations of +16 and +13.7 feet is a hard tan coral with pockets of silty sand. This coral, which is 6 to 14 feet thick here, is categorized as +20 ledge. Beneath is a layer (about 30 feet thick) of coralline debris, composed of tan silty sand and coral fragments. Below the coralline debris is alluvium, described as stiff brown clayey–sandy silt with river-washed gravel and cobbles. This extends to the maximum depth drilled, 101 feet.

Borings south of Nu'uanu Avenue and west of King Street indicated the presence of 3.5 to 8 feet of fill, composed of brown silty sand with gravel and coral fragments. Below is a thin layer (only about 1 foot) of weathered cinders overlying a hard tan coral with pockets of silty sand. The coral, which first appears between elevations of +4 and –1.8 feet, is quite thick here, as much as 42 feet. It extends to the maximum depth drilled (50.5 feet). However, the coral grades down to medium-dense with depth, indicating weaker cementation or possibly the presence of coralline debris. It is classified as the +5 coral ledge.

Borings in the central part of the quad showed 1 to 9 feet of heterogeneous fill, consisting of both coralline and basaltic sand, gravel, cobbles, and boulders, with glass and metal debris. Below is a 1- to 4-foot-thick layer of loose to dense black cinder sand with some brown clayey silt. First encountered between elevations of +9 and +6 feet is a dense tan coral–algal limestone, with pockets of sand. This limestone, classified as the +5 coral ledge, is between 4 and 24 feet thick. Several borings indicated that the uppermost few feet of the ledge is not as well-cemented as the lower areas of the ledge and thus may be decomposed or uncemented coral or possibly coralline debris instead. Below the +5 ledge is a layer (up to 43 feet thick) of more coralline debris that is composed of loose to medium-dense silty–sandy coral gravel, cobbles, and boulders. Beneath is alluvium, described as stiff brown clayey silt with rounded basaltic gravel. Within the alluvium are thin lenses of silty–sandy coralline gravel. The alluvium, intermixed with coralline debris, extends to the maximum depth drilled (126.5 feet) with one exception. In one boring, a hard gray fractured basalt is encountered at an elevation of –95 feet.

Borings in the north-central part of the quad indicated the presence of 2 to 5 feet of fill, consisting of gray to brown silty sand and gravel. Several borings revealed a thin layer (2 or 3 feet) of dense black cinders beneath the fill. First encountered between elevations of +15 and +10 feet is a medium-hard tan coral–algal limestone, classified as the +20 ledge. This is between 7 and 16 feet thick here. Extending from the base of the ledge to the maximum depth drilled (65 feet) is coralline debris, described as tan sandy coral gravel with some cobbles and boulders, intermixed with thin lenses of alluvium (stiff brown clayey silt). Deeper borings are needed in this area to determine the presence or absence of the basalt, but its presence would be expected.

Borings in the northwest corner of the quad and west of Ala Moana Boulevard revealed 1 to 8 feet of fill, composed of brown clayey silt, sand, and gravel. Only one boring log described a 10-foot-thick layer of soft and loose lagoonal deposits, consisting of gray organic sandy silts, below the fill. First encountered between elevations of +6 and –7 feet is a very dense tan–white coral, with pockets of silty sand. This is between 3.5 and 13 feet thick here and is classified as the +5 ledge. Below is coralline debris, described as loose to medium-dense silty–clayey coralline sand and gravel, with coral fragments and cobbles. This extends to the maximum depth drilled (50 feet).

Quad I–11

The coordinates for Quad I–11 are 53000 North to 54000 North and 544000 East to 545000 East (Plates 3 and 4, Appendix B). This quad primarily encompasses piers 13 to 20 of Honolulu Harbor.

Only three borings—all in the eastern part near piers 13 to 15—are located within this quad. Two of these borings revealed lagoonal deposits to the maximum depth drilled, 128.3 feet. The lagoonal deposits—composed of soft dark-gray clayey and sandy silts, with some shells, gravel, cobbles, coral fragments, and decayed wood—are firmer with depth. One boring log describes a moderately hard mottled gray weathered basalt that is first encountered at an elevation of –96 feet and which extends to the bottom of the borehole at 107 feet below grade. It is unclear why no coral ledge is found in this area.

Quad I–12

The coordinates for Quad I–12 are 53000 North to 54000 North and 543000 East to 544000 East (Plates 3 and 4, Appendix B). This quad primarily encompasses piers 22 to 28 of Honolulu Harbor.

Only one boring is located within this quad. It revealed 7 feet of fill—consisting of sand, coral, rock fragments, and wood debris—over 4 feet of soft gray sandy silt with shells, classified as lagoonal deposits. A hard gray–white coral appears at an elevation of –3 feet and extends to the maximum depth drilled, only 25 feet. This formation is tentatively categorized as the +5 coral ledge; however, it could be modern reef growth.

Quad I–13

The coordinates for Quad I–13 are 53000 North to 54000 North and 542000 East to 543000 East (Plates 3 and 4, Appendix B). The shoreline splits this quad into a northeast section and a southwest section.

Only four borings—all in the southeast part along the shoreline—are located within this quad. Borings indicated the presence of 6 to 12 feet of fill, consisting of brown silty sand with white coral fragments and gravel, cobbles, and boulders. Beneath are 4 to 10 feet of soft organic gray silty clays and clayey–sandy gravel, classified as lagoonal deposits. Underneath are thick sequences of coralline debris, described as silty and clayey coralline sand and gravel, with some hard and dense cemented coral limestone, possibly ledge coral. The most prominent coral limestone appears between elevations of –32 and –38 feet; therefore, it is tentatively categorized as the –30 coral ledge. It averages about 20 feet thick here, then it grades down to more coralline debris. The coralline debris extends to the maximum depth drilled, 108 feet.

Quad J–8

The coordinates for Quad J–8 are 54000 North to 55000 North and 547000 East to 548000 East (Plates 3 and 4, Appendix B). Nu‘uanu Avenue divides this quad into a large southeast section and a smaller northwest section.

All borings in the northwest section of the quad are 15 feet deep or less. All revealed alluvium, consisting of medium-stiff mottled gray–brown or orange–brown silty clay and sandy silt with river-washed gravel, for the entire depth.

Only two borings are located in the eastern part of the quad, and both are shallow (11.5 feet deep). These borings showed alluvium, consisting of stiff brown clayey–sandy silt, for the entire depth.

Borings in the southwest corner indicated the presence of up to 5 feet of fill, composed of gray to tan silty coral sand and basalt sand and gravel, over very thick sequences of alluvium and volcanic ash alluvium. This is described as mottled brown–black clayey–sandy silt with some gravel, cobbles, boulders, shells, and decayed vegetation. Within the alluvium are smaller amounts of coralline debris, consisting of weak to moderately cemented silty calcareous sand and gravel. Massive gray andesite or basalt that is slightly vesicular and moderately to severely fractured is present below the alluvium. However, the top surface of this basalt, which first appears between elevations of –60 and –130 feet, appears to be quite irregular. This basalt continues to the maximum depth drilled, 168.6 feet. It is probably part of a Nu‘uanu lava flow.

Quad J–9

The coordinates for Quad J–9 are 54000 North to 55000 North and 546000 East to 547000 East (Plates 3 and 4, Appendix B). Nu‘uanu Avenue cuts across the southeast corner of the quad and Nu'uanu Stream crosses through the northwest corner. Beretania Street divides the quad into a northeast section and a southwest section.

Borings in the southeast corner and the northern half of the quad revealed 3 to 12 feet of fill—consisting of medium-stiff brown sandy silt, clayey silt, and silty sand, with cinders, gravel, cobbles, and coral fragments—and debris including charcoal, concrete, glass, and metal. Below is a layer (up to 25 feet thick) of soft and loose lagoonal deposits, composed of organic gray to black clayey silt with sand and shells. Near Nu'uanu Stream, this layer consists of thick sequences of black mud with some sand, gravel, and boulders. Beneath are alluvial deposits, described as stiff mottled orange–brown sandy silt and silty sand with some clay lenses, as well as rounded gravel, cobbles, and boulders. In the northern part of the quad, the alluvium is intermixed with estuarine sediments, described as soft and loose "peaty" organic silts, with shells and decayed wood fragments. A number of borings in the northern part revealed 6 to 15 feet of gray vesicular basalt, first appearing between elevations of –51 and –72 feet. This basalt is described in some boring logs as jointed and fractured "*puka puka* rock" or blue lava rock. In one boring, alluvial silt continues below the basalt. The maximum depth drilled in this region is 92.5 feet.

Borings in the southwest section of the quad showed 0.5 to 14 feet of fill and alluvial soil, composed of tan sandy silt and silty sand, with coral fragments, coralline gravel, cinders, some cobbles and boulders, and debris including bone, charcoal, glass, metal, and ceramic fragments. A hard white or tan algal coral formation with pockets of sand first appears at elevations as high as +20 feet and as low as +8 feet, averaging +14 feet. This is categorized as the +20 coral ledge. The thickness of this coral ledge is highly variable, ranging from 2.5 to 24 feet and averaging 12 feet. A number of borings indicated the presence of a layer (3.5 to 16 feet thick) of cemented coralline sand or sandstone with coral and shell fragments, possibly beachrock, below the coral ledge. Beneath is a thick layer of alluvium, consisting of stiff mottled orange–brown or red–brown clayey–sandy silt, with rounded river-washed gravel, cobbles, and boulders. Some borings also revealed thin lenses of coralline debris, composed of silty coralline sand and gravel and shells, within the alluvium. A number of borings also revealed some ash and cinders within the alluvium. The alluvium is anywhere from 40 to 120 feet thick. First encountered between elevations of –48 and –109 feet is a hard, vesicular, and fractured gray basalt, with weathered seams of clayey silt. The basalt continues to the bottom of the drill holes, the maximum depth of which is 150.5 feet here. It is possible that some of the shallower occurrences of basalt are actually basalt boulders within the alluvium; however, it is also possible that the upper surface of the basalt is highly irregular. The basalt is assumed to result from a Nu'uanu lava flow.

Quad J–10

The coordinates for Quad J–10 are 54000 North to 55000 North and 545000 East to 546000 East (Plates 3 and 4, Appendix B). Nu'uanu Stream crosses through this quad generally in an east to west direction. King Street divides the quad into an eastern section and a western section. Ala Moana Boulevard cuts through the southwest corner.

Borings in the southwest corner and northern part of the quad indicated the presence of 1.5 to 10.5 feet of fill, composed of loose to medium-dense, light- to dark-brown clayey silt and silty sand, with gravel, cobbles, boulders, coral fragments, and debris including glass, charcoal, and metal. Below are low-energy estuarine and marsh deposits intermixed with alluvium. These deposits are primarily soft and loose, dark-gray and black organic clayey silts with peaty layers. The alluvium is a stiff dark-gray to mottled dark-brown sandy silt with rounded river-washed gravel, cobbles, and boulders. Included are layers of coralline debris, consisting of white to brown silty coralline sand, gravel, shells, and coral fragments. These low-energy and alluvial deposits are as much as 107 feet thick here. First encountered between elevations of –58 and –100 feet is a hard gray vesicular basalt, which continues to the maximum depth drilled, 123 feet.

Borings in the southeastern part of the quad showed 1 to 8 feet of fill and alluvial soils, composed of brown silty sand with traces of clay, some coral fragments, coral and basalt gravel and cobbles, volcanic ash, concrete rubble, and glass shards. Several borings indicated the presence of 6 to 8 feet of soft and loose lagoonal deposits below the fill, described as organic clayey silts with some coral fragments. First encountered between elevations of +17 and +8 feet is a dense tan coral formation, about 15 feet thick in this area. This is classified as the +20 ledge. A number of borings showed this coral ledge to be only about 5 feet thick, grading down to weaker coralline debris that consists of silty coral sand and gravel. Beneath are alluvial sediments, described as stiff mottled brown clayey silts with sand, gravel, cobbles, boulders, and shells. Two borings revealed a 10-foot-thick hard coral at an elevation of about –40 feet within the alluvial sediments. The alluvial silts are as much as 67 feet thick in this area. Between elevations of –66 and –77 feet, a hard gray vesicular basalt appears; it extends to the maximum depth drilled, 108 feet.

Quad J–11

The coordinates for Quad J–11 are 54000 North to 55000 North and 544000 East to 545000 East (Plates 3 and 4, Appendix B). Nimitz Highway crosses through the quad in an east to west direction. Piers 16 through 18 are located within the southeast part of the quad.

Borings in the northeast corner revealed 2 to 8.5 feet of fill, composed of brown silty sand and gravel, with cobbles and shells, over thick layers of low-energy estuarine deposits intermixed with alluvium. The low-energy deposits are soft and loose, dark-gray to black organic clays and silts with some gravel and shells. The alluvium is medium-dense brown silty sand with river gravel and cobbles, with soft organic or peaty layers. These estuarine and alluvial sediments are up to 73 feet thick here. One boring revealed basalt at an elevation of –80 feet. The maximum depth drilled is 85 feet.

Borings in the northwest corner indicated the presence of 1 to 10 feet of fill and alluvial soil, consisting of mottled brown clayey–silty sand and sandy silt with coral fragments. First encountered between elevations of +9 and +1 feet is a dense white coral with some clayey–silty sand and cavities. This coral, which appears to be as much as 31 feet thick here, is tentatively classified as the +5 ledge. The maximum depth drilled is 32 feet.

Quad J–12

The coordinates for Quad J–12 are 54000 North to 55000 North and 543000 East to 544000 East (Plates 3 and 4, Appendix B). Nimitz Highway divides this quad into a northern section and a southern section.

Borings indicated the presence of 1.5 to 10 feet of fill, consisting of brown silty and clayey sand and gravel, with cobbles, shells, and coral fragments. Beneath are 1.5 to 2.5 feet of lagoonal deposits intermixed with some black volcanic cinders. These low-energy lagoonal deposits are described as soft dark-gray clayey–sandy silts with decayed wood, shells, and coral fragments. First encountered between elevations of +9.5 and –4.5 feet is a dense yellow–white coral with pockets of silty sand. This is classified as the +5 coral ledge. In several borings, the top 3.5 to 5.5 feet of the coral ledge consist of weakly cemented coral ledge or coralline debris. The ledge coral grades down to coralline debris, consisting of silty coral sand and gravel and coral fragments. The coral ledge is about 10 feet thick here, and the coral and coralline debris together are as much as 60 feet thick. Below the coralline debris are alluvial sediments, composed of stiff brown clayey–sandy silts, with some coral fragments and basaltic rock fragments. This continues to the maximum depth drilled, 90 feet.

Quad J–13

The coordinates for Quad J–13 are 54000 North to 55000 North and 542000 East to 543000 East (Plates 3 and 4, Appendix B). Nimitz Highway splits this quad into a northeast section and a southwest section.

Borings in this quad indicated the presence of 2 to 7.5 feet of fill, consisting of brown silty–clayey sand and gravel, with shells, coral fragments, and glass debris. Below are 2 to 15 feet of soft and loose organic lagoonal or marsh deposits intermixed with some volcanic cinders. These low-energy deposits are gray to black silts and clays, with some sand, gravel, shells, coral fragments, decayed wood, and weathered cinders. First appearing between elevations of +8 and –4.5 feet is a dense tan–white coral with some voids. This is classified as the +5 ledge. This ledge, which is anywhere from 5 to 25 feet thick here, grades down to medium-dense coralline debris and decomposed clayey coral. The coralline debris is primarily silty–sandy gravel. Several borings revealed up to 4 feet of this coralline debris above the +5 coral ledge. The coral and coralline debris extend to the maximum depth drilled, 48.7 feet.

A number of borings in the northwest corner did not indicate the presence of ledge coral. Instead, the borings indicated the presence of partially cemented calcareous silty sand below the low-energy deposits. Blow counts indicated that this material was not hard enough to be ledge coral. It is possible that this is weakly cemented coral, beachrock, or just coralline debris.

Quad J–14

The coordinates for Quad J–14 are 54000 North to 55000 North and 541000 East to 542000 East (Plates 3 and 4, Appendix B). The shoreline is located in the southwest corner of the quad.

Borings indicated the occurrence of 2 to 9 feet of fill, consisting of brown silty–clayey sand and gravel with volcanic cinders and basalt cobbles. Beneath are soft and loose lagoonal deposits of variable thickness, ranging from less than 2 feet to 38 feet thick. These are gray clays and silts with some sand, gravel, shells, coral fragments, and decayed wood. The lagoonal deposits are stiffer with depth. Three borings revealed the top of a well-cemented algal–coral ledge between elevations of –7 and –11 feet. This is probably the +5 ledge, which is about 20 feet thick here. The remainder of the borings indicated the presence of coralline debris and alluvium to the maximum depth drilled, 150 feet. The coralline debris consists of weak to moderately cemented silty–clayey coralline sand and gravel and coral fragments, and the alluvium is comprised of stiff brown clayey silt and sand with coral fragments and well-rounded basalt gravel. There may have been an alluvial channel crossing this quad at one time.

Quad J–15

The coordinates for Quad J–15 are 54000 North to 55000 North and 540000 East to 541000 East (Plates 3 and 4, Appendix B). The shoreline is located in the eastern part of this quad.

Five borings were done offshore. The first sediment encountered below the waterline is a very soft gray clayey silt that is only 2 to 4 feet thick. Below is coralline debris, consisting of tan coral sand and gravel with brown silt, extending to the maximum depth drilled, 71 feet below the water surface. Two borings revealed a hard white coral limestone or coral sandstone at an elevation of –42 feet. It is about 15 feet thick. Very high blow counts indicate that this could be ledge coral, probably part of the –30 ledge. Other borings in this area revealed dense cemented coralline debris characterized by significantly lower blow counts at this elevation.

Quad K–8

The coordinates for Quad K–8 are 55000 North to 56000 North and 547000 East to 548000 East (Plates 3 and 4, Appendix B). The H-1 Freeway cuts through the northeast corner of the quad, Nu‘uanu Avenue crosses through the southeast corner, and Nu‘uanu Stream cuts across the northwest corner.

Borings in the southwest corner of the quad showed 1 to 7 feet of fill and alluvial topsoil, consisting of medium-stiff brown clayey silt and silty clay with sand, gravel, and cobbles. Below are weathered ash and alluvial deposits to the maximum depth drilled, 63 feet. These are described as mottled gray–brown and orange–brown stiff clayey–sandy silts with river-washed gravel, cobbles, and boulders. Included within these deposits are some low-energy wetland deposits, composed of soft and wet organic black clayey–sandy silts.

The boring located in the northwest corner of the quad revealed 8 feet of fill, consisting of stiff brown sandy silt with gravel. Below is a 4-foot-thick layer of alluvium, described as dark-brown silty clay with sand and gravel. At an elevation of –1 foot is hard and soft lava rock, which continues for 10 feet, to the bottom of the borehole at 22 feet below grade. This is apparently basalt.

Quad K–9

The coordinates for Quad K–9 are 55000 North to 56000 North and 546000 East to 547000 East (Plates 3 and 4, Appendix B). Nu‘uanu Stream divides this quad into a small southeast section and a larger northwest section.

Southeast of Nu‘uanu Stream are 2 to 16 feet of fill and alluvial soil, consisting of medium-stiff gray to brown silty clay with sand, gravel, coral fragments, and concrete rubble. One boring revealed 8 feet of medium-dense black cinders at the base of the fill. Beneath are thick sequences of alluvium and weathered ash, composed of stiff mottled gray and brown silty–clayey sand and river-washed gravel with cobbles and boulders. Close to Nu‘uanu Stream, the alluvium contains layers of low-energy marsh or estuarine deposits, consisting of soft organic black clayey silt with some coral fragments and shells. These highly compressible deposits grade down to the alluvium, which continues to the maximum depth drilled, 91 feet. Farther away from the stream, basalt is encountered between elevations of –16 and –52 feet. This is described as blue rock or blue fractured lava rock with clinker. It continues to the maximum depth drilled (54 feet), except in one boring, which revealed only 5 feet of basalt, with more alluvium below.

Borings in the southwest corner and in the central part of the quad indicated the presence of 2 to 9 feet of fill and alluvial topsoil, consisting of stiff gray and brown silty clay, silty sand and gravel, and coral fragments and concrete rubble. Beneath are thick sequences (as great as 73 feet) of alluvium and low-energy wetland or estuarine deposits. The alluvium consists of stiff mottled brown clayey silt with sand, cinders, and rounded gravel, cobbles, and boulders. The low-energy deposits are soft gray organic sandy silts with some gravel, shells, decayed wood, and peaty layers. A dense blue to gray basalt, described as jointed and weathered with clayey silt in fractures and as *puka puka* rock with large vesicles, is first encountered between elevations of –26 and –73 feet. The basalt, which is typically between 20 and 40 feet thick here, tends to be weathered both on the top and on the bottom. Several borings were made deep enough to reveal more alluvium (brown clayey silt) below the basalt. This alluvium extends to the maximum depth drilled, 102.7 feet. There is a general tendency for the basalt to be found at deeper elevations in the southeast section and at shallower elevations toward the northwest section. However, because a number of borings in the central part of the quad were not made deep enough to encounter the basalt, this finding is speculative. Additional deep borings are needed to reveal more details on the topography of the top of this basalt. It is possible that the basalt is encountered at greater depths closer to Nu'uanu Stream because the lava flowed through, and at least partially filled, an older, deep stream valley.

Borings in the northern part of the quad showed 2.5 to 5.5 feet of fill, described as stiff brown to gray silty clay and sandy silt, with gravel, cobbles, boulders, and coral fragments. Beneath are low-energy deposits intermixed with alluvium and weathered ash. The alluvium consists of stiff mottled brown clayey–sandy silt with river gravel, cobbles, boulders, weathered cinders, and decomposed rocks. The low-energy deposits are composed of very soft gray clayey silts with some gravel and coral fragments. These low-energy deposits tend to be more prevalent in the borings located toward the northwest section of the quad. First encountered between elevations of +0.5 and –2 feet is a basalt, described as hard and soft blue lava rock. The basalt is found in borings in the northeast corner of the quad but not in borings in the north-central part, possibly because borings in the latter area were not made deep enough to encounter the basalt. The maximum depth drilled here is only 31.5 feet. The difference in elevations between the basalt found here and that found in the southwest and central parts of the quad indicates the possibility of several different lava flows in this area. The flows probably originated in the Nu'uanu Valley area. The older, lower one may have come from the Luakaha volcanic cone on the east side of the valley, whereas the younger, upper flow may have originated from the Makuku volcanic cone near the west side of the valley. If the upper flow is indeed Makuku in origin, these borings provide evidence that the flow extends past Nu'uanu Cemetery, contrary to previous findings, which indicated that the flow had not traveled past the cemetery (Macdonald et al. 1986).

Quad K–10

The coordinates for Quad K–10 are 55000 North to 56000 North and 545000 East to 546000 East (Plates 3 and 4, Appendix B). The intersection of Beretania Street with King Street is located near the middle of this quad.

Borings in the southeast section of the quad indicated the presence of 2 to 10 feet of fill and alluvial slopewash, consisting of loose to dense, gray to red–brown silty sand and gravel, with some cinders and boulders. Below are 8 to 17 feet of low-energy deposits intermixed with alluvium and coralline debris. The low-energy deposits are soft and loose, gray to black organic clayey–sandy silts with some gravel, shells, and decayed vegetation. The coralline debris is comprised of silty coral sand with coral fragments, shells, and chunks of decomposed coral. This may be decomposed coral ledge, coralline debris, or coralline debris within alluvium. The alluvium consists of stiff gray to brown sandy silts, with shells, gravel, and coral fragments. Underneath are 2 to 8 feet of highly decomposed basalt, described as brown to gray silty basalt gravel. First encountered between elevations of –23 and –33 feet is a massive gray basalt. This extends to the maximum depth drilled, 40 feet. Several of the shallower borings did not encounter the basalt, which is probably part of a Nu'uanu lava flow.

Borings in the northern part of the quad showed variable conditions. In most, 1 to 8 feet of fill and alluvial soils—consisting of stiff brown clayey–sandy silt with gravel, cobbles, and boulders, and debris including wood, asphalt fragments, and wire—are on top. One boring revealed 3 feet of dense black cinders below the fill. Up to 15 feet of low-energy sediments intermixed with alluvium are beneath. The low-energy deposits consist of soft black organic silts and clays with some shells and coral fragments. The alluvium is stiff dark-gray to brown clayey silt with sand and cobbles. First encountered between elevations of +15 and +10 feet is a dense tan coral with pockets of sand. It is as much as 20 feet thick and grades down to coralline debris intermixed with alluvium, described as silty coral sand and stiff brown clayey silt with gravel and boulders. First encountered between elevations of +5 and –10 feet is a basalt, described as gray *puka puka* lava rock or fractured lava with *puka*. The maximum depth drilled in this area is 31 feet. In some borings, the coral is present over a thin layer of alluvium or decomposed basalt, then basalt is encountered. In others, no coral is encountered and fill or alluvium is located directly over the basalt. In still others, the coral is right at the surface or only a thin layer of fill is above the coral. Several borings did not encounter the basalt. These findings indicate that subsurface conditions are variable in this area. The coral is tentatively assigned to the +20 ledge, and the basalt is probably part of a Nu'uanu lava flow.

Quad K–11

The coordinates for Quad K–11 are 55000 North to 56000 North and 544000 East to 545000 East (Plates 3 and 4, Appendix B). This quad is within the Iwilei district, north of Nimitz Highway.

Three borings are located in the northwest corner. These indicated the presence of 2 to 4 feet of fill, described as medium-dense tan silty coralline sand and gravel with coral fragments and basalt boulders. Below are 30 to 45 feet of soft and loose low-energy marsh sediments, described as organic gray clayey silts and silty sand with shells, peat, coral fragments, and decayed wood fragments. Beneath are about 15 feet of alluvium, composed of stiff mottled gray–brown clayey silt and silty sand with gravel and coral fragments. A hard gray basalt is encountered at an elevation of about –50 feet. This extends to the maximum depth drilled, 68.5 feet. It is most likely part of a Nu'uanu lava flow.

Borings in the southwest part of the quad indicated the presence of 1 to 4 feet of fill, consisting of dense brown silty sand and gravel with concrete rubble. Below is a dense white coral formation with pockets of silty sand. First encountered between elevations of +11 and +3 feet, this coral formation is anywhere from a few feet to 20 feet thick. It is tentatively identified as the +5 ledge. It grades down to medium-dense coralline debris, composed of tan silty coralline sand and gravel, which extends to the bottom of the drill holes. The maximum depth drilled is 21.5 feet.

Quad K–12

The coordinates for Quad K–12 are 55000 North to 56000 North and 543000 East to 544000 East (Plates 3 and 4, Appendix B). This quad is within the Iwilei district.

Borings in this quad revealed 2 to 6 feet of fill, consisting of dense white to brown silty sand and gravel with coral fragments. Below are 1 to 6 feet of soft and loose lagoonal deposits, described as dark-gray saturated silts and clays with fragments of shells. Underneath is a layer of coralline debris of variable thickness, anywhere from 1 to 36 feet thick. It consists of medium-dense tan to white silty coralline sand and gravel with coral fragments. First encountered between elevations of +4 and –4 feet is a medium-hard to hard slightly fractured coral rock, with pockets of dense sand. This is classified as the +5 ledge, which is between 10 and 20 feet thick here. Below are up to 25 feet of stiff brown clayey alluvial silts. Coralline debris, consisting of light-brown silty coralline sand and gravel, extends to the maximum depth drilled, 75 feet.

Quad K–13

The coordinates for Quad K–13 are 55000 North to 56000 North and 542000 East to 543000 East (Plates 3 and 4, Appendix B). Nimitz Highway crosses through the southwest corner of this quad, which is located within the Iwilei district.

Two borings located toward the northeast corner of this quad indicated the presence of 4 feet of fill, composed of medium-dense silty sand and gravel. Beneath are lagoonal deposits and coralline debris intermixed with alluvium. The lagoonal deposits are described as saturated and loose gray sandy silts with some gravel. The coralline debris consists of gray to brown silty coralline sand and gravel. The alluvium is a hard brown clayey–sandy silt. These deposits extend to the maximum depth drilled, 54.5 feet. This is possibly an extension of the alluvial channel described earlier for Quad J–14.

Borings in the northwest corner revealed 3.5 to 8 feet of fill—composed of soft to stiff, gray to brown silty sand and clayey silt with coral and basalt gravel—and fragments of metal, concrete, and asphalt. Beneath are lagoonal deposits intermixed with some coralline debris. The lagoonal deposits are soft saturated organic gray clayey silts and silty sand with some coral fragments. The coralline debris is dense silty–sandy coral gravel. Several borings also revealed a few feet of dense black silty sand, possibly cinders, within this layer. These low-energy deposits intermixed with coralline debris are anywhere from 4.5 to 11.5 feet thick. First encountered between elevations of –2 and –12 feet is a dense tan coral, probably part of the +5 ledge. It is about 8 feet thick here. It grades down to more coralline debris, again described as silty–sandy coral gravel. This continues to the maximum depth drilled, 41 feet. Several borings did not reveal the presence of the ledge coral but revealed coralline debris extending to the bottom of the drill hole instead. A number of borings were not made deep enough to encounter the coral. Additional deep borings are needed in this area to delineate the ledge.

Borings in the southeast section indicated the presence of 3 to 8 feet of fill, consisting of dense tan clayey silt and silty sand with gravel, shells, coral fragments, and glass debris. Beneath are soft and loose lagoonal deposits intermixed with dense black cinders. The lagoonal deposits, comprised of moist organic gray silts and clays with some gravel and coral fragments, are 2 to 16 feet thick. In several borings, a hard tan coral with pockets of cemented sand is encountered between elevations of +0.5 and –6.5 feet. As much as 28 feet thick here, this coral is classified as the +5 ledge. Below is coralline debris. In a number of borings, the ledge is not encountered; instead, coralline debris is found beneath the lagoonal deposits. The coralline debris consists of partially cemented tan calcareous silt with coralline sand and gravel, and some shells and coral fragments. It is as much as 35 feet thick and extends to the maximum depth drilled, 41.5 feet.

Quad K–14

The coordinates for Quad K–14 are 55000 North to 56000 North and 541000 East to 542000 East (Plates 3 and 4, Appendix B). Nimitz Highway cuts through the northeast corner of this quad. Piers 34 and 35 are located in the western part of the quad.

Only two borings were made in this quad, both in the northeast corner. They revealed up to 5.5 feet of fill or topsoil, consisting of stiff brown clayey silt with sand and gravel. Below are about 8 feet of soft and loose lagoonal deposits, described as gray clayey sand and coral fragments. Underneath are stiff brown alluvial silts and sand to the maximum depth drilled, only 26 feet. More borings are needed in this area to determine the presence or absence of any ledge coral.

Quad K–15

The coordinates for Quad K–15 are 55000 North to 56000 North and 540000 East to 541000 East (Plates 3 and 4, Appendix B). Most of the southern part of the quad is underwater in Kapālama Basin. Some piers are located in the northern part of the quad.

Borings revealed as much as 25 feet of heterogeneous fill, described as medium-dense to dense brown silty sand with gravel, cobbles, bricks, decomposed wood, concrete chunks, and coral fragments. At about 15 to 20 feet below grade, there is a basalt boulder layer that is also classified as fill. Beneath the fill are 10 to 17 feet of low-energy lagoonal deposits. An organic dark-gray silty clay with occasional coral fragments and shells overlies a mottled greenish-gray sandy–silty clay with shells and coral fragments, described in several boring logs as decomposed coral. This soft gray decomposed coral, which is found at an elevation of about –20 feet, is over 10 feet thick. Below the gray silty clays and decomposed coral are 22 to 24 feet of coralline debris, described as medium-dense to dense white silty coral sand and gravel. Between elevations of –55 and –85 feet is a stiff to very stiff brown clayey silt layer with some coral sand and gravel. This is probably an alluvial deposit. Beneath is more coralline debris, consisting of coral sand and gravel with coral fragments, alternating with more brown clayey silt layers, to the maximum depth drilled of 122 feet. One boring log indicated the presence of 4 feet of dense olive-green silty sand, possibly a volcanic deposit, at an elevation of about –105 feet. These sequences of alluvium and coralline debris seem to indicate that this entire area is part of the Kapālama drainage system.

Quad K–16

The coordinates for Quad K–16 are 55000 North to 56000 North and 539000 East to 540000 East (Plates 3 and 4, Appendix B). Piers 39 and 40 are located in the northern part of the quad. Most of this quad is underwater in Kapālama Basin. No borings are located within this quad.

Quad K–17

The coordinates for Quad K–17 are 55000 North to 56000 North and 538000 East to 539000 East (Plates 3 and 4, Appendix B). Piers 41 and 42 are in the northwest corner of the quad. The rest of the quad is underwater in Kapālama Basin.

Three borings done in this quad revealed several feet of soft and loose lagoonal deposits, comprised of black to dark greenish-gray silty sand, with shells and coral fragments. Below is a hard coral ledge, described as well-cemented with small voids. The ledge, which is only about 4 feet thick in this area, grades down to compact coralline debris, consisting of white coral fragments and shells in silty sand. This coral may belong to the modern or recent reef. One boring indicated the presence of a second hard coral ledge at an elevation of –12 feet, whereas another boring revealed coral at an elevation of about –30 feet, indicating that the –15 ledge may overlie the –30 ledge here. Both ledges are only a few feet thick. Beneath is more coralline debris, which extends to the maximum depth drilled, 50 feet.

Quad K–18

The coordinates for Quad K–18 are 55000 North to 56000 North and 537000 East to 538000 East (Plates 3 and 4, Appendix B). The shoreline is located along the southern edge of the quad.

The land area is within the district known as Kapālama. Only two borings are located within this quad.

Borings indicated the presence of 5 feet of dense white to brown silty sand and coral fill overlying 14 feet of coralline debris, which is composed of loose to dense tan silty sand and coral fragments. First encountered at an elevation of about –12 feet is a very hard, tannish-white vuggy coral, which extends to the maximum depth drilled, 40.5 feet. This may be part of the –15 ledge. However, according to old maps, this area was completely under water prior to reclamation. Therefore, this coral may belong to the modern reef rather than to one of the older reefs.

Quad K–19

The coordinates for Quad K–19 are 55000 North to 56000 North and 536000 East to 537000 East (Plates 3 and 4, Appendix B). The shoreline divides this quad into an eastern section, which is part of the district of Kapālama, and a western section, which is within Ke'ehi Lagoon.

All borings are located in the northern part of the quad. They revealed 3 to 6 feet of fill, consisting of medium-dense brown clayey–silty sand with gravel and coral fragments. Beneath are lagoonal deposits, described as saturated dark-gray clayey–silty sand and silty gravel with coral fragments. The soft and loose lagoonal deposits are as much as 25 feet thick here. Below is a layer (5 to 10 feet thick) of coralline debris, composed of brown coral sand and gravel in a matrix of clayey silt. First encountered between elevations of –16 and –21 feet is a dense in situ algal–coral formation. This continues to the maximum depth drilled, 31 feet. It is tentatively identified as the –15 coral ledge.

Quad L–8

The coordinates for Quad L–8 are 56000 North to 57000 North and 547000 East to 548000 East (Plates 5 and 6, Appendix B). The H-1 Freeway cuts diagonally across this quad in a northwest to southeast direction. All borings are located in the area southwest of the H-1 Freeway.

Borings showed as much as 21.5 feet of fill and alluvium over decomposed basalt. The fill and alluvium consist of stiff mottled gray–brown silty clay and clayey silt with gravel, debris such as glass, and organics including roots, along with white coral fill. The decomposed basalt is described as stiff gray–brown silty clay with cobbles, boulders, and decomposed rock. First encountered between elevations of +29 and +13 feet is a hard gray basalt (also called blue lava rock), described as weathered, fractured, and highly vesicular, with clinkers and seams of silty clay. This extends to the maximum depth drilled, 22.5 feet. It probably originated from a Nu'uanu volcanic source.

Quad L–9

The coordinates for Quad L–9 are 56000 North to 57000 North and 546000 East to 547000 East (Plates 5 and 6, Appendix B). Liliha Street cuts through the northwest corner of this quad.

Borings in the northeastern part of the quad indicated the presence of 2 to 11 feet of stiff mottled brown silty clay alluvial soil with gravel, cobbles, boulders, decomposed rock, and coral fill. First encountered between elevations of +28 and +12 feet is a hard blue–gray lava rock, described as weathered, fractured, and vesicular. This extends to the maximum depth drilled, only 18 feet. This may be an upper, very shallow lava flow, originating from a Nuʻuanu volcanic source. Or, it could be continuous with the deeper flows, with the shallow depths revealed here indicative of some buried ledge or cliff over which the lava flowed. The basalt is generally found at higher elevations toward the northwest and at lower elevations toward the southeast, which would seem to indicate that the flow was simply following the topography. Deeper borings are needed to reveal the continuity of the basalt with depth. Additionally, petrographic examinations of the rocks could help determine whether these basalts originated from a single flow or from multiple flows.

Borings in the southwestern part of the quad revealed basalt at intermediate elevations. On top is as much as 30 feet of coral fill and alluvium. The alluvium consists of mottled brown clayey silt and silty clay, with sand, gravel, cobbles, boulders, and decomposed rock. The coral fill includes silty sand, coral fragments, coral gravel, and debris such as bricks. Some logs mention the occurrence of low-energy deposits, such as soft peaty pockets and wet gray adobe clay, within the alluvium. First encountered between elevations of +4 and –10 feet is a hard blue weathered basalt. This continues to the maximum depth drilled, 31.5 feet. This basalt may have originated from the same flow mentioned above, with the difference in elevation merely being a result of pre-existing topography or erosion. Additional studies are needed to determine the exact relationship between the various basalts found in this part of the study area.

Quad L–10

The coordinates for Quad L–10 are 56000 North to 57000 North and 545000 East to 546000 East (Plates 5 and 6, Appendix B). The intersection of King Street, Liliha Street, and Dillingham Boulevard is located in the southwest corner of this quad.

Borings southeast of Liliha Street revealed from 2 to 29 feet of fill and alluvial soils on top. The fill is composed of coral sand and gravel, with coral fragments and chunks, and basalt cobbles and boulders, with some debris such as ashes and pottery fragments. The alluvium is stiff brown silty clay, black cinder sand, and decomposed rocks. Included are some low-energy deposits, described as soft gray wet adobe clay and organic matter. Several borings revealed soft to hard, white or tan coral with some pockets of clayey silt, between elevations of +13 and +9 feet. The coral is between 3 and 13 feet thick here. It is tentatively classified as the +20 ledge. Beneath is a layer (up to 8 feet thick) of more alluvium and decomposed basalt that is described as brown clayey cobbles and boulders. A fractured and weathered hard gray basalt, with clinkers and with *puka* or vesicles, is first encountered between elevations of +6 and –10 feet. This continues to the maximum depth drilled, 40 feet. In borings that did not reveal the presence of coral, the basalt is encountered beneath the top layer of fill and alluvium. The basalt is probably from a Nu‘uanu volcanic source.

Borings northwest of Liliha Street and in the southwest corner of the quad showed from 1 to 21 feet of fill and alluvial soil on top. The fill includes coral sand and gravel, with coral chunks, concrete rubble, and basalt gravel, cobbles, and boulders. The alluvium consists of stiff mottled gray–brown silty clay and decomposed rock, with some low-energy deposits such as soft gray silts and clays with organic matter. First encountered between elevations of +15 and +10 feet is a soft to hard, white or tan coral that is as much as 19 feet thick here. It is tentatively classified as the +20 ledge. Below is a 10-foot-thick layer of alluvium and decomposed basalt, described as dense brown clayey gravel, cobbles, and boulders. First encountered between sea level (0.0) and –14 feet is a gray fractured *puka puka* lava. This continues to the maximum depth drilled, 35 feet. It is most likely basalt resulting from a Nu‘uanu lava flow. Several borings did not encounter the coral; instead, they revealed basalt beneath the upper fill and alluvium.

Quad L–11

The coordinates for Quad L–11 are 56000 North to 57000 North and 544000 East to 545000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard divides this quad into a northern section and a southern section.

Borings south of Dillingham Boulevard indicated the presence of 2 to 7 feet of fill, consisting of tan silty coralline sand and gravel, with coral fragments, basalt boulders, and chunks of concrete. Below are soft and loose lagoonal deposits, between 18 and 35 feet thick. These are gray to black saturated silts and clays, with shells, coral fragments, some gravel, and organic debris such as pieces of wood. Several boring logs describe 5 to 9 feet of dense brown to black cinders at the bottom of the lagoonal deposits. At an elevation of about –12 feet, coralline debris or coral is encountered in some borings. This material is described as dense massive coral with sand in one boring log and as silty coralline sand and gravel in other boring logs. It is between 7 and 10 feet thick and is possibly a continuation of the +5 ledge. Below is alluvium, described as stiff brown clayey silt and silty clay with some coralline debris. The alluvium, which is as much as 15 feet thick, overlies a slightly weathered and vesicular massive gray basalt, which first appears between elevations of –32 and –45 feet. The basalt extends to the maximum depth drilled, 56 feet. Only two borings were made deep enough to encounter the basalt. Additional deep borings are needed to determine the extent of the coral and the basalt here.

Borings north of Dillingham Boulevard indicated the presence of 0.5 to 14.5 feet of fill and alluvial soil on top. The fill is primarily medium-dense brown silty coralline sand and gravel, with coral fragments, cobbles, and debris including concrete, metal, and glass fragments. The fill grades down into the alluvium, which consists of stiff mottled orange–brown clayey silt with gravel and cobbles. Below the fill and alluvium is a layer of soft and loose lagoonal deposits of variable thickness. These deposits are described as gray sandy silt with shells, coral fragments, and decomposed organic material. In some borings, this layer of deposits is of negligible thickness, whereas in others it is up to 35 feet thick. First encountered between elevations of +11.6 and –1.2 feet is a dense tan coral with pockets of silty sand. This coral, which is 1.5 to 12 feet thick, is probably +5 ledge. There is a thin layer (5.5 feet or less) of alluvium or decomposed basalt below the coral. First encountered between elevations of +6.6 and –11 feet is a dense gray basalt with weathered seams. Two borings first encountered gray vesicular basalt at respective elevations of –23 and –40 feet. The basalt extends to the maximum depth drilled here, 50 feet. It is possible that there are two basalt flows here, or the basalts may actually all be part of the same flow, with the elevation difference a result of pre-existing topography or erosion. More deep borings or petrographic analyses are needed to determine the history of the basalt(s) in this area.

Quad L–12

The coordinates for Quad L–12 are 56000 North to 57000 North and 543000 East to 544000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard cuts across the northeast corner of the quad.

One boring in the southeast corner revealed 3.5 feet of fill, consisting of tan silty sand and coral fragments, on top of 27 feet of soft and loose gray lagoonal deposits, composed of silty sand, shells, coral fragments, and decayed wood. The maximum depth drilled is 30.5 feet.

The remainder of the borings located south of Dillingham Boulevard in this quad indicated the presence of about 4 feet of fill, composed of medium-dense light-brown silty sand and gravel with coral fragments. Below are 12 feet of soft and loose organic gray clay, classified as lagoonal deposits. One boring revealed gray–white decomposed clayey coral at an elevation of –10 feet. This may be the +5 ledge. It extends to the maximum depth drilled, 16.5 feet.

Two borings located in the northeast corner of the quad revealed 2 to 9 feet of medium-dense tan silty sand and coral fill. At an elevation of +5 to –2 feet, a dense white to tan clayey coral with some silty sand appears. This continues to the maximum depth drilled, 21.5 feet. It is categorized as the +5 ledge.

Quad L–13

The coordinates for Quad L–13 are 56000 North to 57000 North and 542000 East to 543000 East (Plates 5 and 6, Appendix B). This quad is located within the area known as Iwilei.

Borings located toward the northwest part of the quad revealed 4.5 to 7 feet of fill, composed of stiff silty sand and silty clay with some gravel and coral fragments. Below are about 5 feet of soft and loose lagoonal deposits, described as moist organic blue–gray silty sand and clayey silt with some coral fragments. Between elevations of –2.5 and –3.5 feet is a medium-dense gray coral, which continues to the maximum depth drilled, 20 feet. This is probably the +5 coral ledge.

Borings toward the south and southeast parts of the quad revealed 4 to 8 feet of fill, consisting of soft to stiff, white to brown silty sand and coral fragments. Below are thick sequences of lagoonal deposits, described as organic gray clays with some coral fragments and shells. These soft and loose low-energy deposits continue to the maximum depth drilled, 29 feet. Either this is an area of nondeposition for the coral ledge, or the coral was eroded away through here. This may be the area of a former alluvial channel. Additional borings to greater depths are needed to delineate the coral ledge in this area.

Quad L–14

The coordinates for Quad L–14 are 56000 North to 57000 North and 541000 East to 542000 East (Plates 5 and 6, Appendix B). Nimitz Highway cuts diagonally across this quad, running in a northwest to southeast direction. Kapālama Canal empties into Kapālama Basin in the northwest corner.

Borings in this quad revealed 3 to 8.5 feet of fill, consisting of brown silty sand and gravel, with shells, coral fragments, cobbles, boulders, and debris such as concrete and metal pieces. Beneath are soft and loose, highly compressible lagoonal deposits of variable thickness (between 6 and 30 feet thick). The lagoonal deposits consist of organic gray to black wet clays and silts with some coral fragments, gravel, and shells. Below are 9 to 13.5 feet of alluvial sediments, described as stiff mottled brown or orange–brown silty clays with some sand and gravel. Both the lagoonal deposits and alluvial sediments contain some black sand, possibly cinders. Beneath are 8 to 15 feet of decomposed clayey coral. Below the decomposed coral is more alluvium (stiff brown silty clay), which extends to the maximum depth drilled, 69.5 feet. This area is probably within the Kapālama drainage system.

Quad L–15

The coordinates for Quad L–15 are 56000 North to 57000 North and 540000 East to 541000 East (Plates 5 and 6, Appendix B). Kapālama Canal empties into Kapālama Basin in the northeast corner of this quad, and Nimitz Highway cuts across the northeast corner. This quad is part of the district called Kapālama.

Borings revealed 5 to 25 feet of medium-dense brown silty coral sand and gravel, identified as fill. Below are very soft to soft, slightly organic, dark-gray or greenish-gray clayey silts with coral sand and gravel and with some traces of decomposed wood. These are classified as lagoonal deposits. A number of boring logs refer to these sediments as harbor muds. These muds, which are about 17 feet thick in this area, overlie a medium-stiff to stiff brown clayey silt and silty clay with some fine sand and coral gravel. In several boring logs this is called decomposed coral, but the description and blow counts indicate that it may be alluvium. This deposit is between 3 and 8 feet thick. Beneath are 18 to 24 feet of coralline debris, described as soft to medium-stiff, white to tan to brown silty–clayey coral sand and gravel. In a number of boring logs this material is labeled marl. The marl overlies a stiff dark-brown clayey silt, with some coral and basalt gravel, probably another alluvial deposit. The alluvium is first encountered at an elevation of about –44 feet and is 20 to 24 feet thick. It overlies another layer of coralline debris, described as tan to white silty coral sand and gravel and as gravelly and sandy clay. This coralline debris is called decomposed coral in some logs and marl in others. From here to the maximum depth drilled (140 feet), layers of brown alluvial sandy silt alternate with layers of coralline debris, primarily consisting of sandy–silty coral gravel. This area is within the Kapālama Channel.

Quad L–16

The coordinates for Quad L–16 are 56000 North to 57000 North and 539000 East to 540000 East (Plates 5 and 6, Appendix B). This quad is located within the Kapālama district.

The three borings located within this quad indicate the presence of as much as 23 feet of fill, consisting of silty coralline sand and gravel with cobbles, boulders, and coral fragments. Below the fill, a weathered decomposed clayey coral first appears. It grades down to coralline debris, primarily weakly cemented silty coral sand and gravel. One boring is deep enough to show alluvium below the coralline debris. The alluvium, composed of stiff brown clayey silt with gravel- and cobble-sized coral fragments, extends to the maximum depth drilled, 70 feet. This is probably Kapālama drainage channel alluvium.

Quad L–17

The coordinates for Quad L–17 are 56000 North to 57000 North and 538000 East to 539000 East (Plates 5 and 6, Appendix B). The shoreline is located in the southeast corner of the quad. No borings are located within this quad.

Quad L–18

The coordinates for Quad L–18 are 56000 North to 57000 North and 537000 East to 538000 East (Plates 5 and 6, Appendix B). This quad is located in the Kapālama district. No borings are located within this quad.

Quad L–19

The coordinates for Quad L–19 are 56000 North to 57000 North and 536000 East to 537000 East (Plates 5 and 6, Appendix B). The shoreline is located along the western edge of this quad. This quad is located in the Kapālama district.

Borings in the northeast part of the quad showed 4 to 5 feet of fill, consisting of medium-dense tan silty sand with coral fragments. Below are 6 to 9 feet of soft and loose lagoonal deposits, composed of gray moist sandy silts with some coral fragments. First encountered between elevations of –3 and –5 feet is a dense tan coral formation with pockets of sand. This continues to the maximum depth drilled, 20.5 feet. It is tentatively classified as the +5 ledge, although it may actually belong to the modern reef.

Borings in the southwest corner revealed 3 to 6 feet of fill, consisting of medium-dense light-brown gravelly–silty sand. Below are 15 to 25 feet of soft and loose lagoonal deposits, described as saturated gray to black silty clays and silty gravel. Several borings indicated the presence of 2 to 5 feet of dense gray to black silty sand, possibly cinders, below the lagoonal deposits. Between elevations of –13 and –21 feet, a dense white in situ algal coral formation, with sand-filled cavities, appears. The coral continues to the maximum depth drilled, 31.5 feet. It is tentatively classified as part of the –15 ledge.

Quad L–20

The coordinates for Quad L–20 are 56000 North to 57000 North and 535000 East to 536000 East (Plates 5 and 6, Appendix B). The shoreline is located in the northeast corner of the quad. Most of this quad is underwater in Ke'ehi Lagoon.

Two borings were done offshore here. They revealed soft and loose harbor muds or lagoonal deposits—comprised of organic gray clayey–sandy silts with decayed wood, shells, and some coral fragments—to the maximum depth drilled, 166 feet.

Quad M–9

The coordinates for Quad M–9 are 57000 North to 58000 North and 546000 East to 547000 East (Plates 5 and 6, Appendix B). The H-1 Freeway divides this quad into a northeast section and a southwest section. All borings are located in the area southwest of the freeway.

Borings indicated the presence of 0.5 to 3 feet of fill or topsoil, consisting of crushed coral with silty sand and gravel and clay. Beneath are alluvial soils, composed of soft, light-gray to gray–green clayey silt, with stiff brown silt, sand, gravel, and cobbles. Boring logs refer to the gray clayey silt as adobe. The alluvium, which is 3 to 7 feet thick, grades down to decomposed basalt, with pockets of hard mottled gray to brown sandy–silty clay. First encountered between elevations of +48 and +22.5 feet is a hard lava rock, with clinker layers and clay seams. This rock—also described as weathered, fractured, and vesicular *'a'ā* basalt—continues to the maximum depth drilled here, only 15.5 feet. It is probably part of a Nu'uanu lava flow.

Quad M–10

The coordinates for Quad M–10 are 57000 North to 58000 North and 545000 East to 546000 East (Plates 5 and 6, Appendix B).

Borings revealed 2 to 6.5 feet of fill and alluvial topsoil, consisting of brown silty volcanic cinder sand, clayey–silty gravel and cobbles, coral fragments, decomposed rocks, bottles, and undifferentiated organic material. Beneath is a layer (3 to 7 feet thick) of adobe, described as stiff mottled grayish-brown or grayish-green clayey silt or silty clay, with some sand and gravel. Below is coralline debris, described as silty coral sand or clayey sand with coral. Blow counts were low for ledge coral, but it could be weakly cemented +20 ledge coral. First encountered between elevations of +18 and +16 feet, it is 8 to 12 feet thick. Below is a 3- to 9-foot-thick layer of alluvium and decomposed basalt, described as hard mottled gray–brown clayey silt or as mottled orange weathered rock and boulders. Between elevations of +14 and +4 feet, a hard blue–gray basalt is encountered. It extends to the maximum depth drilled (29 feet). It is probably from a Nu‘uanu volcanic source.

Quad M–11

The coordinates for Quad M–11 are 57000 North to 58000 North and 544000 East to 545000 East (Plates 5 and 6, Appendix B). King Street splits this quad into a northeast section and a southwest section.

Borings in this quad indicated the presence of 3 to 12 feet of fill and alluvial soils on top. The fill consists of coralline and basalt gravel, beach sand, and coral fragments. This overlies alluvial soils, composed of stiff mottled brown clayey silt, with some coral sand, gravel, and shells. First encountered between elevations of +19 and +14 feet is a dense tan to white coral with pockets or layers of silty sand. This is probably the +20 ledge, which grades down into weakly cemented coral or coralline debris with depth. The coral is anywhere from 5 to 26 feet thick here. Below is a 3- to 9-foot-thick layer of alluvium and decomposed basalt, described as stiff mottled orange–brown clayey silt with basalt gravel and cobbles and with fragments of weathered or decomposed basalt. First encountered between elevations of +8 and –11 feet is a dense blue or gray vesicular basalt. This extends to the maximum depth drilled, 35 feet. It is probably part of a Nu‘uanu lava flow. Two borings did not indicate the presence of coral; they revealed only fill and alluvium over decomposed basalt and basalt.

Quad M–12

The coordinates for Quad M–12 are 57000 North to 58000 North and 543000 East to 544000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard cuts across the southwest corner of this quad.

Borings in the southeast corner revealed 2 to 9 feet of fill and alluvial topsoil, composed of medium-dense tan silty–clayey sand and gravel with coral fragments, and mottled brown silty clay. First encountered between elevations of +11 and –2 feet is a dense white to tan vuggy coral, with pockets of cemented silty sand. This grades down to coralline debris, consisting of soft silty sand and loose clayey coral, with coral fragments. The coral and coralline debris continue to the maximum depth drilled, 31.5 feet. The coral is classified as the +5 ledge.

A site reconnaissance in this area revealed an outcrop of coral on the side of a sloping embankment located on the grounds of Honolulu Community College. The top of this outcrop is located at an elevation of about +10 feet. The ledge is at least 5 feet thick; its total thickness could not be determined as the bottom of the unit could not be discerned. This outcrop is probably part of the +5 coral ledge. This same outcrop can be seen paralleling the *mauka* sidewalk along Dillingham Boulevard for a short distance in this same vicinity.

Borings in the western part of this quad and along the eastern edge of Quad M–13 revealed 2 to 5 feet of fill and alluvial topsoil, composed of stiff brown silty clay with coralline sand, gravel, cobbles, and boulders. Beneath is a layer (10 to 36 feet thick) of soft and loose low-energy lagoonal and marsh deposits, consisting of gray organic silts and clays with coral fragments, shells, and some clayey coral. Below are 5 to 18 feet of loose clayey coralline sand, also called decomposed coral in some logs. Beneath are 15 to 28 feet of alluvium, grading down to decomposed basalt with depth. This layer is described as stiff mottled brown silty clay, with coral fragments, cobbles, boulders, and decomposed rock. Between elevations of –32 and –54 feet, a dark-gray vesicular basalt with pockets of clay is encountered. The basalt is between 10 and 20 feet thick. Beneath is more alluvium, described as stiff mottled brown clayey silt with some sand and gravel, which continues to the maximum depth drilled, 100.5 feet. This may be part of the Kapālama drainage system.

Quad M–13

The coordinates for Quad M–13 are 57000 North to 58000 North and 542000 East to 543000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard runs through this quad in a northwest to southeast direction, and Kapālama Canal crosses through it in a northeast to southwest direction.

Borings southeast of Kapālama Canal and north of Dillingham Boulevard revealed 1.5 to 6.5 feet of fill, consisting of brown silty sand, gravel, and coral fragments, with concrete rubble. Below are 10 to 13 feet of soft and loose lagoonal deposits, composed of dark-gray organic silts and silty sand, with some coral fragments. Beneath is a layer (6 to 18 feet thick) of alluvium, described as stiff mottled gray–brown silty clay and sandy silt with gravel and coral fragments. Several borings revealed 4.5 to 6 feet of dense black volcanic cinders at the top of the alluvium. Below is a 10- to 20.5-foot-thick occurrence of soft clayey coral, characterized by low blow counts. This is probably coralline debris rather than ledge coral. Beneath is more alluvium, described as stiff mottled brown silty clay and sandy silt, with sand, gravel, and some coral fragments. This extends to the maximum depth drilled, 80.5 feet.

Borings southwest of Dillingham Boulevard revealed 2 to 5 feet of fill, consisting of medium-dense tan silty coral sand, gravel, and coral fragments. Beneath are soft and loose lagoonal deposits, composed of dark-gray to black organic silts and clays, with some sand, gravel, and coral fragments, along with decomposed wood and shells. These lagoonal deposits are anywhere from 4 to 13.5 feet thick. Below is alluvium, described as stiff brown sandy–clayey silt, with some sand, gravel, coral fragments, and black cinders. The alluvium is 15 to 37.5 feet thick here. Below are 6 feet of tannish-white silty coral sand and gravel, classified as coralline debris. Below is more alluvium, described as stiff mottled brown clayey silt with some sand and gravel, extending to the maximum depth drilled, 41.5 feet. This area is apparently within the Kapālama Channel.

Quad M–14

The coordinates for Quad M–14 are 57000 North to 58000 North and 541000 East to 542000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard cuts across the northeast corner of this quad, Waiakamilo Road crosses through the northwest corner, and Kapālama Canal runs through the southeastern section.

Borings southeast of Kapālama Canal indicated the presence of 3 to 5.5 feet of fill, consisting of gravelly coral sand with coral fragments and coral cobbles. Below is a layer (7 to 15 feet thick) of soft and loose lagoonal deposits, consisting of gray to black organic sandy clay, with some silty coralline sand and gravel, coral fragments, cobbles, shells, and decomposed wood. Beneath is a layer (about 15 feet thick) of alluvium, composed of stiff dark-brown clayey silt and sandy–silty clay. Extending to the maximum depth drilled (41.5 feet) is a tannish-white gravelly coral sand with some silt and clay, probably weakly cemented coralline debris.

Borings northwest of Kapālama Canal revealed 3 to 8 feet of fill, consisting of brown to gray silty sand and gravel, with coral fragments, basalt boulders, and debris including wood, wire, tar, and rubber. Below are 2 to 10 feet of soft and loose wet lagoonal deposits, composed of dark-gray to black organic clayey silt, with coral fragments, shells, decayed wood, cobbles, and boulders. Beneath are up to 30 feet of alluvium intermixed with coralline debris. The alluvium is brown sandy–clayey silt with some coral fragments, and the coralline debris is tannish-white silty coralline sand and gravel. The alluvium intermixed with coralline debris continues to the maximum depth drilled, 39.5 feet. This area is within the Kapālama Channel.

Quad M–15

The coordinates for Quad M–15 are 57000 North to 58000 North and 540000 East to 541000 East (Plates 5 and 6, Appendix B). The intersection of Waiakamilo Road with Nimitz Highway is located in the middle of this quad.

Borings southeast of Waiakamilo Road indicated the presence of 3.5 to 9 feet of fill, consisting of medium-dense brown silty coralline sand and gravel. Below are 3 to 8 feet of soft and loose saturated lagoonal deposits intermixed with some coralline debris. These are described as gray to black organic clay and silt mixtures, with decomposed wood, and some coral sand and gravel. Between elevations of –3 and –7 feet, a hard white coral is encountered. One boring log describes this as coralline gravel, but blow counts are high enough to categorize it as ledge coral. This is categorized as the +5 coral ledge. It extends to the maximum depth drilled here, 39.5 feet.

Borings northwest of Waiakamilo Road showed 1 to 3.5 feet of fill or alluvial topsoil, consisting of stiff brown clayey silt with sand, gravel, coral fragments, black cinders, and occasional boulders. First encountered between elevations of +14 and +11 feet is a dense tan coral limestone, tentatively classified as the +20 ledge. It grades from hard to medium-hard to soft and extends to the maximum depth drilled, 30 feet. One boring indicated the presence of only 5 feet of coral ledge, with black cinders and coralline debris below. This may indicate that a former alluvial channel is present; however, it is not likely since nearby borings do not reveal the presence of a channel. It is possible that cinders and coralline debris from the fill layer fell into the drill hole and were misinterpreted as an in situ deposit.

Quad M–16

The coordinates for Quad M–16 are 57000 North to 58000 North and 539000 East to 540000 East (Plates 5 and 6, Appendix B). Kalihi Street cuts across the northwest corner of the quad.

The two borings in this quad, both located in the northwest corner, revealed 1 to 4 feet of fill or topsoil, consisting of brown clayey silt with gravel. A hard tan coral, with pockets of dense sand, is encountered at an elevation of about +12 feet and continues to the maximum depth drilled, 15 feet. It is categorized as the +20 ledge.

Quad M–17

The coordinates for Quad M–17 are 57000 North to 58000 North and 538000 East to 539000 East (Plates 5 and 6, Appendix B). Kalihi Street runs through this quad in a northeast to southwest direction. No borings are located within this quad.

Quad M–18

The coordinates for Quad M–18 are 57000 North to 58000 North and 537000 East to 538000 East (Plates 5 and 6, Appendix B). Only two borings are located within this quad.

The borings indicated the presence of 2.5 to 8 feet of fill and alluvium, composed of tan clayey–silty sand and gravel, with coral fragments, and stiff brown clayey silt. Below is a layer (up to 3.5 feet thick) of soft and loose lagoonal deposits, described as gray silty sand with coral fragments. Between elevations of +3.5 and –4 feet, a hard tan coral appears. The boring logs refer to this as dense silty sand and gravel, or a highly weathered coral formation, but blow counts are high enough to categorize it as the +5 coral ledge. The coral formation continues to the maximum depth drilled, 22 feet.

Quad M–19

The coordinates for Quad M–19 are 57000 North to 58000 North and 536000 East to 537000 East (Plates 5 and 6, Appendix B).

Borings in this quad indicated the presence of 2.5 to 7 feet of fill (consisting of tan silty sand with coral fragments, gravel, cobbles, and metal debris) on top of soft, loose, and moist lagoonal deposits (composed of gray organic sandy–clayey silt, with some coral fragments). The lagoonal deposits are of variable thickness, ranging from negligible to as much as 8 feet thick. In several borings, a thin layer (5 feet or less) of alluvium, consisting of stiff brown clayey silt with sand, gravel, and cobbles, is found below the lagoonal deposits. First encountered between elevations of +3.5 and –7.3 feet is a hard tan coral with pockets of dense sand; it extends to the maximum depth drilled, 31 feet. This is probably the +5 coral ledge.

Quad M–20

The coordinates for Quad M–20 are 57000 North to 58000 North and 535000 East to 536000 East (Plates 5 and 6, Appendix B). The shoreline divides this quad into a northeast section, which is within the area known as Kalihi Kai, and a southwest section, which is part of Ke'ehi Lagoon.

Borings revealed 4.5 to 18 feet of fill, composed of tan coral sand, gravel, cobbles, and some concrete rubble. Beneath are soft and loose lagoonal deposits, consisting of wet gray sandy silt and silty sand, with some coral fragments and shells, and organic black clayey silt and silty clay. This extends to the maximum depth drilled, 81.5 feet. One boring log describes a 10-foot-thick layer of hard gray moist clay at an elevation of –28 feet as tuff. This material is not mentioned in other boring logs, however.

Quad N–10

The coordinates for Quad N–10 are 58000 North to 59000 North and 545000 East to 546000 East (Plates 5 and 6, Appendix B). The H-1 Freeway divides this quad into a northeast section and a southwest section. All borings are located in the southwest section.

Borings revealed 2 to 6 feet of fill and alluvial topsoil, consisting of stiff brown silty sand and clayey silt, which the logs also refer to as adobe. First encountered between elevations of +22 and +18 feet is weakly cemented tan coral sand or coral reef formation. This may be part of the +20 coral ledge. However, the low blow counts indicate that this may be coralline debris rather than ledge coral. The coral formation, which is about 10 feet thick here, is underlain by about 5 feet of alluvium, described as stiff mottled brown and gray clayey silt. Between elevations of +14 and +4 feet, a weathered basalt appears; this material is also described in the logs as dense brown silty basalt gravel and boulders. It extends to the maximum depth drilled, 25.5 feet. One boring did not reveal the presence of any coral formation; it revealed only alluvium over the basalt. The basalt is probably part of a Nu'uanu lava flow.

Quad N–11

The coordinates for Quad N–11 are 58000 North to 59000 North and 544000 East to 545000 East (Plates 5 and 6, Appendix B). The H-1 Freeway cuts through the northeast corner of the quad, Kapālama Canal crosses through the northwest corner, and King Street passes through the southwest corner.

Only three borings are located within this quad. The two borings located in the southern section revealed 2 to 5 feet of fill or alluvium, consisting of stiff brown clayey silt. Between elevations of +20 and +17 feet, a dense tan–white coral with silty sand appears. Blow counts were high here for the coral formation, which is 9 to 12 feet thick. It is tentatively identified as the +20 coral ledge. Beneath is a layer (up to 14 feet thick) of coralline debris, composed of loose to medium-dense tan silty sand with coral fragments. In one boring log, a cobble or boulder, which may be basalt, is encountered at an elevation of –6 feet. However, because drilling only continued 1 foot into this deposit, positive identification is not possible. Deeper borings are needed to confirm or deny the presence of the Nu‘uanu basalt here. The maximum depth drilled is 29 feet.

One boring is located in the central part of the quad. It revealed 4 feet of fill, consisting of brown silty sand with gravel, cobbles, and concrete rubble. Below is a low-energy deposit, 5.5 feet thick, described as dark grayish-brown organic clayey silt. Beneath is yellow–brown silty sand with coral fragments, possibly coralline debris. The boring is only 10.5 feet deep. This may be an area of low-energy flood plain alluvium from the nearby Kapālama Canal, but more borings are needed to determine this.

Quad N–12

The coordinates for Quad N–12 are 58000 North to 59000 North and 543000 East to 544000 East (Plates 5 and 6, Appendix B). King Street cuts through the northeast corner of the quad, and Kapālama Canal divides this quad into a southeast section and a northwest section.

All borings in this quad showed thick sequences of alluvium and low-energy deposits, probably due to their proximity to Kapālama Stream. On top is 4.5 to 11 feet of fill, consisting of gray–brown silty clay, with sand, gravel, coral fragments, volcanic tuff fragments, and some black organic clayey silt with wood fragments, labeled as partly cemented incinerator waste. Beneath, to the maximum depth drilled (160 feet), are low-energy deposits intermixed with alluvium and some coralline debris. The low-energy deposits consist of soft and loose slightly organic gray silts and sand, with shells and coral fragments. The alluvium is stiff mottled orange–brown clayey silt and silty clay, with some sand, gravel, cobbles, and boulders. Intermixed is coralline debris, up to 8 feet thick, described as medium-dense tan silty coralline sand and gravel.

Quad N–13

The coordinates for Quad N–13 are 58000 North to 59000 North and 542000 East to 543000 East (Plates 5 and 6, Appendix B). Kapālama Canal cuts through the southeast corner, and Waiakamilo Road passes through the northwest corner of this quad.

Only one boring is located in this quad. It revealed 7 feet of fill, consisting of medium-stiff grayish-brown silty clay with sand, gravel, and coral fragments. Below are 6 feet of lagoonal deposits, composed of soft wet sandy silt with coral fragments. Eight feet of alluvium, described as stiff brown silty clay and clayey silt, are beneath the lagoonal deposits. Tan coralline debris then continues to the maximum depth drilled, only 29.5 feet.

Quad N–14

The coordinates for Quad N–14 are 58000 North to 59000 North and 541000 East to 542000 East (Plates 5 and 6, Appendix B). The intersection of Waiakamilo Road with Dillingham Boulevard is located in this quad.

One boring is located in the southeastern corner of the quad. It indicated the presence of 6.5 feet of fill, composed of brown silty clay and silty sand, with coral fragments and cobbles. Below are low-energy deposits, consisting of soft dark-gray organic silt with sand and shells. These continue to the maximum depth drilled, only 11.5 feet here.

Two borings are located just north of the intersection of Waiakamilo Road with Dillingham Boulevard. These borings showed 0.5 to 1.5 feet of fill or alluvial topsoil, composed of stiff brown clayey silt with gravel. At an elevation of +13 feet, a hard tan coral appears and continues to the maximum depth drilled, 15 feet. This is tentatively classified as the +20 coral ledge.

Quad N–15

The coordinates for Quad N–15 are 58000 North to 59000 North and 540000 East to 541000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard crosses through the northeast corner of the quad.

Borings indicated the presence of 0.5 to 6.5 feet of fill, consisting of stiff brown clayey silt and silty clay, with boulder-sized coral chunks, crushed coral, and rubbish. First appearing between elevations of +15.5 and +12 feet is a dense coral limestone with pockets of sand. Varying between soft and hard coral with depth, this limestone extends to the maximum depth drilled, 21 feet. Characterized by high blow counts in this area, it is tentatively classified as the +20 coral ledge.

Quad N–16

The coordinates for Quad N–16 are 58000 North to 59000 North and 539000 East to 540000 East (Plates 5 and 6, Appendix B). The intersection of Kalihi Street with Nimitz Highway is located within this quad.

Borings showed 1 to 7 feet of fill, consisting of stiff brown clayey silt with coral sand and gravel. First appearing between elevations of +17.5 and +12 feet is a hard white to tan coral with pockets of sand. Characterized by high blow counts, this coral is categorized as the +20 ledge. It extends to the maximum depth drilled, 30 feet.

Quad N–17

The coordinates for Quad N–17 are 58000 North to 59000 North and 538000 East to 539000 East (Plates 5 and 6, Appendix B). Nimitz Highway crosses through the northeast corner of the quad.

Only three borings are located in this quad, all in the southeast area. They revealed 0.5 to 5.5 feet of fill, composed of brown clayey silt, sand, gravel, cobbles, and miscellaneous rubbish. First appearing between elevations of +11 and +10 feet is a hard tannish-white coral with pockets of cemented sand. This continues to the bottom of the drill hole, 19.8 feet below grade. It is tentatively classified as the +20 coral ledge.

Quad N–18

The coordinates for Quad N–18 are 58000 North to 59000 North and 537000 East to 538000 East (Plates 5 and 6, Appendix B). This quad is within the area known as Kalihi Kai.

Borings in the southwest corner revealed 1.5 to 2.5 feet of fill, consisting of gray and tan clayey sand and gravel. Beneath is a thin layer (0.5 to 5.5 feet) of alluvium, composed of stiff brown clayey silt. Between elevations of +4 and –1 feet, a tan coral formation appears. In some logs this is described as dense silty coralline sand and gravel, whereas in other logs it is referred to as highly weathered coral. Blow counts were variable but high enough in some logs to classify this coral formation as the +5 ledge. It extends to the maximum depth drilled, 15 feet.

Borings in the northern half of the quad indicated the presence of 0.5 to 6.5 feet of fill, composed of stiff brown clayey silt with gray silty–sandy basalt and coral gravel. First appearing between elevations of +9.5 and –1 feet is a hard white–tan algal coral, described as moderately fractured. In several borings, this grades to dense coral sand and gravel with depth. This is classified as the +5 coral ledge, which extends to the maximum depth drilled, 20 feet.

Quad N–19

The coordinates for Quad N–19 are 58000 North to 59000 North and 536000 East to 537000 East (Plates 5 and 6, Appendix B). This quad is within the area referred to as Kalihi Kai.

All borings are located in the southern part of the quad. The borings revealed 3 to 7.5 feet of fill, composed of stiff brown clayey silt with sand and gravel. Several borings indicated the presence of up to 8 feet of alluvial soils, consisting of mottled tan to brown clayey–sandy silt with coral fragments, below the uppermost fill. First appearing between elevations of +4 and –4 feet is a hard tan coral, which grades to medium-hard coral with depth and extends to the maximum depth drilled (33.5 feet). This is tentatively classified as the +5 coral ledge.

Quad N–20

The coordinates for Quad N–20 are 58000 North to 59000 North and 535000 East to 536000 East (Plates 5 and 6, Appendix B). The shoreline is located in the western part of this quad.

Borings revealed 3 to 11 feet of fill, composed of dense gray–brown silty clay and silty sand and gravel, with coral fragments, volcanic tuff fragments, and pieces of concrete. Beneath are thick sequences of lagoonal deposits, called harbor sediments in the logs. The low-energy lagoonal deposits are soft and loose, gray to black organic clayey silts and silty sand, with gravel, shells, and coral and wood fragments. The lagoonal deposits are intermixed with alluvium and marl. The alluvium is stiff mottled tan to brown clayey silt with some sand and gravel, and the marl is clayey coral. These intermixed deposits extend to the maximum depth drilled, 144.2 feet.

Quad O–12

The coordinates for Quad O–12 are 59000 North to 60000 North and 543000 East to 544000 East (Plates 5 and 6, Appendix B). The H-1 Freeway cuts through the northeast corner, and King Street runs through this quad in a northwest to southeast direction.

Borings in the southeast corner showed 2 to 3.5 feet of fill or alluvial topsoil, composed of brown clayey silt and silty clay with sand, gravel, and coral fragments. Beneath is stiff mottled gray–brown silty clay, with some sand and gravel, probably alluvium. It is between 4.5 and 14.5 feet thick. Below is a layer of mottled tan soft silty coralline debris, characterized by low blow counts. This layer is as thin as 2.5 feet and as thick as 17 feet here. Beneath is a second layer of alluvium, described as stiff mottled gray–brown or orange–brown silty clay, extending to the maximum depth drilled (65.5 feet).

Borings in the northwest corner indicated the presence of 3 to 4.5 feet of fill and alluvial slopewash materials, consisting of stiff mottled brown silty clay, with sand, gravel, coral fragments, and charcoal debris. Below is a layer (5 to 11 feet thick) of low-energy alluvial sediments, composed of soft gray organic clay with silt, sand, and some cobbles. A 10-foot-thick layer of sandy clay or clayey sand with coral is then encountered. Beneath are more alluvial deposits, extending to the maximum depth drilled, 52 feet. These are stiff mottled gray and brown silty clays and clayey silts with sand and decomposed rocks.

Borings located along the western edge of the central part of the quad revealed about 3 feet of fill or alluvial topsoil, consisting of hard brown clayey silt with orange weathered cinders. Below, to the maximum depth drilled (30 feet), are alluvial silts, described as stiff brown and mottled brown–gray clayey silt with sand and rounded gravel and coral fragments.

This entire area is apparently part of a Kapālama drainage system; however, deeper borings are needed to determine the depth of the Kapālama Channel here and to discover whether there is basalt at depth.

Quad O–13

The coordinates for Quad O–13 are 59000 North to 60000 North and 542000 East to 543000 East (Plates 5 and 6, Appendix B). King Street crosses through the northeast corner, and Waiakamilo Road divides the quad into a southeast section and a northwest section.

Borings southeast of Waiakamilo Road indicated the presence of as much as 6 feet of fill, composed of brown silty sand, gravel, cobbles, and boulders. Below, to the maximum depth drilled (21.5 feet), is alluvium. Toward the top, it is comprised of soft gray or black silty clay, probably deposited in a low-energy environment. With depth, it grades to stiff brown or mottled orange–brown silty clay. Included are rounded coral and basalt gravel, thin layers of soft organic silts, and some coralline debris consisting of loose coral fragments in a silty–sandy clay matrix.

In the southwest corner, borings indicated the presence of 0.5 to 2.5 feet of fill or alluvial topsoil, composed of brown clayey silt with gravel. First encountered between elevations of +19.5 and +17.5 feet is a dense to very dense tannish-white coral formation with some silty sand. The coral formation is up to 22 feet thick. Beneath is soft to stiff tan silty–sandy clay with coral fragments and shells, possibly coralline debris or decomposed coral. This extends to the maximum depth drilled, 32 feet. The coral formation is classified as the +20 ledge.

Borings in the northeast corner indicated the presence of 2 to 8 feet of fill or alluvial slopewash materials, consisting of stiff mottled gray–brown clay with sand, gravel, boulders, coral, and decomposed rock. First encountered between elevations of +33 and +26 feet is a fractured gray lava rock with some empty voids and seams of gray clay. This continues to the maximum depth drilled, 20.5 feet. It may have originated from a Kalihi Valley lava flow (Stearns 1985).

Quad O–14

The coordinates for Quad O–14 are 59000 North to 60000 North and 541000 East to 542000 East (Plates 5 and 6, Appendix B). This is part of the area referred to as Kalihi.

There are only two borings located in this quad, both in the northwest section. On top is a layer (2 to 3 feet thick) of fill, consisting of dense brown silty sand. Below are 3 to 6 feet of alluvium, composed of stiff dark-brown clayey silt and silty clay. At elevations of +19 and +16.5 feet, a dense white coral, 4 to 10 feet thick, is encountered. This is probably the +20 coral ledge. One boring encountered basalt rock at an elevation of +15 feet. The basalt is probably part of a Kalihi Valley lava flow. The maximum depth drilled is 15 feet.

Quad O–15

The coordinates for Quad O–15 are 59000 North to 60000 North and 540000 East to 541000 East (Plates 5 and 6, Appendix B). The intersection of Kalihi Street and Dillingham Boulevard is located in this quad.

Borings in the eastern part of the quad revealed a top layer of only 2 feet or less of fill, consisting of dense brown silty sand. Below is a layer of about 5 feet of alluvium, composed of stiff dark-brown clayey silt and silty clay. The top surface of a coral ledge is first encountered between elevations of +20.5 and +16 feet. This coral is tannish-white, cemented, and very dense. One boring log describes it as decomposed, and another calls it gravelly sand, but blow counts were consistently high enough to categorize this as the +20 coral ledge. It is between 2 and 12 feet thick. One boring revealed a 2-foot-thick layer of fractured dark-gray basalt at an elevation of +15 feet. Below is more dense white coral. The maximum depth drilled is only 16 feet.

Borings in the southwest corner indicated the presence of 1 to 3 feet of fill or topsoil, composed of reddish-brown clayey silt with coral fragments. Between elevations of +17 and +15 feet, a dense tan cemented coral appears; it continues to the maximum depth drilled, 13 feet. This is categorized as the +20 coral ledge.

Quad O–16

The coordinates for Quad O–16 are 59000 North to 60000 North and 539000 East to 540000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard crosses through the northeast corner of the quad.

Borings indicated the presence of 1 to 9.5 feet of fill and alluvial topsoil, consisting of loose to stiff reddish-brown silty clay and clayey silt, with dense silty coral sand, gravel, and coral fragments. First encountered between elevations of +21.5 and +13 feet is a layer (16 to 18 feet thick) of dense white to tan cemented coral formation, with pockets of sand. It is classified as the +20 coral ledge. Below is alluvium, described as very stiff brown clayey–sandy silt with cobbles and boulders. This extends to the maximum depth drilled, 35 feet.

Quad O–17

The coordinates for Quad O–17 are 59000 North to 60000 North and 538000 East to 539000 East (Plates 5 and 6, Appendix B). Nimitz Highway passes through this quad, dividing it into a large northeast section and a smaller southwest section.

Borings in this quad indicated 1 to 5 feet of fill and alluvium, consisting of dense silty–sandy coral gravel, with rock fragments, asphalt and concrete debris, and stiff brown clayey silt. The top surface of a hard white to tan cemented coral, with pockets of light-brown silty sand, first appears between elevations of +18 and +12 feet. This extends to the maximum depth drilled, 35 feet. Two borings encountered 1 to 4.5 feet of black cinders on top of the coral formation. The coral is classified as the +20 coral ledge.

Quad O–18

The coordinates for Quad O–18 are 59000 North to 60000 North and 537000 East to 538000 East (Plates 5 and 6, Appendix B). Nimitz Highway cuts across the northeast corner of the quad.

Borings in the southeast part of this quad showed 2 to 9 feet of fill, consisting of dense gray to brown clayey–sandy silt with coral and basalt gravel, cobbles, boulders, and debris such as concrete chunks. Below is a thin layer of lagoonal deposits, varying from negligible to 5 feet thick. The deposits are described as soft dark-gray or black organic clayey silt with shells and coral fragments. Beneath is a thin layer (ranging from negligible up to 6 feet thick) of alluvium, described as stiff brown silty clay and sandy silt with some gravel. First appearing between elevations of +10 and –5 feet is a hard tannish-white moderately fractured coral, classified as the +5 coral ledge. In some logs, this is recorded as alternating with coralline debris, which is described as silty–sandy coral gravel and gravelly sand. The coral formation extends to the maximum depth drilled, 20 feet.

In the northwest part of the quad, borings indicated the presence of 5 to 14 feet of fill, consisting of gray–brown clayey–silty sand, gravel, cobbles, coral fragments, and debris including metal and glass fragments. Below is a layer (16 to 18 feet thick) of soft and loose lagoonal deposits, composed of gray to black silty clay and sandy silt with gravel, shells, and coral fragments. First encountered between elevations of –10.5 and –14 feet is a hard light-gray volcanic tuff, which some logs describe as dense siltstone. This extends to the maximum depth drilled, 60.5 feet. It may have originated from the Aliamanu, Salt Lake, or Makalapa tuff eruptions or from a Kalihi Valley eruption.

Quad O–19

The coordinates for Quad O–19 are 59000 North to 60000 North and 536000 East to 537000 East (Plates 5 and 6, Appendix B). The shoreline is located along the northwest side of the quad.

Four borings in the southern part of the quad indicated 7 to 8 feet of fill, composed of brown to black silty sand, with gravel, wood, coral, metal, and glass fragments. Below are soft and loose lagoonal deposits, consisting of slightly organic gray silty sand, with shell and coral fragments. These deposits extend to the maximum depth drilled, 15.5 feet.

Borings in the northern part of the quad showed 6.5 to 10 feet of fill, described as tan silty sand with coral fragments and metal debris. Below is a layer (13 to 18 feet thick) of soft and loose wet lagoonal deposits, consisting of gray sandy silt with coral fragments and organic clay. First encountered between elevations of –14.5 and –17 feet is a hard and dense light-gray volcanic tuff, with shell fragments. The tuff, also described as siltstone, extends to the maximum depth drilled, 63 feet. It may have originated from the Aliamanu, Salt Lake, or Makalapa tuff eruptions or from an eruption up Kalihi Valley.

Quad O–20

The coordinates for Quad O–20 are 59000 North to 60000 North and 535000 East to 536000 East (Plates 5 and 6, Appendix B). The shoreline is located along the southeast side of the quad. Most of this quad is underwater in Ke‘ehi Lagoon.

Borings indicated the presence of thick sequences (up to 98 feet thick) of harbor sediments or lagoonal deposits. These are soft and loose, gray to black organic clayey silts and silty sand, with gravel, coral fragments, and pieces of wood. Below are alluvial deposits, consisting of stiff mottled gray–brown and orange–brown clays, silts, and sand, with some gravel, cobbles, boulders, and coral fragments. These sediments extend to the maximum depth drilled, 165.5 feet.

Quad P–12

The coordinates for Quad P–12 are 60000 North to 61000 North and 543000 East to 544000 East (Plates 5 and 6, Appendix B). The H-1 Freeway splits this quad into a northeast section and a southwest section. The H-1 Freeway overpass at Waiakamilo Road is within this quad. All borings are located in the southwest section of the quad.

Borings indicated the presence of 4.5 to 7 feet of fill or alluvial topsoil, consisting of brown clay with coral fragments, sand, gravel, cobbles, and boulders. Below is more alluvium, described as stiff mottled brown silty–sandy clay, with traces of decomposed rock. This extends to the maximum depth drilled, 26.5 feet. It is possible that the decomposed rock referred to in the logs is actually a weathered lava flow, but it is not likely because blow counts were too low for this material to be basalt.

Quad P–13

The coordinates for Quad P–13 are 60000 North to 61000 North and 542000 East to 543000 East (Plates 5 and 6, Appendix B). King Street runs diagonally through this quad in a northwest to southeast direction.

There are only three borings in this quad, all located in the southeast part. Two of these revealed conditions similar to that described for Quad P–12: alluvial slopewash materials overlying older alluvium, which includes some brown and black cinder sand here. The alluvium extends to the maximum depth drilled, 21.5 feet. One boring indicated the presence of a top layer of 2.5 feet of fill and slopewash soil, described as brown clayey silt with gravel and coral fragments. At an elevation of +32.5 feet, lava rock appears and continues to the bottom of the drill hole, 21.5 feet below grade. Blow counts were high. This is most likely part of the Kalihi Valley lava flow in the Honolulu Volcanic Series.

Quad P–14

The coordinates for Quad P–14 are 60000 North to 61000 North and 541000 East to 542000 East (Plates 5 and 6, Appendix B). King Street cuts through the northeast corner of the quad, and Kalihi Street divides the quad into a southeast section and a northwest section.

Two borings in the southwest corner of the quad revealed a top layer (6 to 9.5 feet) of stiff dark-brown clayey silt, classified as alluvial slopewash topsoil. A hard dark-gray vesicular basalt appears at elevations of +19 and +14.5 feet and extends to the maximum depth drilled, 15 feet.

Borings in the northern part of the quad indicated the presence of 4 feet or less of fill, composed of mottled brown silty clay, silty sand, and sandy silt, with some gravel, and concrete and coral fragments. Beneath is a layer (1 to 5 feet thick) of alluvium, consisting of soft to stiff moist grayish-brown silty clay (adobe) with gravel and some boulders. First encountered between elevations of +52 and +33 feet is a hard gray basalt with weathered seams. The top 1 to 2 feet of the basalt is highly weathered but dense. The basalt continues to the maximum depth drilled, 15.5 feet. This may be part of a Kalihi Valley lava flow in the Honolulu Volcanic Series.

Quad P–15

The coordinates for Quad P–15 are 60000 North to 61000 North and 540000 East to 541000 East (Plates 5 and 6, Appendix B). Kalihi Street cuts through the southeast corner. This quad is part of the area called Kalihi.

The two borings located in the southeast corner revealed 5 to 10 feet of alluvial topsoil, consisting of stiff dark-brown clayey silt. This grades to decomposed coral at the base of the deposit. The two borings indicated the presence of a hard gray to white coral first appearing at elevations of +22 and +16 feet, respectively. This coral is described as decomposed but very dense. It continues to the maximum depth drilled (16.5 feet) but grades to weathered basalt at the bottom of the drill hole. This appears to be an area where the +20 coral ledge overlies a Kalihi lava flow.

The three borings in the northwest part of the quad indicated the presence of 2.5 feet or less of fill, composed of stiff clayey silt with cinders. Beneath is a layer (2 to 4.5 feet thick) of alluvium, consisting of firm brown silty clay with cobbles and boulders. A hard gray basalt is encountered at an elevation of about +35 feet and continues to the bottom of the drill hole, 15 feet below grade. This is probably part of a Kalihi Valley lava flow in the Honolulu Volcanic Series.

Quad P–16

The coordinates for Quad P–16 are 60000 North to 61000 North and 539000 East to 540000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard passes through the southwest corner of the quad.

All borings in this quad are located in the southwest area. The borings indicated the presence of 1 to 3 feet of fill and alluvial topsoil, composed of dense tan sand, gravel, coral fragments, some ash and organic matter, and stiff brown silty clay. First appearing between elevations of +21 and +19 feet is a dense tan–white coral, with some silty sand and traces of clay. The coral formation, which is about 15 feet thick here, grades to decomposed rock with depth. It is classified as the +20 coral ledge. Below is alluvium, described as stiff mottled brown clayey silt and silty sand, with gravel and decomposed rock. This continues to the maximum depth drilled, 31.5 feet.

Two borings in the southwest corner did not reveal the presence of the coral ledge; instead, they showed alluvium intermixed with some coralline debris to the maximum depth drilled, 21.5 feet. This may be an area of weak coral ledge, as opposed to coralline debris, or an area of nondeposition or erosion of the ledge.

Quad P–17

The coordinates for Quad P–17 are 60000 North to 61000 North and 538000 East to 539000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard cuts through the northeast corner of this quad.

Borings in this quad revealed 1 to 11.5 feet of fill, consisting of reddish-brown silt or silty clay, with brown sandy gravel and coral fragments. The areas of thicker fill are apparently due to infilling after underground storage tank removal. First appearing between elevations of +19 and +10 feet is a hard white to tan well-cemented coral, with some cavities and some pockets of silty sand and gravel. Categorized as the +20 coral ledge, it is between 15 and 23 feet thick; in some places it grades to moderately cemented or weakly cemented coral. Beneath is alluvium intermixed with coralline debris to the maximum depth drilled, 36.5 feet. The coralline debris is a medium-dense tan sandy gravel and silty sand with coral fragments, and the alluvium is primarily a stiff brown clayey silt with sand and gravel.

Quad P–18

The coordinates for Quad P–18 are 60000 North to 61000 North and 537000 East to 538000 East (Plates 5 and 6, Appendix B). Nimitz Highway divides this quad into an eastern section and a western section.

Only two borings are located within this quad, both in the northeast corner. The borings indicated the presence of 8.5 feet of fill, consisting of loose to dense, tan to brown silty clay with sand and gravel. Below are 16 to 26 feet of soft and loose lagoonal deposits, composed of black organic silts and clays with wood and shell fragments. One boring indicated the presence of 8.5 feet of coralline debris (medium-dense white silty sand and coral fragments) over alluvium, whereas the second boring revealed only alluvium below the lagoonal deposits. The alluvium, described as stiff mottled brown clayey silt with sand and gravel, extends to the maximum depth drilled (51.5 feet).

Quad P–19

The coordinates for Quad P–19 are 60000 North to 61000 North and 536000 East to 537000 East (Plates 5 and 6, Appendix B). The shoreline runs through the western part of the quad, and the area where Kalihi Stream enters Ke'ehi Lagoon is also in the western part.

All borings in this quad are shallow, 15 feet or less. They revealed 3.5 to 7 feet of fill, composed of medium-dense to dense tan silty sand and gravel with coral fragments. Below are soft lagoonal deposits to the maximum depth drilled. These consist of slightly organic dark-gray clayey–sandy silts with coral fragments and decayed wood. It is probable that Kalihi Stream alluvium is present below the lagoonal deposits.

Quad Q–14

The coordinates for Quad Q–14 are 61000 North to 62000 North and 541000 East to 542000 East (Plates 5 and 6, Appendix B). King Street crosses through the southwest corner, Kalihi Street cuts through the southeast corner, and the H-1 Freeway passes through the northeast corner.

Borings in this quad revealed a top layer (1 to 7 feet) of brown clay soils, called adobe in several logs. Between elevations of +62 and +49.5 feet, a hard gray basalt is encountered; it continues to the maximum depth drilled, only 13.5 feet. This may be part of a Kalihi Valley lava flow in the Honolulu Volcanic Series.

Quad Q–15

The coordinates for Quad Q–15 are 61000 North to 62000 North and 540000 East to 541000 East (Plates 5 and 6, Appendix B). King Street divides this quad into a northeast section and a southwest section. Kalihi Stream passes through the northwest corner.

Borings in the southern part of the quad revealed 1.5 to 2.5 feet of fill, consisting of dark-brown clayey silt, with cinders, gravel, cobbles, and glass fragments. Beneath are 2 to 2.5 feet of alluvium, composed of stiff brown silty clay (adobe) with some gravel. A weathered clinker zone (up to 3.5 feet thick), described as very dense mottled brown and white clayey sand and gravel, is below the clayey alluvial soils. The top surface of a hard gray vesicular basalt, also described as widely fractured and slightly weathered, is encountered between elevations of +39 and +33 feet. It extends to the maximum depth drilled, 15 feet.

Borings in the northwest corner of the quad revealed 4 feet or less of fill, consisting of stiff brown clay with coral fragments, and loose mudrock, which is possibly tuff fragments. Below is a layer (up to 20 feet thick) of alluvium, comprised of stiff mottled brown clay, with some silty sand, gravel, cobbles, and boulders. First encountered between elevations of +34.5 and +22 feet is a dense blue fractured lava rock, with some vesicles and clinker zones. This continues to the bottom of the drill holes, 25 feet below grade. This area is most likely composed of Kalihi Stream alluvium over Honolulu Volcanic Series basalt that originated from a vent farther up Kalihi Valley.

Quad Q–16

The coordinates for Quad Q–16 are 61000 North to 62000 North and 539000 East to 540000 East (Plates 5 and 6, Appendix B). Kalihi Stream subdivides the quad into a northern section and a southern section.

On top is 2.5 to 5.5 feet of fill, consisting of loose to stiff brown silty clay with sand, gravel, and cobbles. Below is alluvium, composed of stiff mottled brown clayey silt, silty sand, and clayey gravel, with cobbles and boulders. The alluvium, classified as Kalihi Stream alluvium, extends to the maximum depth drilled, 20.5 feet. Deeper borings are needed to determine the presence or absence of Honolulu Volcanic Series basalt below the alluvium, but it is likely to be encountered.

Quad Q–17

The coordinates for Quad Q–17 are 61000 North to 62000 North and 538000 East to 539000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard crosses through the southwest corner, and Kalihi Stream passes through the northern part of the quad.

One boring located along the eastern edge of this quad revealed subsurface conditions similar to that described for Quad Q–16. Two borings located in the southwest corner of the quad revealed 6 to 7 feet of fill, composed of brown silty clay, with coral, glass, metal, and concrete fragments. Below is alluvium to the maximum depth drilled, 20 feet. The alluvium is described as soft to stiff mottled orange, brown, or gray silty clay and silty sand, with some cobbles and boulders.

The other borings in the southwest corner indicated the presence of 3 to 5.5 feet of fill, consisting of brown silty clay with sand, gravel, coral fragments, and concrete rubble. First encountered between elevations of +14 and +12 feet is a dense tan–white coral, with some silty or clayey sand. The coral, which is about 12 feet thick here, is classified as +20 ledge. Below is a thin layer (less than 2 feet thick) of alluvium, composed of soft to stiff gray–brown silty clay and silty sand. Coral again appears between elevations of +2.8 feet and sea level and continues to the bottom of the drill hole, 18 feet below grade. This may indicate that the +20 ledge overlies the +5 coral ledge in this area.

Quad Q–18

The coordinates for Quad Q–18 are 61000 North to 62000 North and 537000 East to 538000 East (Plates 5 and 6, Appendix B). Dillingham Boulevard divides the quad into a northeast section and a southwest section. Nimitz Highway cuts through the southwest edge. Kalihi Stream subdivides the quad into a southeast section and a northwest section. Borings are located only in the area south of Kalihi Stream.

Borings in this quad revealed 9 to 16 feet of miscellaneous fill on top. It includes silty clay and clayey silt, with both coralline and basalt sand and gravel. Beneath are soft and loose lagoonal deposits, anywhere from 15 to 44 feet thick. These consist of dark-gray to black silty sand with organic material, coralline sand and gravel, shells, and decomposed wood. Below the lagoonal deposits is alluvium, described as stiff brown clayey silt with some sand and rounded gravel. The alluvium extends to the maximum depth drilled, 61.5 feet.

Quad Q–19

The coordinates for Quad Q–19 are 61000 North to 62000 North and 536000 East to 537000 East (Plates 5 and 6, Appendix B). Kalihi Stream passes through the southeast edge of the quad.

Only one boring is located within the study area in this quad. The boring revealed 9 feet of fill, composed of white to brown silty and clayey calcareous sand and gravel with coral fragments, grading from soft to dense. Beneath are lagoonal deposits intermixed with alluvium to the maximum depth drilled, 75 feet. These are described as soft to dense, dark-gray or brown clayey–sandy silts, with coral fragments, rounded gravel, decomposed wood, and shells.

APPENDIX B
SUBSURFACE GEOLOGIC MAPS

Plates 1, 3, and 5 show the locations of the boreholes and subsurface cross-sections. Data coverage is indicated by the small crosses within each quad that mark the location of the boreholes. Plates 2, 4, and 6 are subsurface geology maps with the topmost layers of fill and lagoonal sediments removed, so that the first competent layer for foundation-bearing purposes is shown. The maps are labeled with the quad numbering system used in this report.

Range of occurrence of coral ledges:

+20 coral ledge	+22 to +10 feet elevation
+5 coral ledge	+10 to –10 feet elevation
–15 coral ledge	–15 to –29 feet elevation
–30 coral ledge	–30 to –50 feet elevation

Coral ledges can be anticipated at those elevations where coral is noted on the maps. However, their continuous presence cannot be assumed, due to the fact that alluvial channels may have eroded through the coral. These channels may be several hundred feet thick and may include alluvial silt, sand, gravel, cobbles, and boulders; low-energy or lagoonal sediments; cinders; and coralline debris.

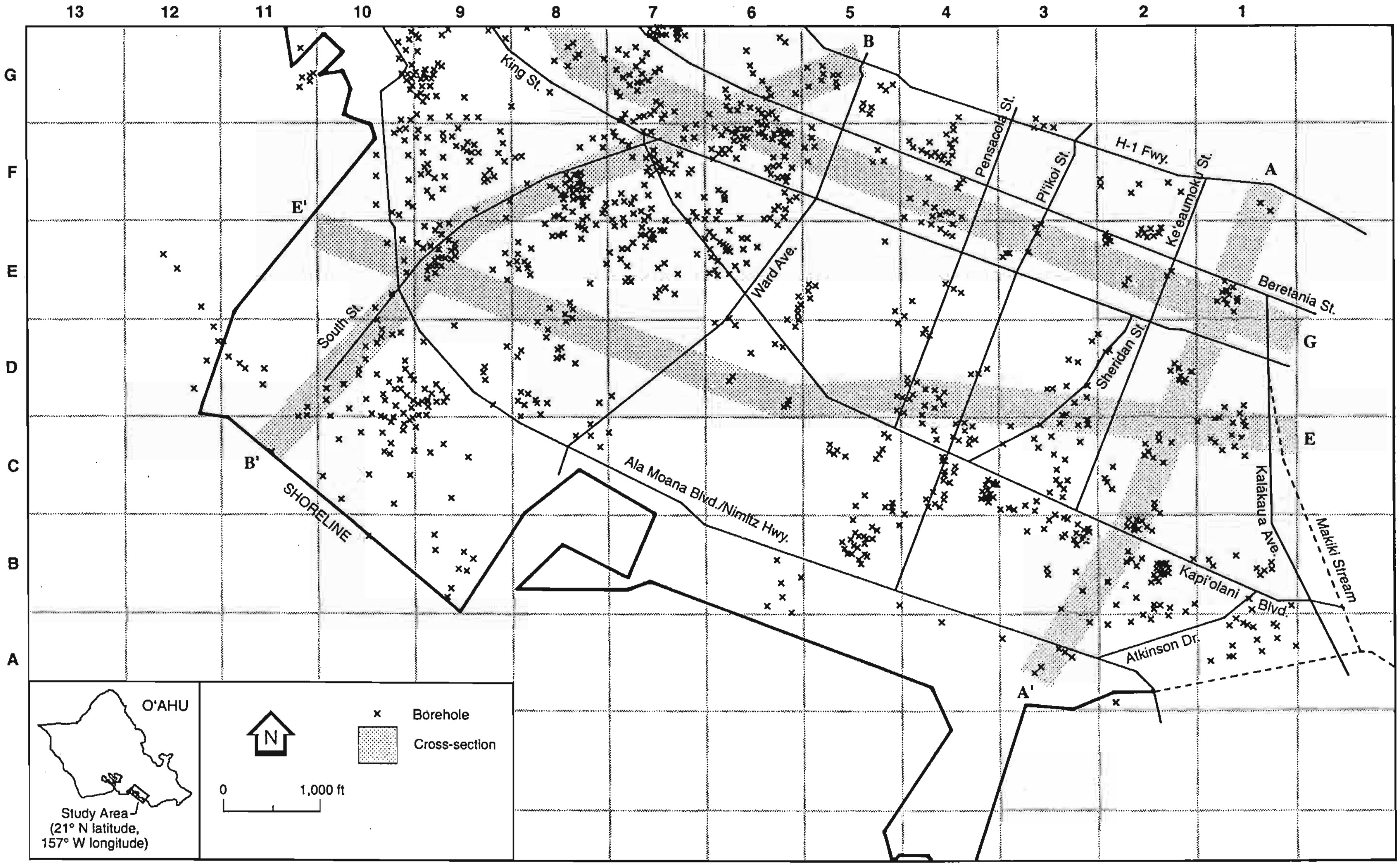

PLATE 1. Southeast quads: borings and cross-sections

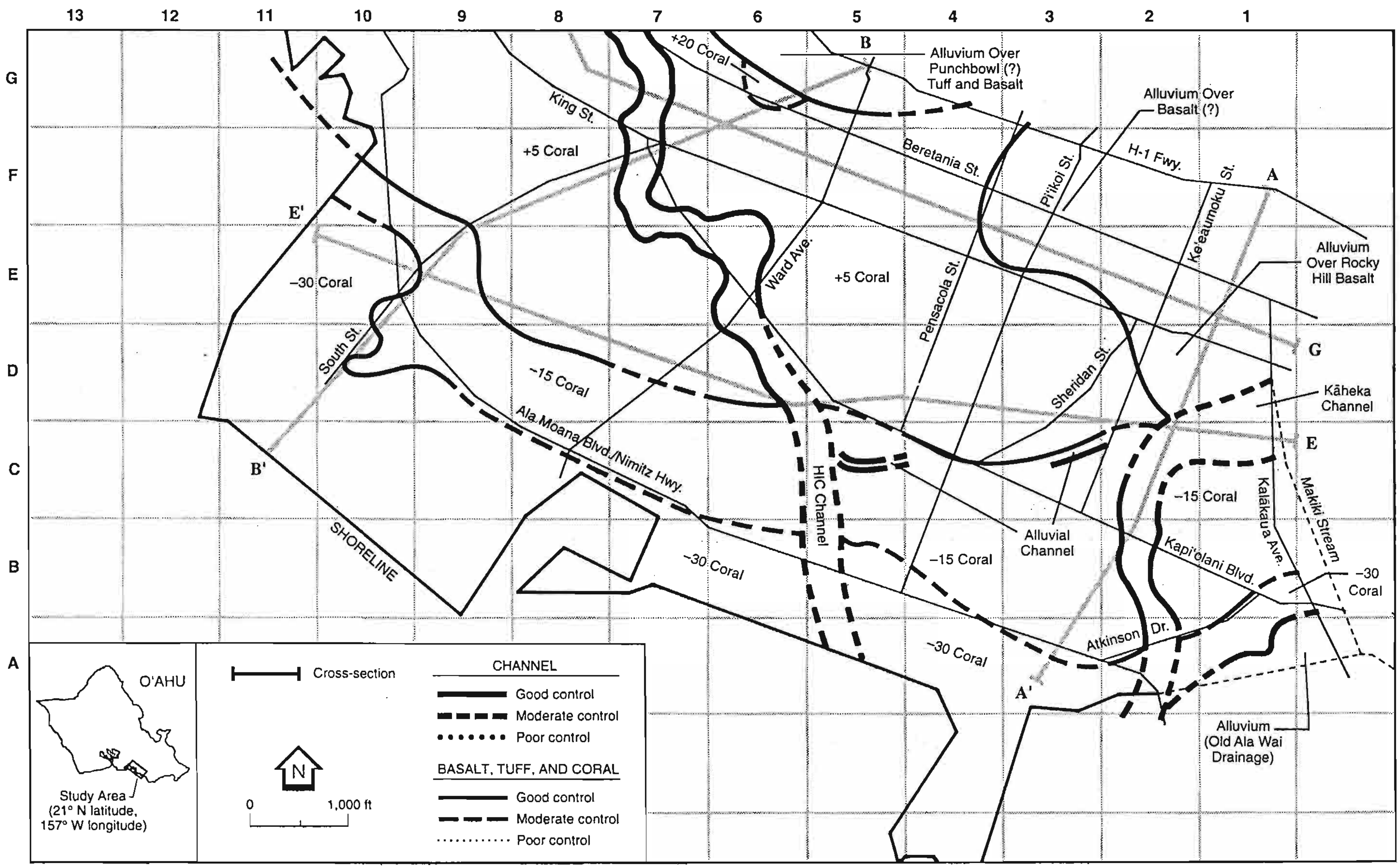

PLATE 2. Southeast quads: subsurface geology

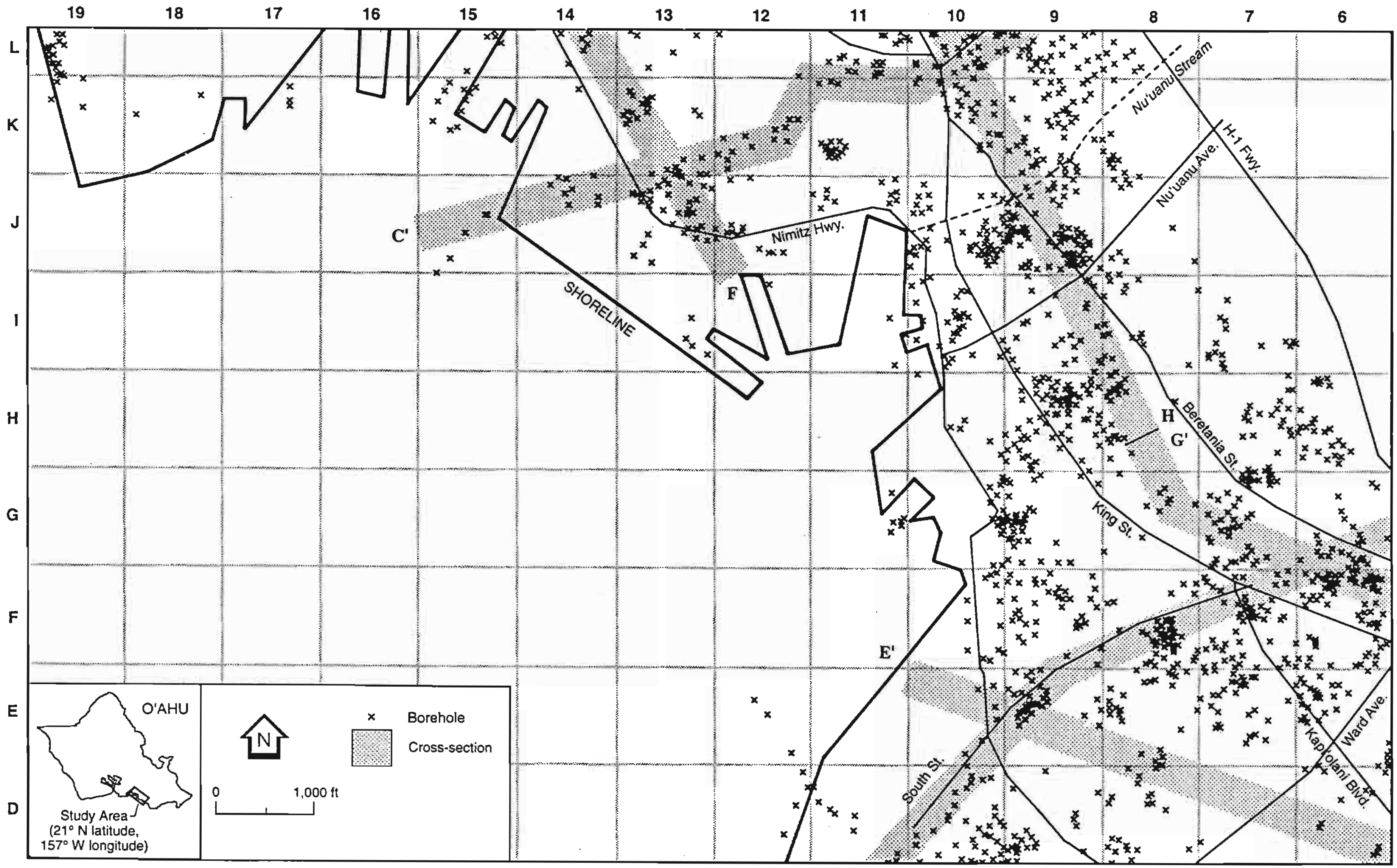

PLATE 3. Central quads: borings and cross-sections

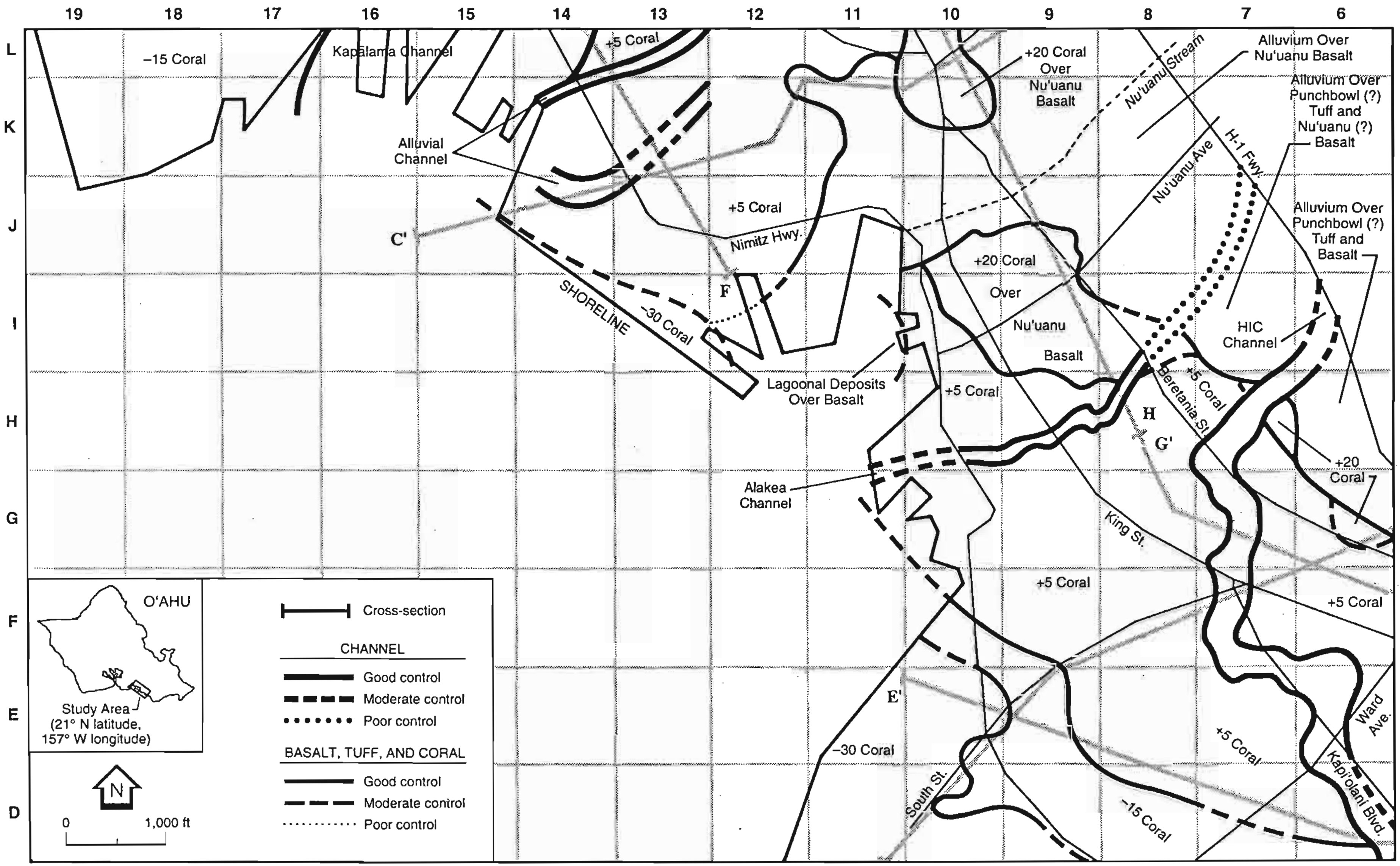

PLATE 4. Central quads: subsurface geology

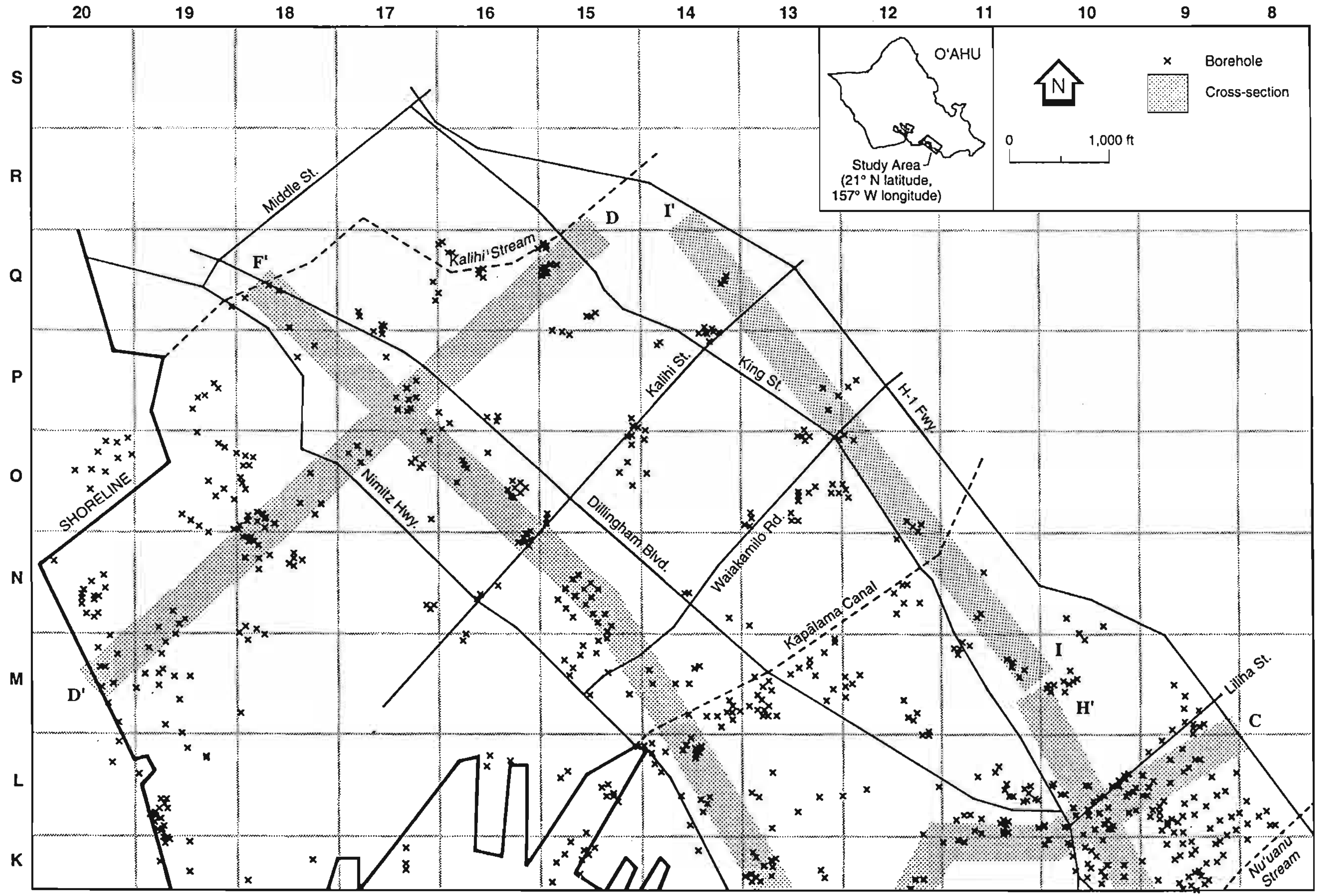

PLATE 5. Northwest quads: borings and cross-sections

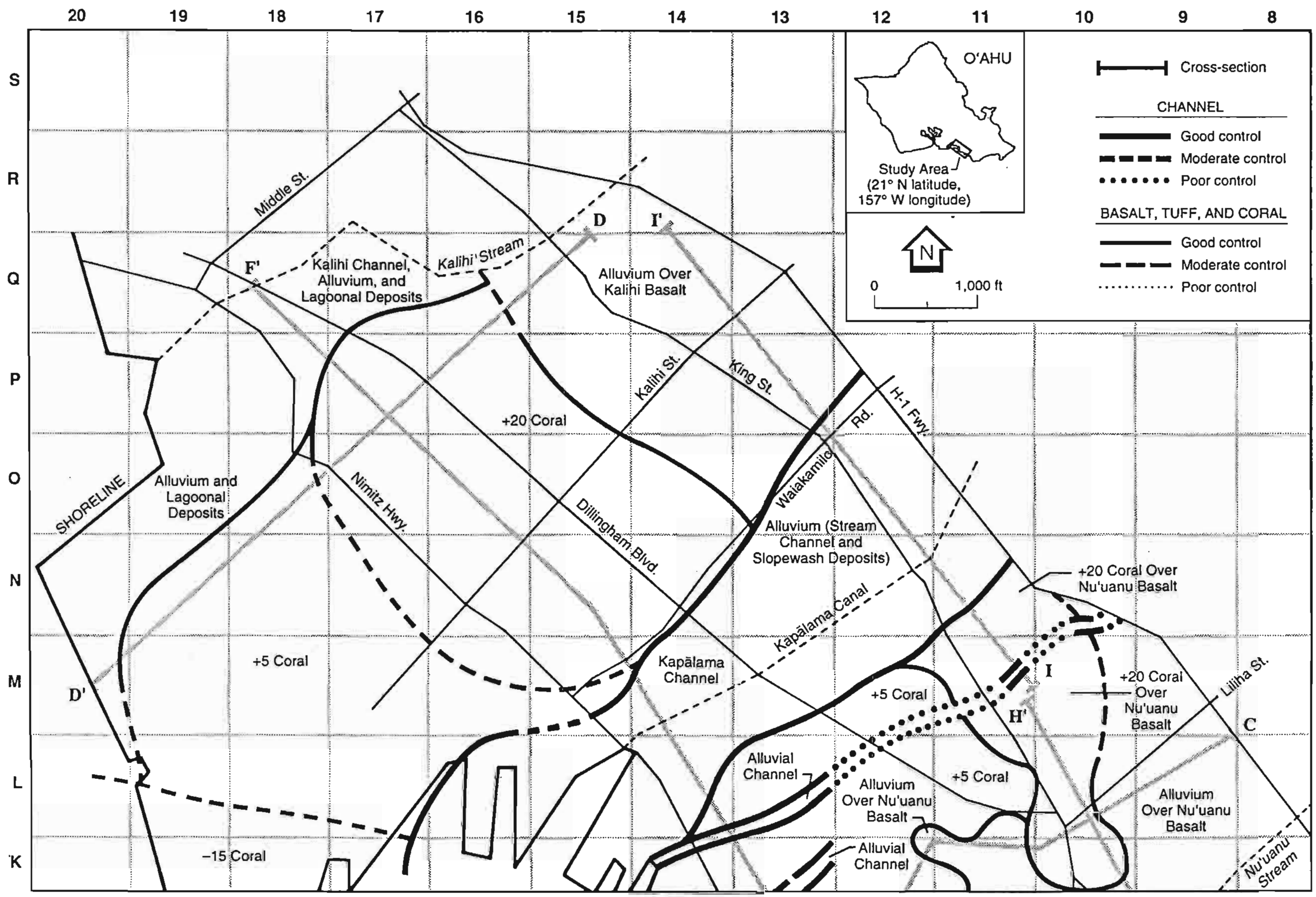

PLATE 6. Northwest quads: subsurface geology

APPENDIX C.
SUBSURFACE GEOLOGIC CROSS-SECTIONS

Nine subsurface cross-sections (Plates 7 through 15) are presented at a vertical exaggeration of 10:1. The location of each cross-section is shown on the maps presented in Appendix B. Each cross-section includes borings located within 200 feet on either side of the actual line of section. The locations of street intersections are noted for each cross-section.

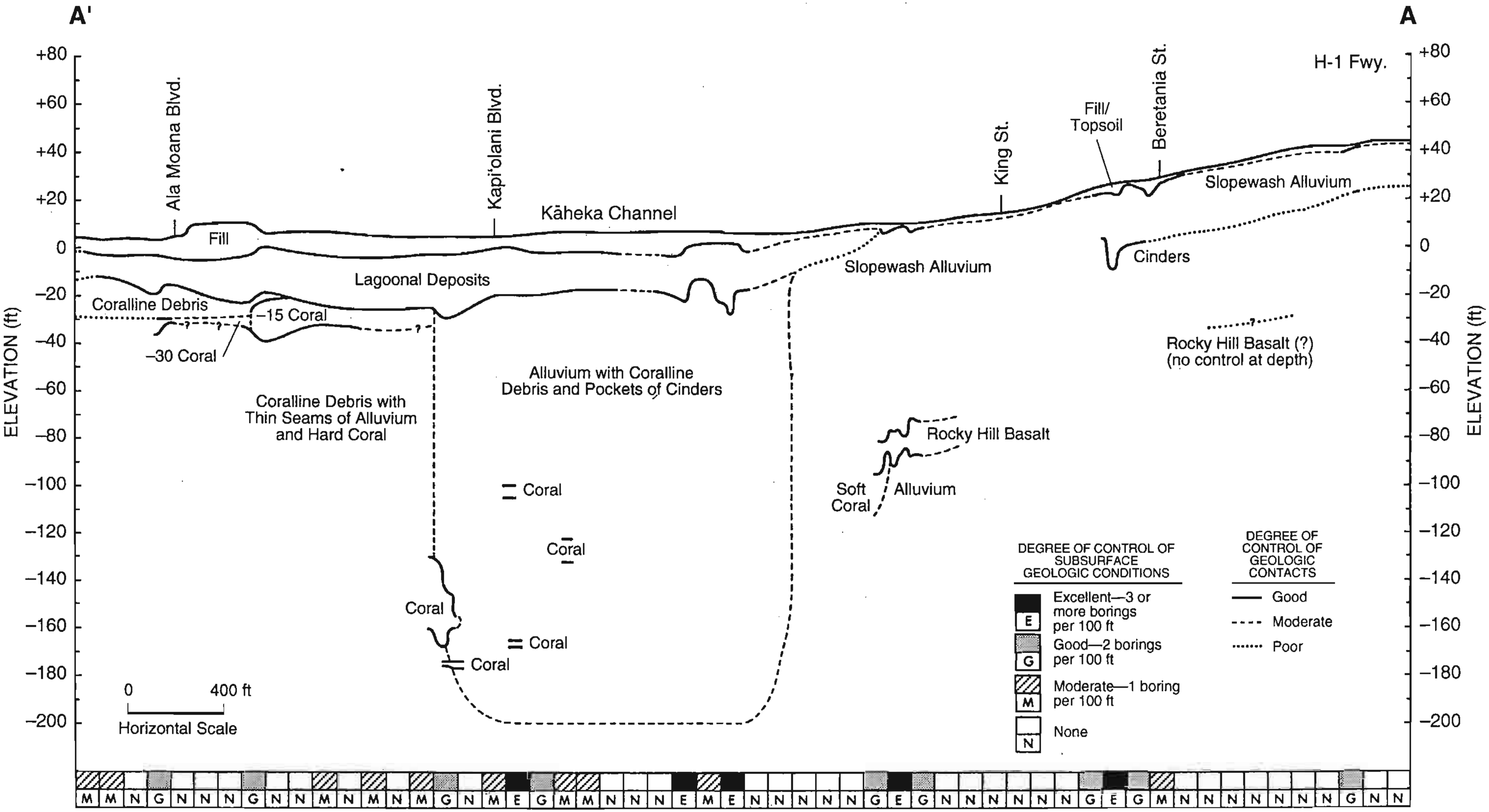

PLATE 7. Subsurface section A–A' for the downtown Honolulu study area

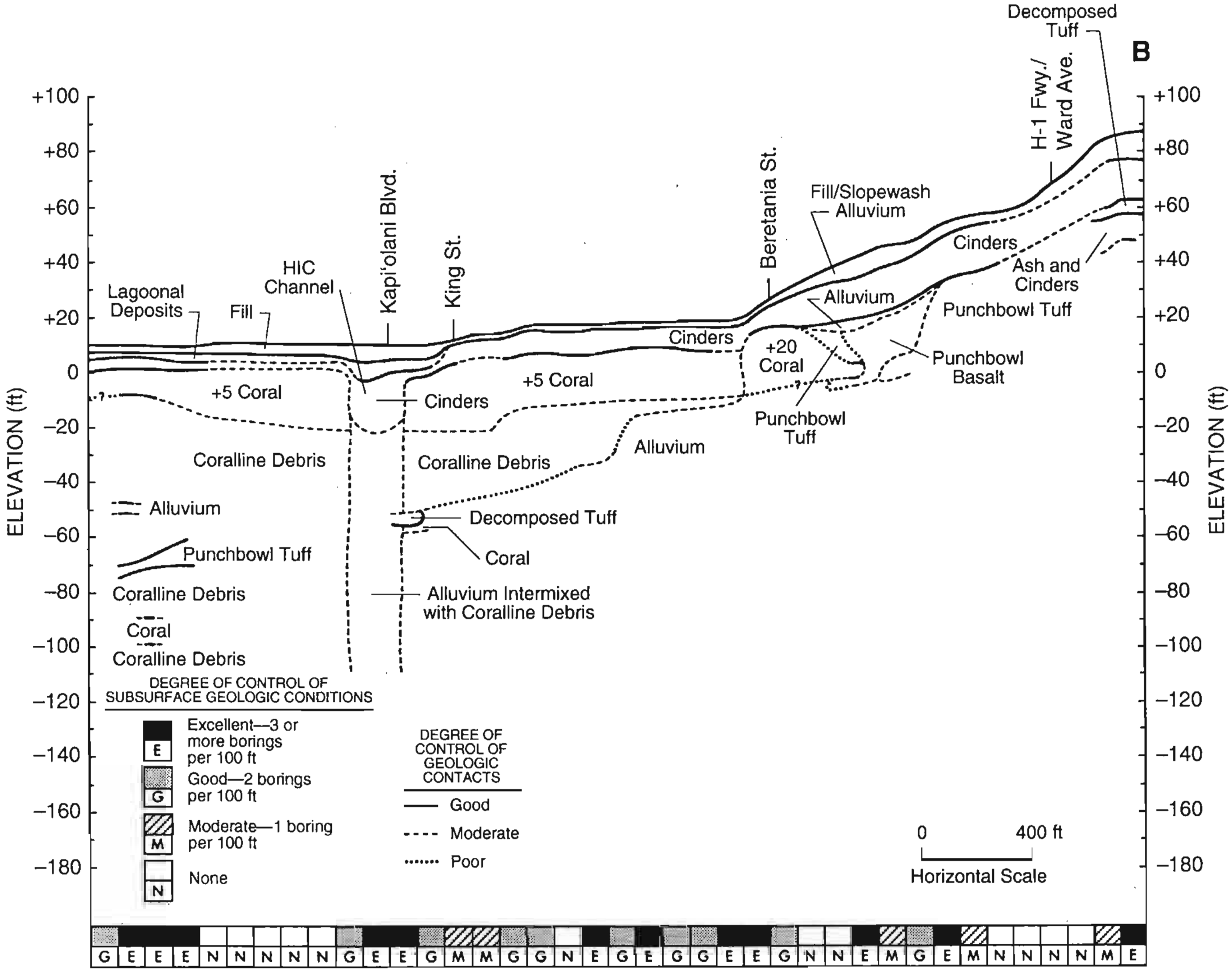

PLATE 8. Subsurface section B–B' for the downtown Honolulu study area

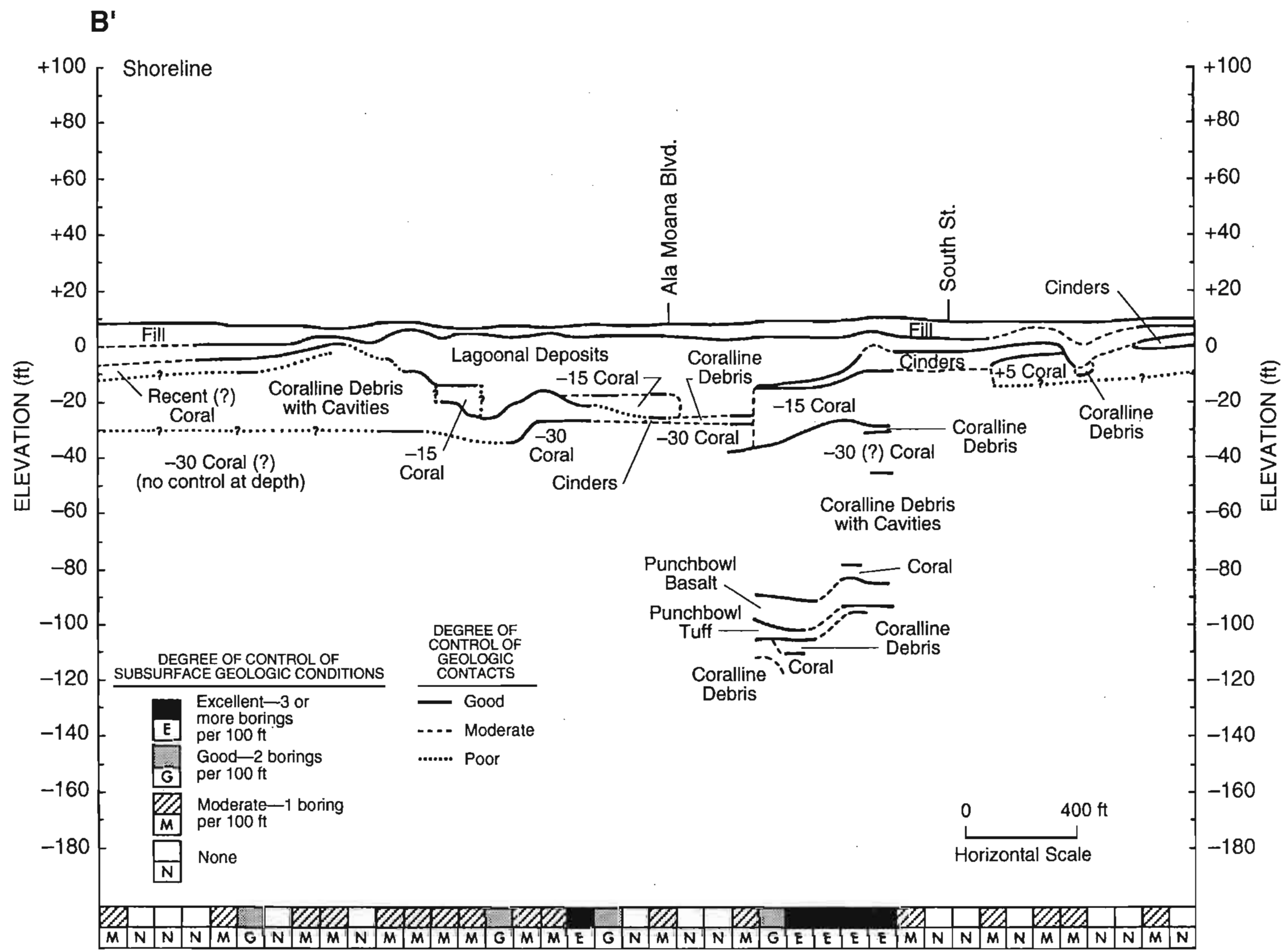

PLATE 8—*Continued*

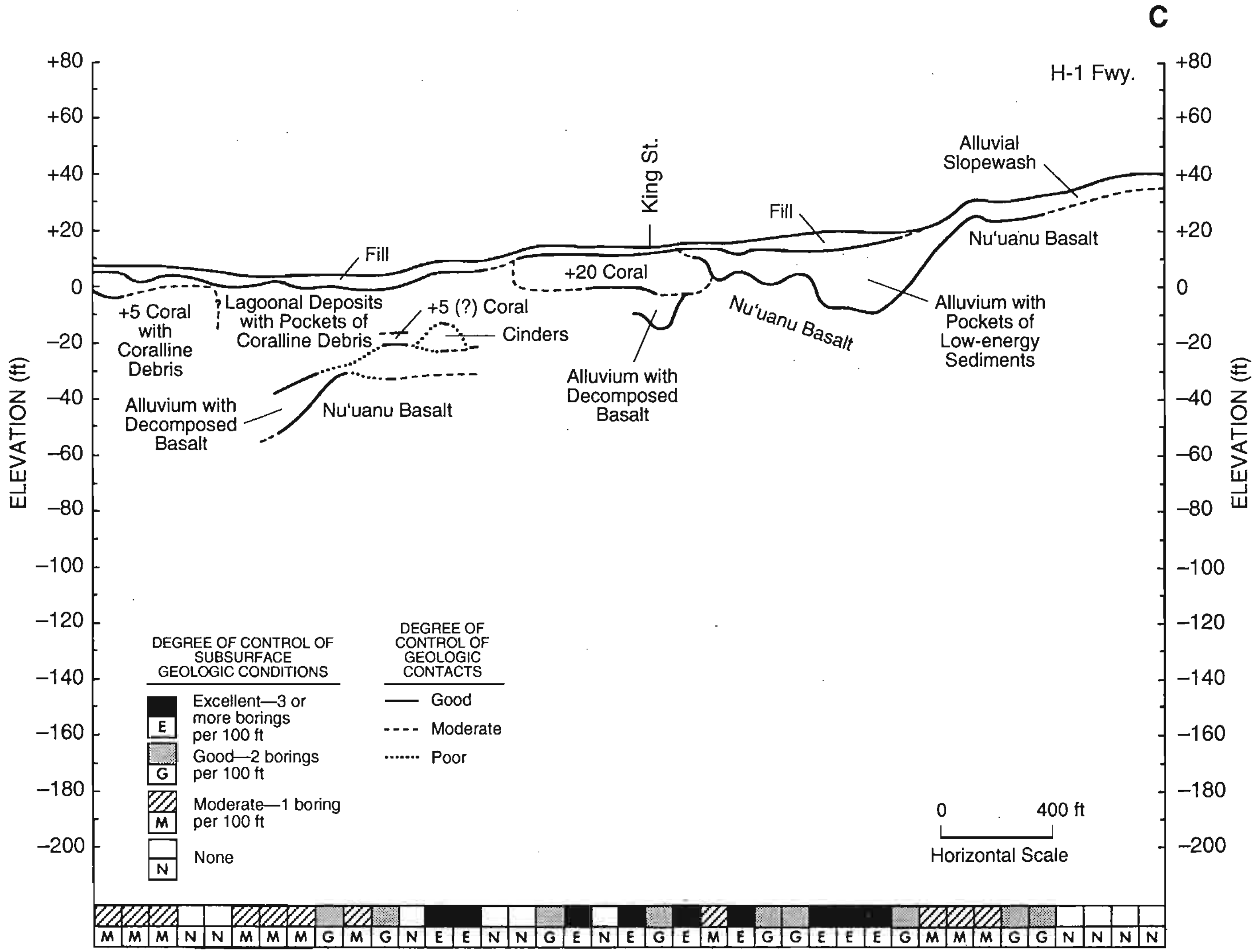

PLATE 9. Subsurface section C–C' for the downtown Honolulu study area

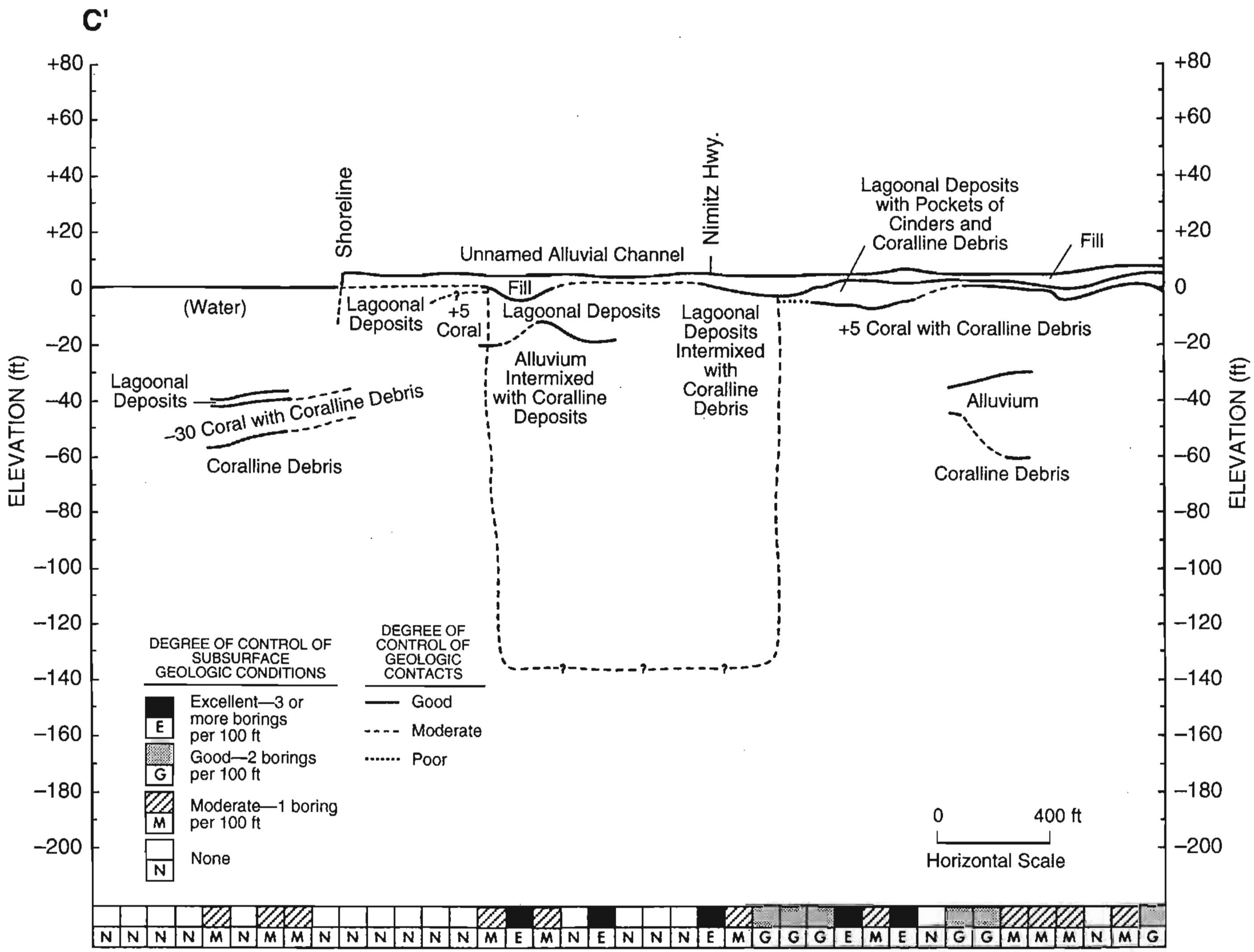

PLATE 9—*Continued*

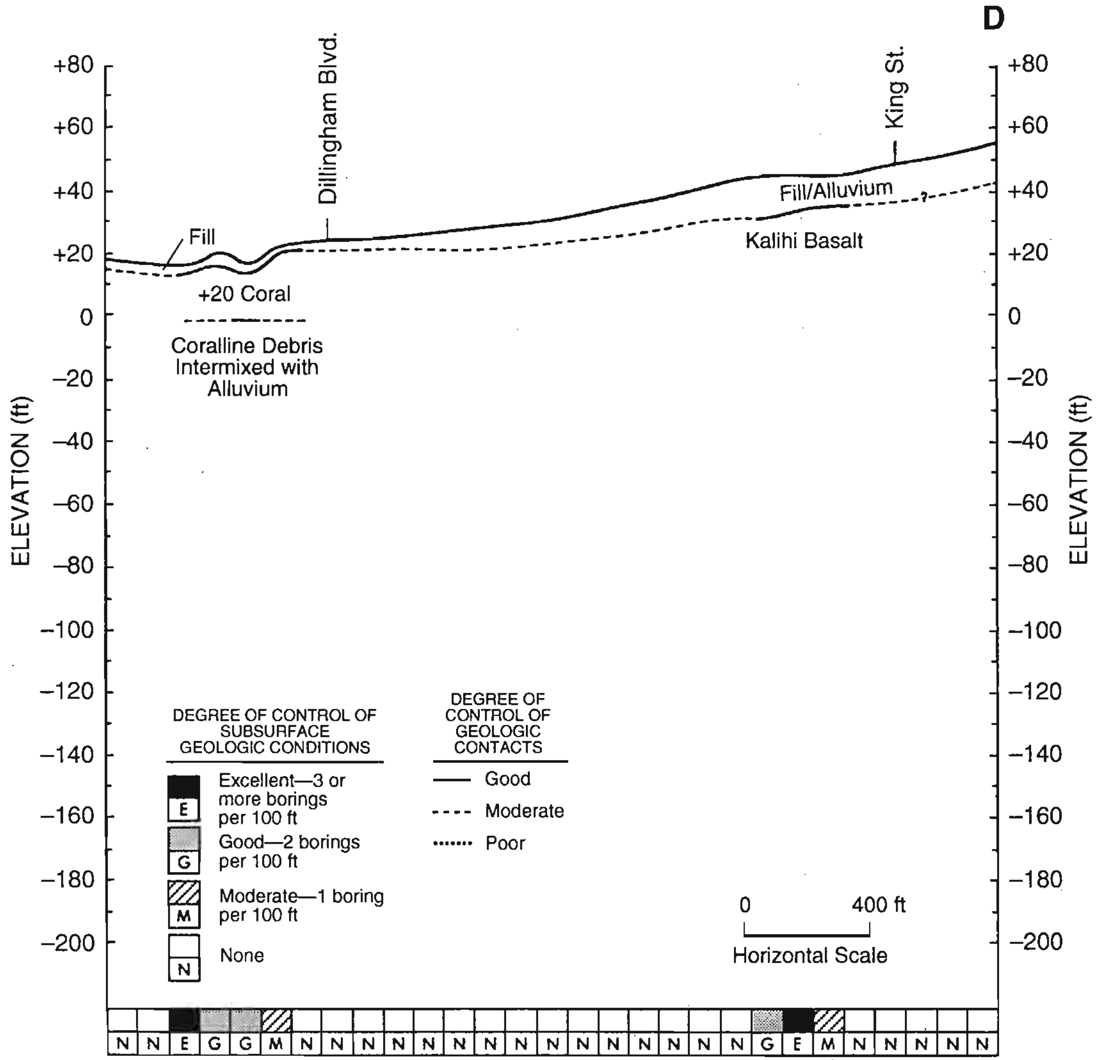

PLATE 10. Subsurface section D–D' for the downtown Honolulu study area

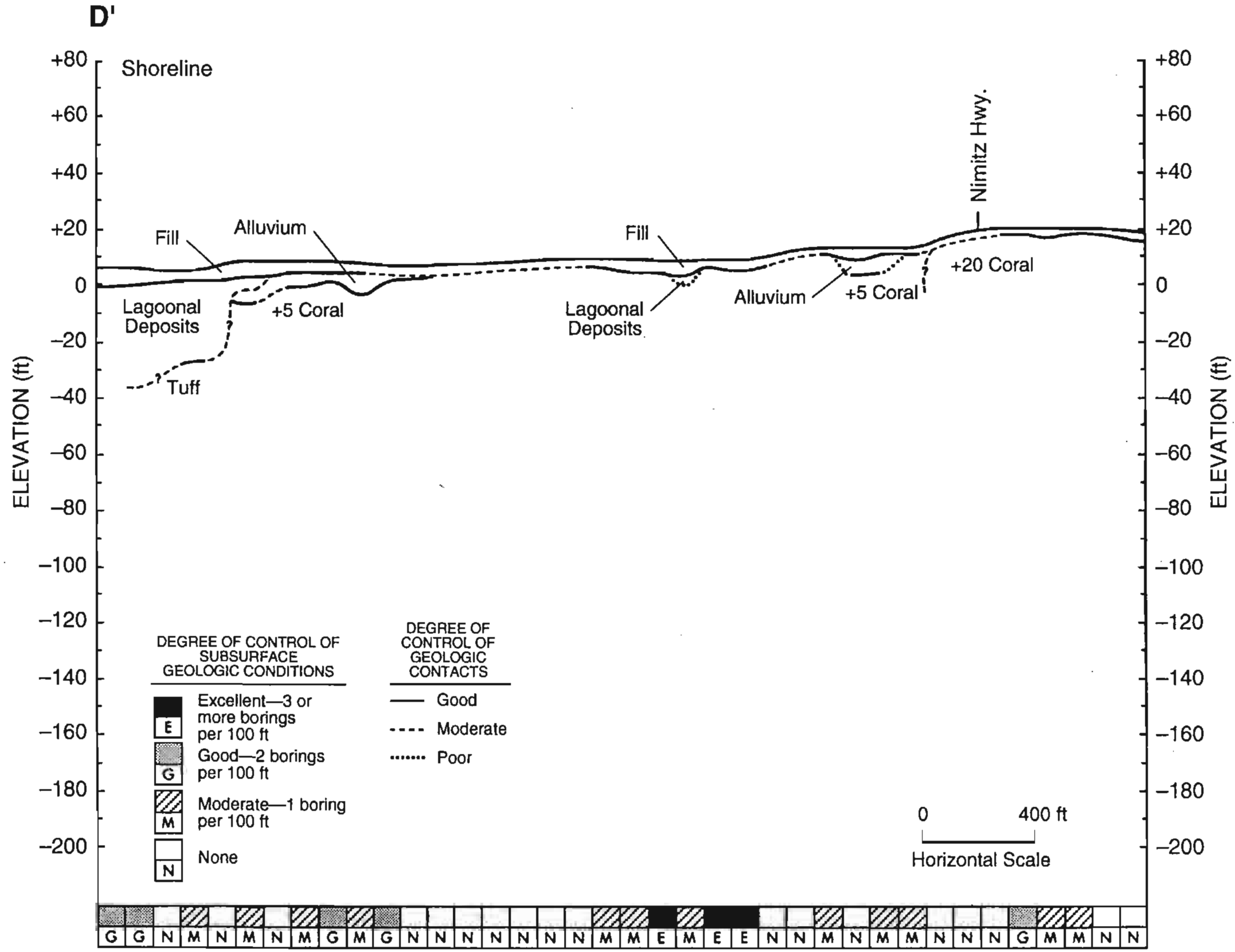

PLATE 10—*Continued*

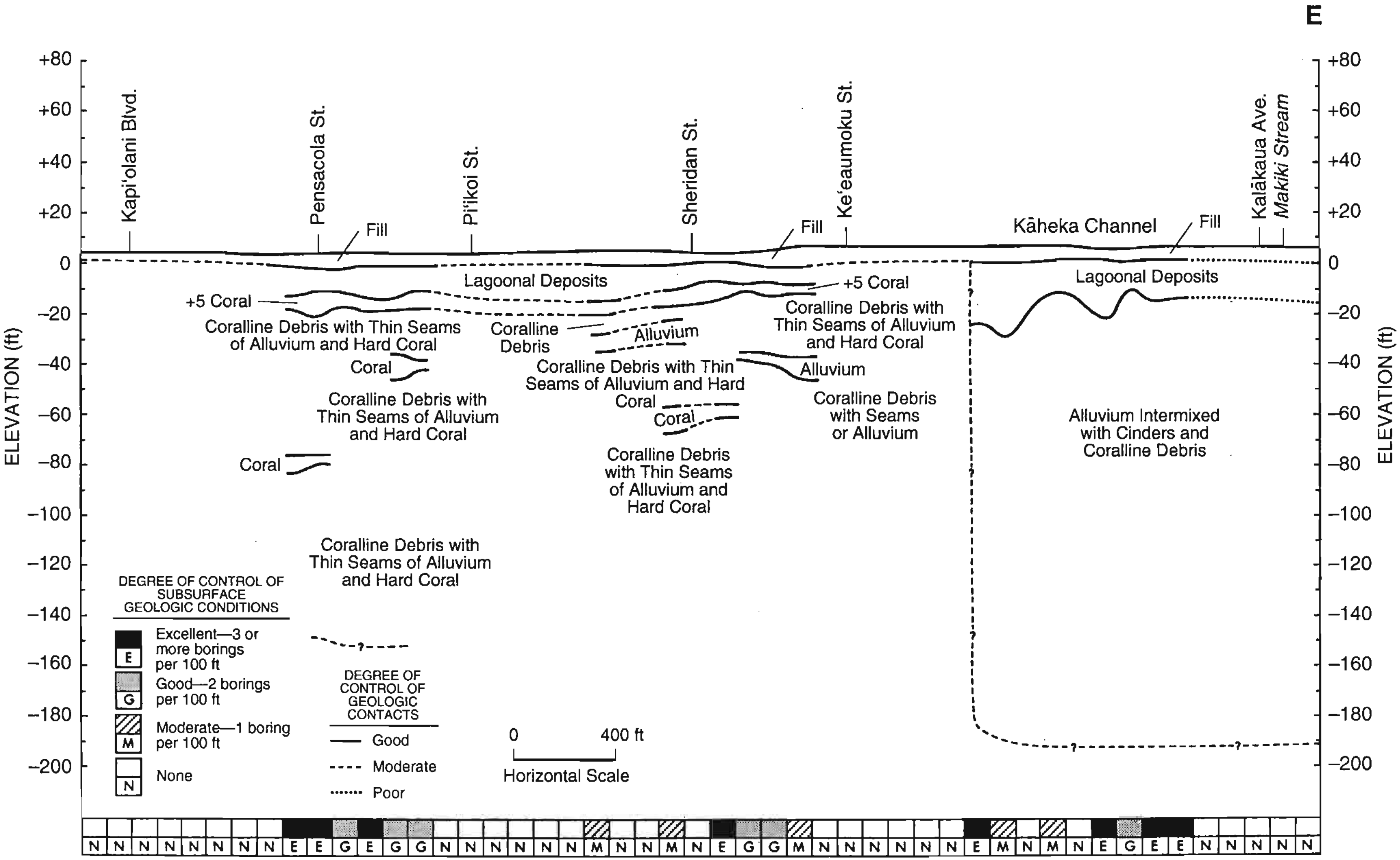

PLATE 11. Subsurface section E–E' for the downtown Honolulu study area

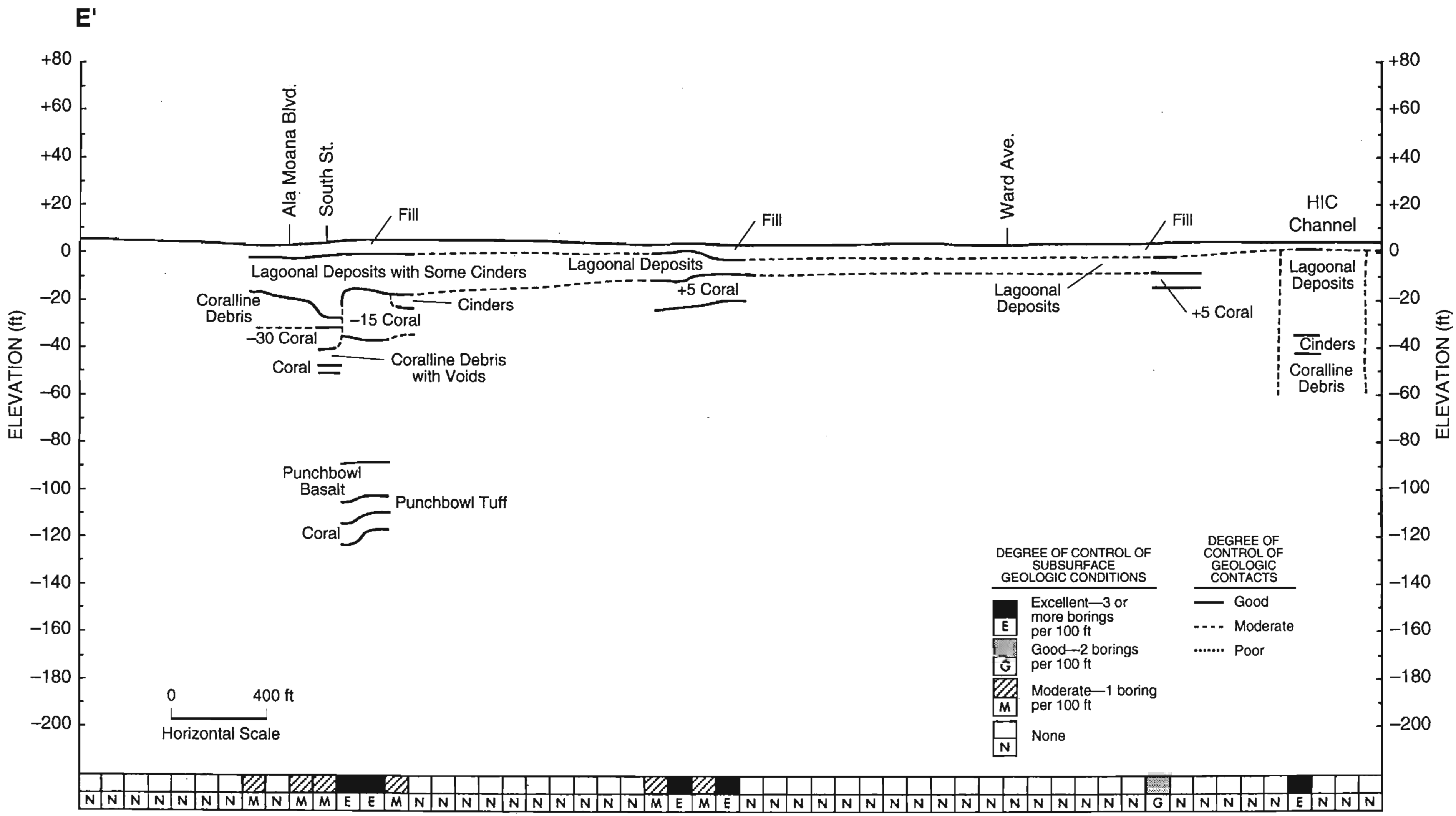

PLATE 11—*Continued*

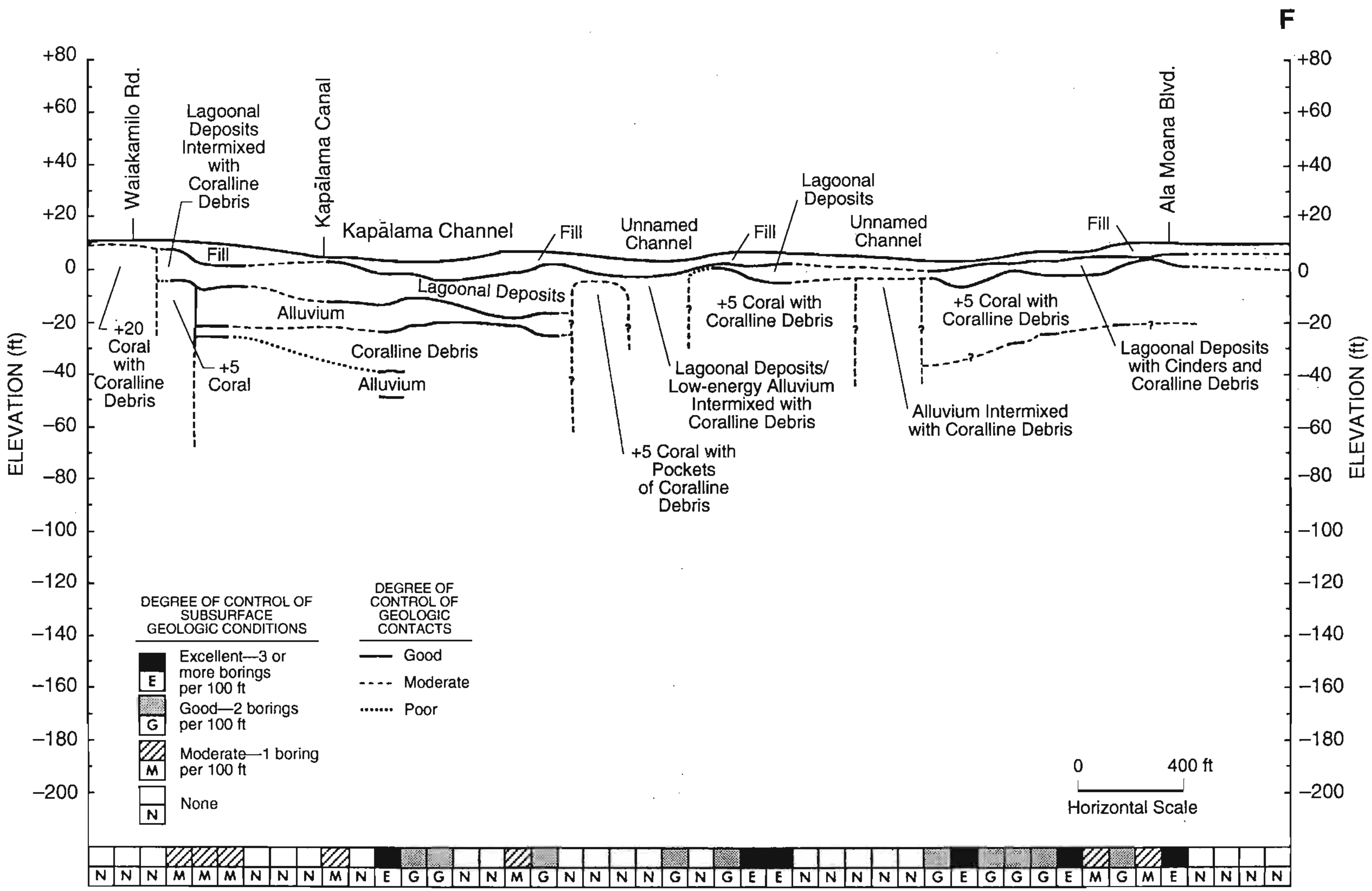

PLATE 12. Subsurface section F–F' for the downtown Honolulu study area

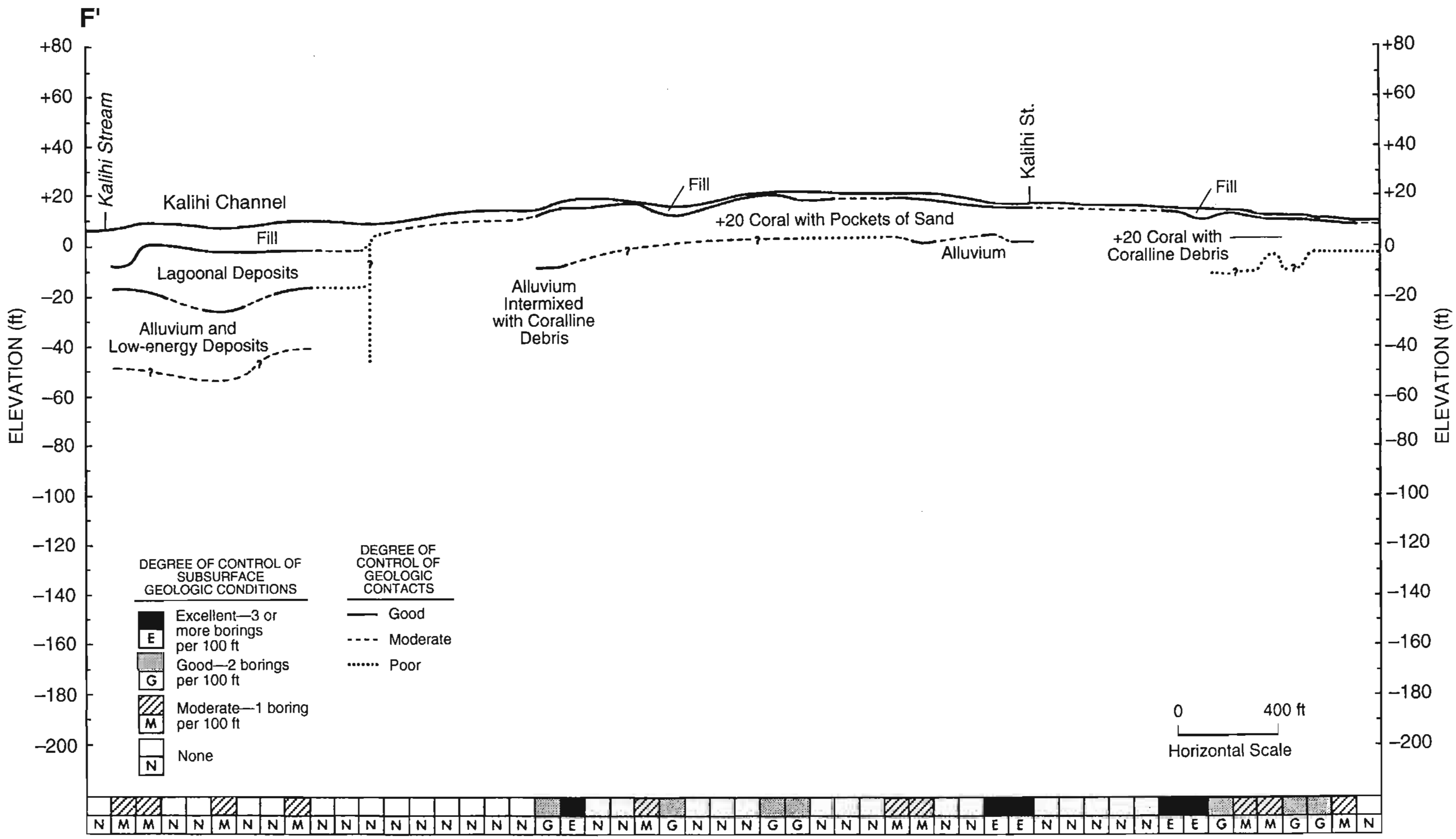

PLATE 12—*Continued*

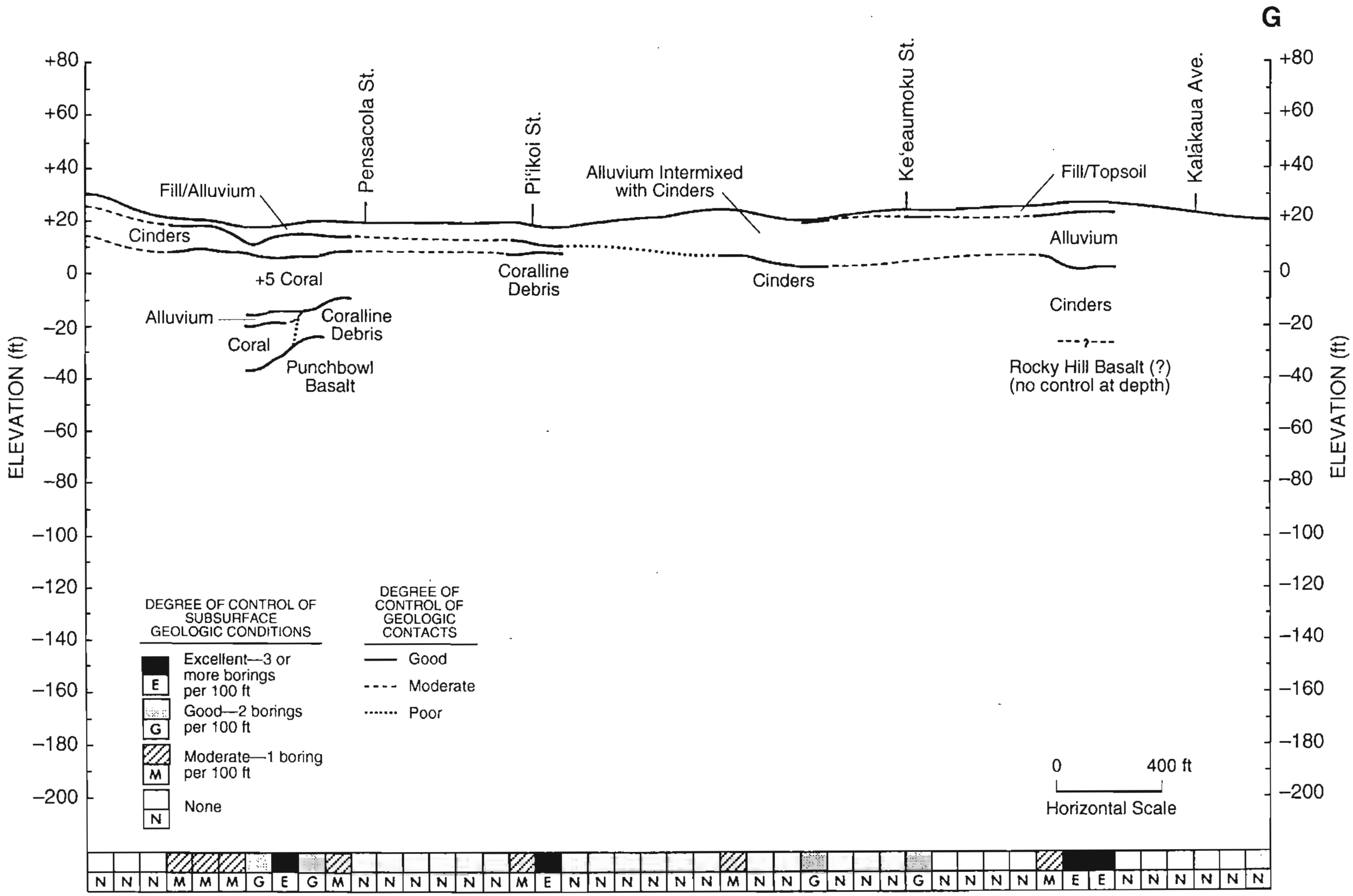

PLATE 13. Subsurface section G–G' for the downtown Honolulu study area

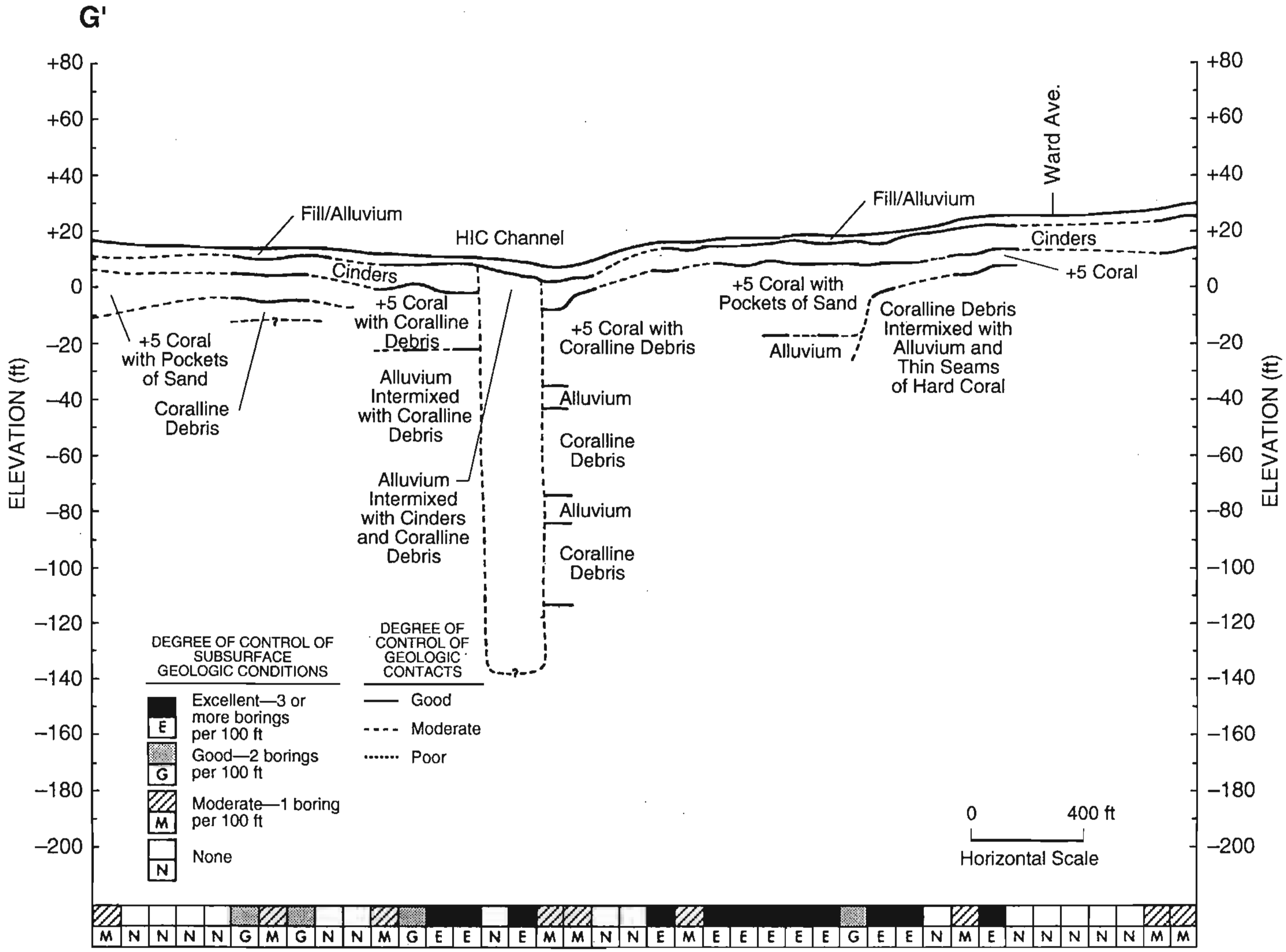

PLATE 13—*Continued*

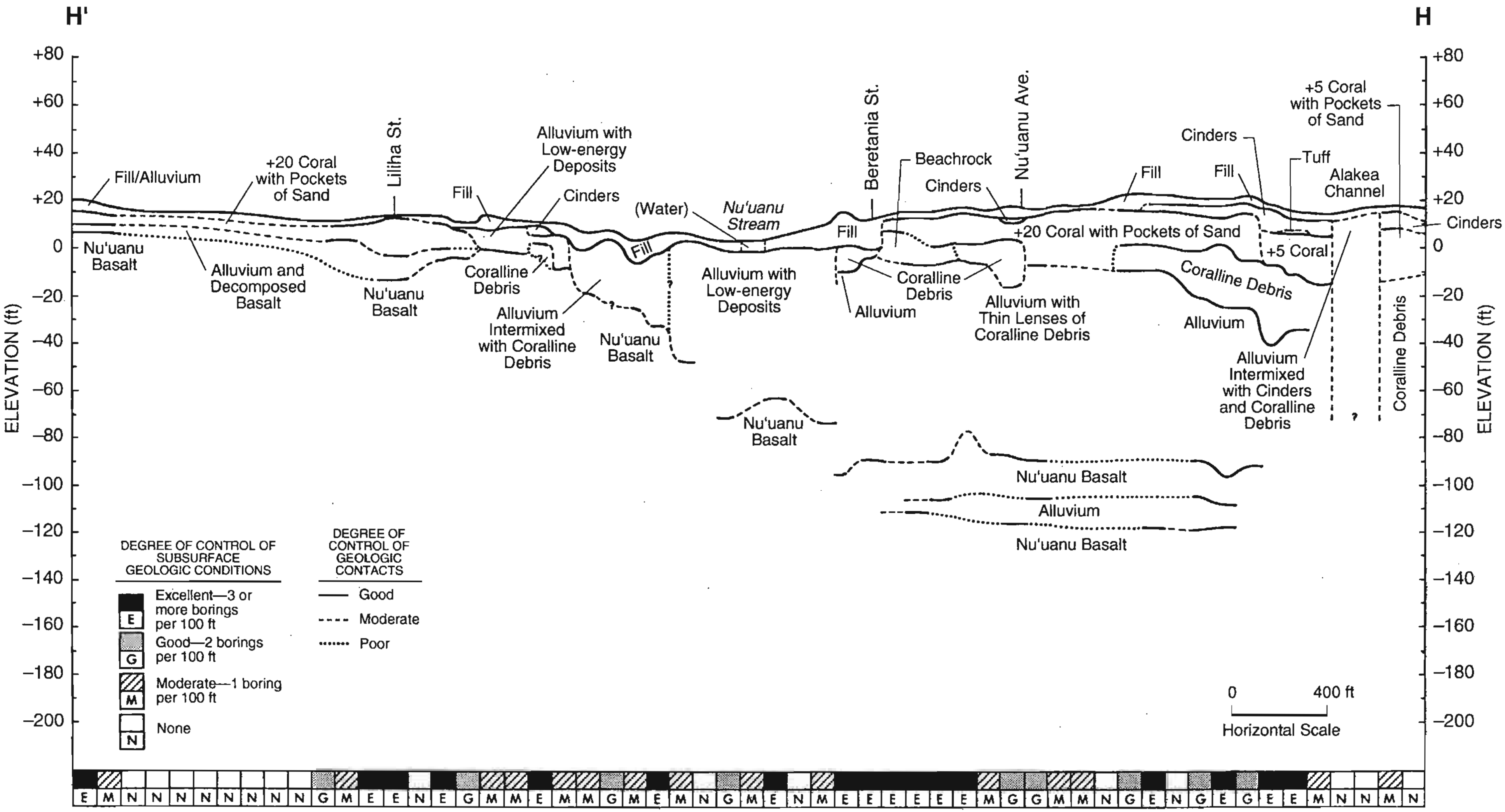

PLATE 14. Subsurface section H–H' for the downtown Honolulu study area

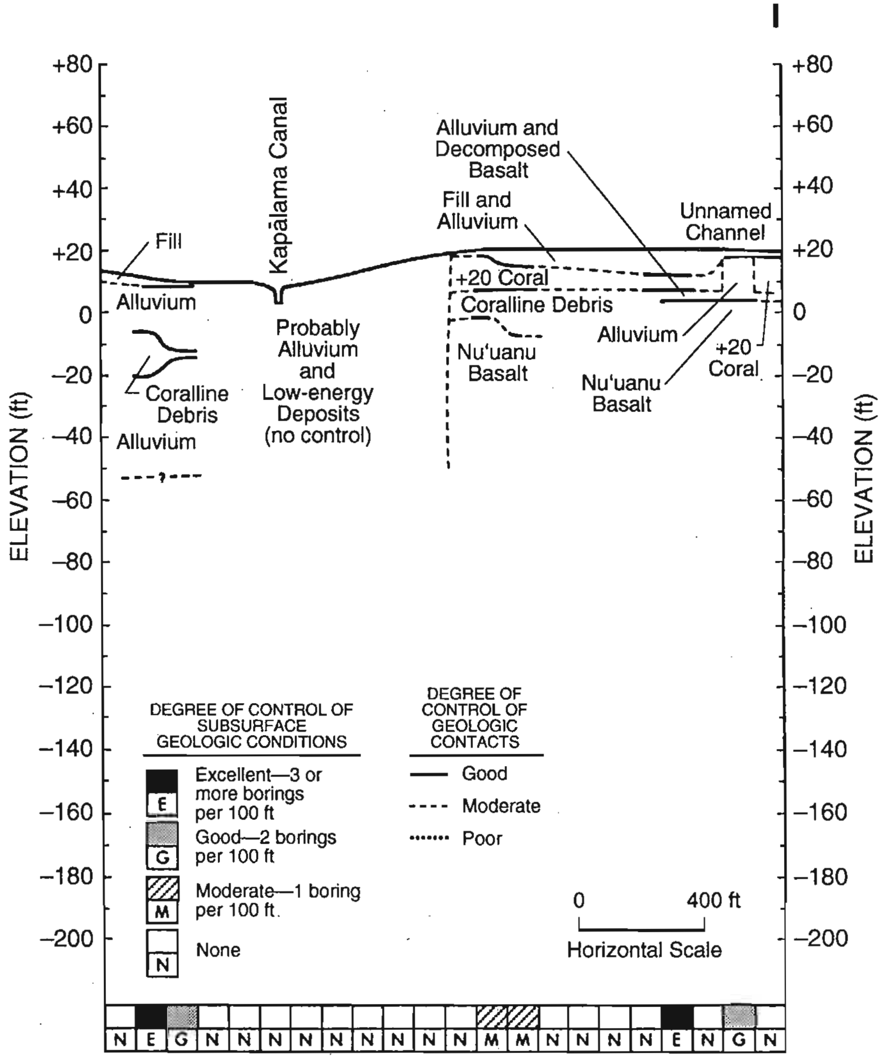

PLATE 15. Subsurface section I–I' for the downtown Honolulu study area

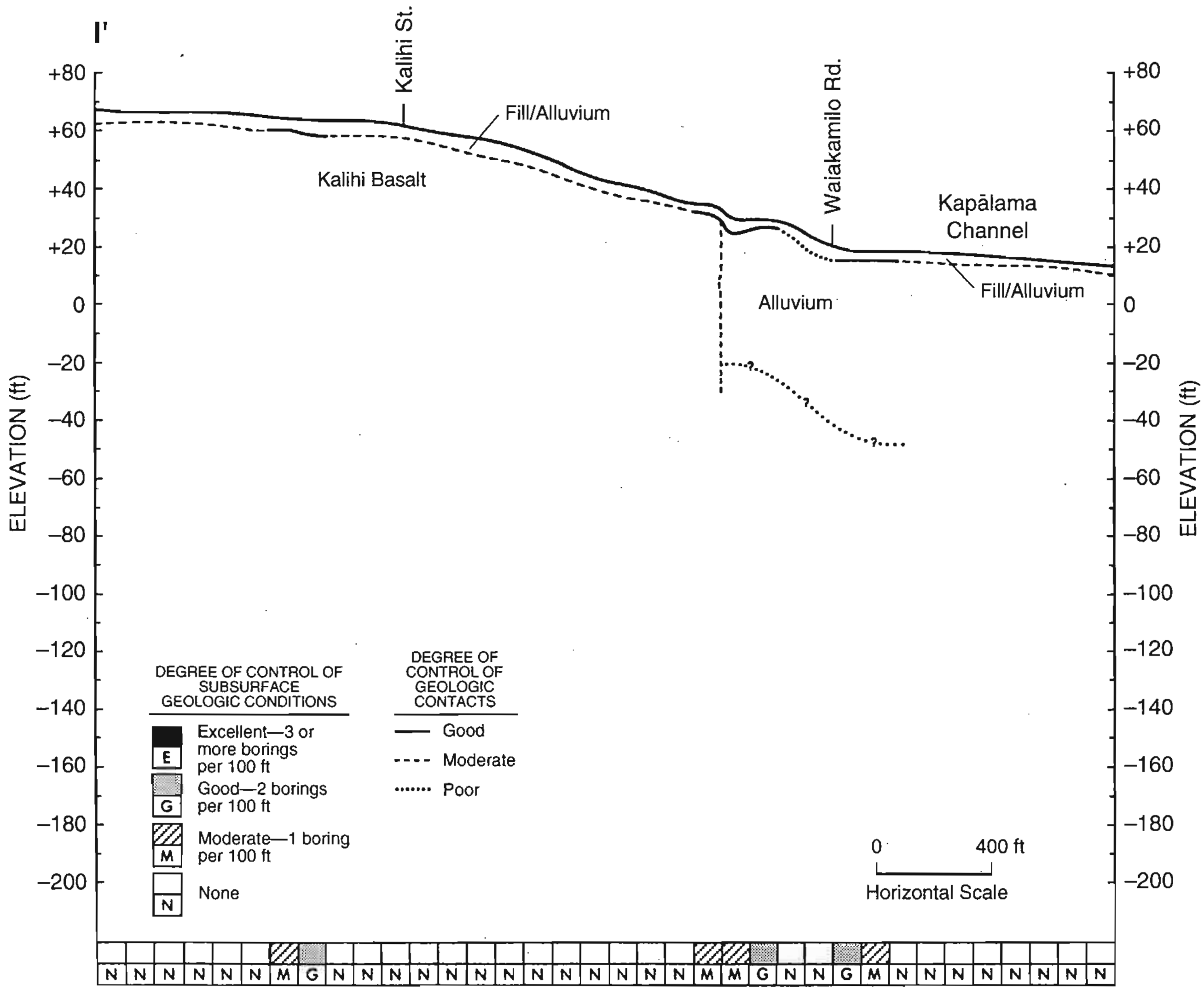

PLATE 15—*Continued*

APPENDIX D. CONTAMINATION DATA FOR SITES IN THE DOWNTOWN HONOLULU STUDY AREA

Four hundred six sites are included in the composite table presented. Data were taken from the CERCLA, LUST, UST, and RCRA lists, and duplicate listings were combined so that each facility is listed only once.

Summary of Environmental Data for Sites in the Downtown Honolulu Area

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
502 N Nimitz Hwy	502 N Nimitz Hwy	R / 984466565						SQG		mixed industrial/business
548 Cooke St—see Hawaii Community Development Authority										
7-11 Dillingham Blvd	1900 Dillingham Blvd	U / 9-101197					gas	30,000 gal	3 in use	gasoline station/fuel svc
7-11 Young St	1323 Kalakaua Ave	U / 9-101172					gas	24,000 gal	3 in use	gasoline station/fuel svc
A-1 Union—see Unocal 76 SS2877/A-1/Ala Moana										
A.B. Dela Cruz Inc	243 Kalihi St	U / 9-100156					gas	4,000 gal	2 in use	mixed industrial/business
AAA Hawaii Bldg	590 Queen St	U / 9-100155					unknown	24,000 gal	3 permanently out of use	mixed industrial/business
ABF Freight System	2282 Hoonee St	R / 984466623						LQG		mixed industrial/business
ABL Computer Tech	875 Waimanu St	R / 981972318						SQG		mixed industrial/business
Academy Sales & Service—see Unocal 76 SS3941/Academy										
Affinity Inc/Market Center Service Station	1020 Auahi St	U / 9-101471 R / 077685634					gas, used oil	LQG; 7,000 gal	2 in use, 1 temporarily out of use	mixed industrial/business
Air Engineering	2308 Pahounui Dr	U / 9-101397 R / 982482341					gas	LQG; 6,000 gal	1 in use, 1 removed 12/84	mixed industrial/business
Air Flow Express	525 Helekauwila St	R / 033173907						transporter only		mixed industrial/business
Ala Moana Center	1450 Ala Moana Blvd	R / 982489502 R / 984466730						SQG		mixed industrial/business
Ala Moana Hotel	410 Atkinson Dr	U / 9-101159					diesel	1,000 gal	1 in use	mixed industrial/business
Ala Moana Unocal—see Unocal 76 SS2877/A-1/Ala Moana										
Ala Moana Volkswagen/ Makena Hawaii Ltd	800 Ala Moana Blvd	L / 9-100911 U / 9-100911 R / 981967193	Rank 3	5,000–10,000 gal	Pb-gas	FP on gw, soil contamination	gas, used oil	SQG; 6,000 gal	1 in use, 3 removed 5/90	automotive, mixed industrial/business
Ala Moana Wastewater Pump	210 Keawe St	U / 9-100135					diesel	10,000 gal	1 in use	mixed industrial/business
Alakea GTE Hawaiian Tel—see GTE Hawaiian Tel/Alakea										
Alii 1—see Unocal 76 SS3282/Alii 1										
Alii Place	Richards St & S Hotel St	U / 9-101969					unknown	unknown	permanently out of use	mixed industrial/business
Alii Tire Inc	1707 Hoe St	R / 981655814						no longer engaged in activity		automotive
Allied Floor Corp	1727 Democrat St	U / 9-100166					gas	1,000 gal	1 removed 10/90	mixed industrial/business
Aloha Ala Moana	451 Piikoi St	L / 9-101180 U / 9-101180	Rank 3	10,000–25,000 gal	Pb-gas, gas	dissolved in gw, soil contamination	gas, used oil, diesel	12,835 gal	3 removed 8/88, 2 removed 4/77	gasoline station/fuel svc

Summary—*Continued*

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Aloha Fender Inc	915 Kaaahi Pl	R / 984469817						CEG		automotive
Aloha Motorcycle UDrive	1216 Waimanu St	R / 982428989						SQG		automotive
Aloha Motors Site	Kapiolani Blvd & Kalakaua Ave	C / 984466060 L / 9-102160 U / 9-102160	high priority; Rank 2	500–5,000 gal	diesel, oil, unknown	dissolved in gw, soil contamination	unknown	unknown	permanently out of use	automotive
Aloha Petroleum—see Aloha Ala Moana										
Aloha Petroleum—see Pacific Resources Inc/BHP/Aloha Petroleum										
Aloha Tower Development	Fort St & Ala Moana Blvd	C / 984466060	no ranking listed							mixed industrial/business
Alpac Corporation	815 Waiakamilo Rd	L / 9-102546 U / 9-101194	Rank 3	500–5,000 gal	gas, diesel	soil contamination	gas, diesel	10,000 gal	2 removed 1/92	mixed industrial/business
Amelco Bldg/Amelco Corp	645 Halekauwila St	C / 984466383 U / 9-101356	no further remedial action				gas, unknown	8,000 gal	2 in use, 2 permanently out of use	mixed industrial/business
Amensty Day Hawaii	690 Pohukaina St	R / 981403769						SQG		mixed industrial/business
American Scientific Prod—see Tongg Publishing Co/American Scientific Prod										
Ameron HC&D Concrete	2344 Pahounui Dr	U / 9-100171 R / 980370191					diesel	SQG; 10,000 gal	1 in use	mixed industrial/business
Amfac Distributors	465 Coral St	U / 9-101490					gas	unknown	1 permanently out of use, 1 removed 12/87	mixed industrial/business
Another Shadow Inc	444 Keawe St	R / 981667249						SQG		mixed industrial/business
Apollo Systems	1728 Home Rule St	U / 9-102020					gas	500 gal	1 removed 7/90	mixed industrial/business
ARA Services	746 Auahi St	L / 9-102521 U / 9-102521	Rank 3	500–5,000 gal	Pb-gas	dissolved in gw, soil contamination	gas	unknown	3 removed 2/92	mixed industrial/business
Art Omine Auto Service	602 Dillingham Blvd	R / 981629199						LQG		automotive
Associated Steel Workers Ltd	1714 Silva St	U / 9-100163					gas	1,000 gal	1 removed 12/88	mixed industrial/business
Astro Pak Corp	1718 Democrat St	R / 934468058						CEG		mixed industrial/business
Auto Center—see Cutter Dodge										
Auto Surgeon/Texaco	1111 Kapiolani Blvd	U / 9-100334 R / 984468587					gas, used oil	SQG; 35,550 gal	5 in use	automotive
Auto Tech Service Center/Fumiseal Inc	1301 Moonui St	R / 033183963 R / 981688724						SQG; transporter only		automotive mixed industrial/business
B&S Automotive Technician	1789 Kapiolani Blvd	R / 981573959						SQG		automotive
Balloons & Things	993 Waimanu St	R / 981653421						SQG		mixed industrial/business
Bank of Hawaii Annex	800 Nuuanu Ave	U / 9-100813					diesel	1,000 gal	1 in use	mixed industrial/business
Baxter Healthcare Corp	238 Sand Island Access Rd	R / 982439804						CEG		mixed industrial/business

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Beretania BWS Station—see BWS Beretania Station										
Beretania Chevron	1378 S Beretania St	L / 9-101720 U / 9-101720	Rank 3	5,000–10,000 gal	gas	dissolved in gw	gas	30,000 gal	3 in use	gasoline station/fuel svc
Blair Ltd	404 Ward Ave	R / 009149287						LQG		mixed industrial/business
BMW of Honolulu	1080 Young St	R / 981653546						SQG		automotive
BMW of Honolulu Ltd.	1075 S Beretania St	L / 9-100174 U / 9-100174	Rank 3	<500 gal	oil	soil contamination	used oil	500 gal	1 temporarily out of use	automotive
Bob's Auto Repair	1138 N King St	R / 981660905						SQG		automotive
Brewer Chemical Corp	311 Pacific St	C / 059472357 U / 9-100850 R / 059472357	no further remedial action				diesel, gas, bunker oil	LQG; 3,550 gal	2 removed 7/88, 1 closed in ground	mixed industrial/business
Brewer Chemical Corp	1318 Hart St	R / 000611912						LQG		mixed industrial/business
Browning–Ferris Industry	207 Puuhale Rd	L / 9-101719 U / 9-101719 R / 981655871	Rank 3	500–5,000 gal	Pb-gas	dissolved in gw, soil contamination	gas, diesel	SQG; 9,000 gal	3 removed 7/92, 1 closed in ground	mixed industrial/business
BWS Beretania Station	630 S Beretania St	U / 9-100118 R / 982476673					diesel, gas	SQG; 20,500 gal	3 in use, 3 permanently out of use	mixed industrial/business
BWS Honolulu City and County	222 Ahui St	R / 981967557						SQG		government
BWS Kalihi Pump Station	1381 N King St	U / 9-102663					bunker oil	5,200 gal	2 removed 12/70	government
C.K. Cash	2026 Colburn St	U / 9-102697					gas	1,000 gal	1 removed 12/75	mixed industrial/business
Castle & Cooke Dole Plant	650 Iwilei Rd	R / 009143637 R / 981424385	Rank 3	10,000–25,000 gal	hazardous-solvents, vinyl	FP on gw, dissolved in gw, soil contamination		LQG		mixed industrial/business
CBI Inc	614 South St	L / 9-102467 U / 9-102467	Rank 3	500–5,000 gal	Pb-gas, unknown	soil contamination	unknown	1,000 gal	1 removed 9/91	mixed industrial/business
Central Division GTE Hawaiian Tel—see GTE Hawaiian Tel/Central Division										
Central Fire Station	104 S Beretania St	U / 9-100071					gas	2,000 gal	1 in use, 1 removed 1/91	government
Certified Auto Repair	1644 Kahai St	R / 981657752						SQG		automotive
Charles & Janet Fujii	903 Waimanu St	U / 9-100254					gas	500 gal	1 in use	mixed industrial/business
Chevron Pier 30 Terminal	666 Nimitz Hwy	R / 000615203						LQG		gasoline station/fuel svc
Chevron USA	753 Ala Moana Blvd	U / 9-101261					unknown	unknown	1 removed 1/84	gasoline station/fuel svc
Circle K N. King	1860 N King St	U / 9-101186					gas, diesel, used oil	49,450 gal	8 in use, 2 temporarily out of use	gasoline station/fuel svc
Civic Center pårking structure	1100 Alapai St	U / 9-100121					gas	2,000 gal	2 in use	mixed industrial/business

Summary—*Continued*

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Clara Takekuchi	848 Ilaniwai St	U / 9-102532					gas	550 gal	1 removed 10/91	mixed industrial/business
Clee Ltd Assoc Chemical	930 Austin Ln	R / 982402695						transporter only		mixed industrial/business
Complete Silk Screen Shop	860 Halekauwila St	U / 9-101543					unknown	unknown	1 removed 3/87	mixed industrial/business
Consolidated Environmental	1232 Waimanu St	R / 982434771						transporter only		mixed industrial/business
Consolidated Refining	1312 Kaumualii St	R / 981426489						LQG; transporter		mixed industrial/business
Continental Cars Ltd	1069 S Beretania St	U / 9-100184 R / 981573777					used oil	SQG; 1,050 gal	1 in use, 1 removed 3/89	automotive
Contractors' Equipment & Service Corp	625 Auahi St	R / 981578743						LQG		mixed industrial/business
Coralco Corp	501 Sumner St	R / 982437667						transporter only		mixed industrial/business
Courtesy Pontiac AMC Jeep/Rainbow	1391 Kapiolani Blvd	U / 9-100185 R / 981657042					used oil	SQG; 500 gal	1 in use	automotive
CPM&F Inc	285 Sand Island Access Rd	L / 9-100809 U / 9-100809 R / 084546969	no ranking listed	5,000–10,000 gal	gas, diesel	unknown	gas, diesel	transporter only; 10,000 gal	2 in use	mixed industrial/business
CQ Yee Hop & Co	111 N King St	U / 9-101429					gas	unknown	2 in use	mixed industrial/business
Cutter Dodge	735 Dillingham Blvd	U / 9-101718 R / 982354078					used oil	SQG; 1,000 gal	unknown	automotive
Cutter Mitsubishi/Rainbow Chevrolet	1341 Kapiolani Blvd	U / 9-101423 R / 982411852					gas, used oil	SQG; 3,000 gal	2 in use	automotive
DAGS-Automotive Management Division—see State of Hawaii/DAGS Automotive Management Division										
Dan's Makiki Union L-0344—see Unocal 76 SS0344/Don's										
Daniels Management Inc	1132 Bishop St	U / 9-102653					unknown	550 gal	1 in use	mixed industrial/business
Deen Morita Plumbing	1658 Auiki St	U / 9-100793					gas	2,500 gal	2 removed 7/88	mixed industrial/business
Dennis Chevron Service	1201 S King St	U / 9-101099 R / 981573652					gas, used oil	SQG; 31,000 gal	4 in use	gasoline station/fuel svc
Department of Education Auxiliary	1039 S King St	R / 982010282						SQG		government
DMC Waiakamilo/Tropical Fruits Distributors	429 Waiakamilo Rd	U / 9-100853 R / 981638109					gas	LQG; 1,000 gal	1 removed 5/88	mixed industrial/business
DOH	1250 Punchbowl St	R / 980736987						LQG		government
Dole Can(nery) Plant	601 Iwilei Rd	L / 9-100757 U / 9-100757					solvent, vinyl coat/lacquer	23,550 gal	4 removed 12/88, 1 removed 3/92	mixed industrial/business

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Dole Foods—see Castle & Cooke Dole Plant										
Dole Pineapple Cannery/Iwilei	801 Dillingham Blvd	C / 981424385 U / 9-100746	low priority				gas, solvent, fuel oil	107,030 gal	2 in use, 3 closed in ground	mixed industrial/business
Dollar Rent a Car	1801 Kalakaua Ave	U / 9-101267					gas, used oil	unknown	4 removed 6/79, 2 removed 12/88	automotive
Don's Makiki Union Service—see Unocal 76 SS0344/Don's										
DOT Harbors Division	79 S Nimitz Hwy	R / 982510018 R / 982510158					gas, diesel	SQG; 4,000 gal	3 in use	government
DOT Harbors Division/Maintenance	48 Sand Island Access Rd	U / 9-101443 R / 982026395						SQG		mixed industrial/business
Downtown Chevron	17 S Beretania St	L / 9-101100 U / 9-101100	Rank 3	500–5,000 gal	oil	soil contamination	gas, used oil	26,000 gal	4 removed 9/90	gasoline station/fuel svc
Durant Realty	450 Piikoi St	U / 9-102184					gas	2,000 gal	2 removed 12/85	mixed industrial/business
Dynamite Inc	101 N Nimitz Hwy	R / 113221303						transporter only		mixed industrial/business
Earl Scheib Autopainting	580 N Nimitz Hwy	R / 984466961						CEG		automotive
Ed Dang Machine Works	1804 Democrat St	U / 9-100196					gas, diesel	4,500 gal	3 in use	mixed industrial/business
Edsung Food Service	1337 Mookaula St	U / 9-108440					gas	3,000 gal	1 in use	mixed industrial/business
Edward Enterprises Inc	641 Waiakamilo Rd	R / 009197716						LQG		mixed industrial/business
Engstroms Volvo Service	600 Kokea St	R / 981653959						SQG		automotive
Erich's Eurocars	1937 Home Rule St	R / 981658289						SQG		automotive
Farrington High School	1564 N King St	L / 9-102162	Rank 3	500–5,000 gal	diesel	soil contamination				government
Fay Investments Assoc	1927 Republican St	U / 9-100790					gas	1,000 gal	1 removed 12/85	mixed industrial/business
Firestone Holiday Mart/Store	801 Kaheka St	L / 9-102403 U / 9-102591 R / 981577265	Rank 3	<500 gal	oil, unknown	dissolved in gw, soil contamination	gas	32,000 gal	5 in use	automotive
First Development	1777 Kapiolani Blvd	R / 984466060						CEG		mixed industrial/business
Flamingo Enterprises/Steven S. Nagamine	574 Ala Moana Blvd	U / 9-100884 U / 9-100885					gas, diesel	5,600 gal	3 removed 6/87	mixed industrial/business
Flint Ink Corp	223 Cooke St	R / 044845493						CEG		mixed industrial/business
Flynn–Learner/Hawaii Metal Recycling	120 Sand Island Access Rd	C / 984468363 U / 9-100209 R / 984468363	no ranking listed				gas	SQG; 1,000 gal	1 in use	mixed industrial/business
Former Shelly Motors—see Lexus of Hawaii										

Summary—*Continued*

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Frank's Kalihi Chevron	2160 N King St	R / 981655285					gas, used oil	SQG; 31,000 gal	4 in use	gasoline station/fuel svc
French Wrench	520 Ward Ave	U / 9-100316					gas, used oil	30,550 gal	4 in use	automotive
Fuller O'Brien Paint	770 Ala Moana Blvd	U / 9-102671					gas, paint thinner	2,000 gal	2 removed 12/85	mixed industrial/business
Fumiseal Inc—see Auto Tech Service Center/Fumiseal Inc										
Funai's Union Service	1810 Kapiolani Blvd	U / 9-100047					gas, used oil, hydraulic oil	14,330 gal	5 removed 6/91	gasoline station/fuel svc
Gas Express Station #11	940 Auahi St	L / 9-100916 U / 9-100916	Rank 1	10,000–25,000 gal	gas	FP on sw	gas	40,000 gal	4 in use	gasoline station/fuel svc
Gas Express Station #12	1529 Dillingham Blvd	L / 9-100915 U / 9-100915	Rank 3	<500 gal	gas	soil contamination	gas	48,000 gal	2 in use, 3 removed	gasoline station/fuel svc
Gas Express Station #18	1549 S King St	U / 9-100059					gas	30,000 gal	3 in use	gasoline station/fuel svc
Gas N Glo Inc	1670 Makaloa St	U / 9-100834					gas, diesel	40,000 gal	5 in use	gasoline station/fuel svc
Gas Plus	1524 S King St	U / 9-100224					gas	32,000 gal	3 in use	gasoline station/fuel svc
Gasco Inc	515 Kamakee St	U / 9-100917 R / 981665664					gas	SQG; 1,500 gal	1 in use, 1 closed in ground	gasoline station/fuel svc
Gaspro, Kalihi	2305 Kamehameha Hwy	L / 9-100861 R / 980817712	Rank 3	5,000–10,000 gal	hazardous-acetone	dissolved in gw		SQG		mixed industrial/business
General Tire Service	505 Waiakamilo Rd	U / 9-101339 R / 982482531					boiler oil	SQG; 250 gal	1 removed 3/88	automotive
German Car Service	1310 Mookaula St	R / 981655228						SQG		automotive
GM Auto Center	1137 Waimanu St	R / 981674591						LQG		automotive
Goo's Golden Tire Shop	1923 Democrat St	U / 9-102429					gas	1,000 gal	1 removed 12/76	automotive
Graffiti Inc	743 Waiakamilo Rd	R / 981654700						SQG		mixed industrial/business
GRG Enterprise	115 Ahui St	U / 9-100212					gas, diesel	16,000 gal	3 in use, 1 permanently out of use	mixed industrial/business
Grosvenor Center/International	733 Bishop St	U / 9-101521 R / 984469767					diesel	SQG; 1,000 gal	1 in use	mixed industrial/business
GTE Hawaiian Tel/Alakea	1177 Bishop St	U / 9-100492 R / 984469528					diesel	SQG; 44,500 gal	3 in use, 3 closed in ground	mixed industrial/business

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
GTE Hawaiian Tel/Central Division	207 Keawe St	U / 9-100496					gas	10,000 gal	1 in use	mixed industrial/business
GTE Kalihi Central Office	1025 Kaili St	U / 9-100508					diesel	1,500 gal	1 in use	mixed industrial/business
Gushi Kuma's Inc—see Shell Oil/Gushi Kuma's										
H. Hamada Store	885 Queen St	U / 9-101673					gas	1,000 gal	1 temporarily out of use	mixed industrial/business
H. Hironaka Trucking—see Schuman Carriage Co/H. Hironaka Trucking										
Hakuyosha Hawaii	730 Sheridan St	L / 9-101855 U / 9-101855 R / 050340850	Rank 3	500–5,000 gal	hazardous-solvent	soil contamination	solvent, diesel	SQG; 2,500 gal	1 removed 8/89, 2 closed in ground	mixed industrial/business
Hal's City Chevron/Lee's Dillingham Chevron	1901 Dillingham Blvd	U / 9-101112 R / 981577323					gas, used oil	CEG; 31,000 gal	4 in use	gasoline station/fuel svc
Hale O' Pili	155 N Beretania St	U / 9-100057					diesel	2,000 gal	1 in use	mixed industrial/business
Hall-Mark Cleaners	1470 Liliha St	L / 9-101378 U / 9-101378	Rank 3	<500 gal	diesel, hazardous-solvent	soil contamination	solvent, diesel	750 gal	1 temporarily out of use, 1 closed in ground	mixed industrial/business
HandiPantry #14	659 N King St	U / 9-101026					gas	30,000 gal	3 in use	mixed industrial/business
Harbor Court Project	Queen St & Bethel St	U / 9-102464 L / 9-102464	Rank 3	500–5,000 gal	diesel	FP on gw, dissolved in gw, soil contamination	unknown	750 gal	1 removed 7/91	mixed industrial/business
Harbor Graphics	2222 Kamehameha Hwy	R / 982402851						SQG		mixed industrial/business
Harbors Maintenance—see DOT Harbors Division/Maintenance										
Harry Nakai Inc	1640 Kahai St	R / 984469429						SQG		mixed industrial/business
Hart St Wastewater Pump	1200 Hart St	U / 9-100137					diesel	5,000 gal	1 in use	mixed industrial/business
Hawaii Community Development Authority	524 Cooke St	U / 9-102417	Rank 3	500–5,000 gal	oil	FP on gw, soil contamination	gas, used oil	4,900 gal	3 permanently out of use, 2 removed 4/91	government
Hawaii Community Development Authority	548 Cooke St	L / 9-102418 R / 984467431						SQG		government, mixed industrial/business
Hawaii Electricians Training	2002 Kalani St	U / 9-100367					gas	1,000 gal	1 permanently out of use	mixed industrial/business
Hawaii Hochi Ltd	917 Kokea St	R / 984468314						LQG		mixed industrial/business
Hawaii Metal Forming	151 Puuhale Rd	U / 9-102487					gas	300 gal	1 temporarily out of use	mixed industrial/business
Hawaii Metal Recycling—see Flynn–Learner/Hawaii Metal Recycling										
Hawaii Motor Rebuilders	831 Pohukaina St	R / 981629397						SQG		automotive
Hawaii Newspaper Agency	605 Kapiolani Blvd	L / 9-100938 U / 9-100938 R / 982368474	no ranking listed	5,000–10,000 gal	gas	unknown	gas	LQG	2 in use, 1 removed 9/89	mixed industrial/business

Summary—*Continued*

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Hawaii Press Newspaper	2100 N Nimitz Hwy	U / 9-102564 R / 984469114					used oil	SQG; 500 gal	1 in use	mixed industrial/business
Hawaii State BWS—see BWS Honolulu City and County										
Hawaii State Department of Education	1270 Queen Emma St	R / 980665731						LQG		government
Hawaii Transfer Co	Pier 36	L / 9-100890	Rank 3	500–5,000 gal	diesel, ?gas	FP on gw, soil contamination				mixed industrial/business
Hawaii/Hawaiian Bitumuls & Paving	248 Sand Island Access Rd	C / 006926919 L / 9-100764 U / 9-100764 R / 006926919	Rank 3	10,000–25,000 gal	Pb-gas	FP on gw	gas, diesel, engine lube	SQG; 31,000 gal	4 removed 8/88	mixed industrial/business
Hawaii/Hawaiian Stevedores	798 N Nimitz Hwy	L / 9-100934 U / 9-100934 R / 981657731	no ranking listed	500–5,000 gal	gas, diesel		gas, diesel	SQG; 2,500 gal	2 in use	mixed industrial/business
Hawaiian Candies & Nuts	707 Waiakamilo Rd	L / 9-101980 U / 9-101980	Rank 3	5,000–10,000 gal	diesel	soil contamination	diesel	10,000 gal	1 removed 12/67	mixed industrial/business
Hawaiian Grain Corp	Pacific St & N Nimitz Hwy	L / 9-100852 U / 9-100852	no ranking listed	500–5,000 gal	gas	soil contamination	gas, diesel, boiler fuel	11,550 gal	3 in use	mixed industrial/business
Hawaiian Marine Sales & Service	2223 Hoonee St	R / 981613144						SQG		mixed industrial/business
Hawaiian Sun Products	1614 Republican St	U / 9-101363					heating oil, bunker fuel	5,550 gal	2 in use, 1 closed, 1 removed 5/92	mixed industrial/business
Hawaiian Tug & Barge Corp	705 N Nimitz Hwy	R / 982411357						SQG		mixed industrial/business
HECO Generating Plant/Station	170 Ala Moana Blvd	C / 000150680 U / 9-100961 R / 000150680	no ranking listed				gas, diesel	LQG; transporter; 15,000 gal	1 removed 9/89, 4 permanently out of use	mixed industrial/business
HECO Iwilei Tank Yard	855 N Nimitz Hwy	L / 9-100958 U / 9-100958	Rank 3	500–5,000 gal	diesel	FP on gw				mixed industrial/business
HECO Ward Ave Complex	820 Ward Ave	L / 9-100957 U / 9-100957 R / 000610907	Rank 3	500–5,000 gal	oil	FP on gw, soil contamination	gas, diesel, used oil	SQG; 34,000 gal.	3 in use, 5 removed 2/92	mixed industrial/business
Heide & Cook Ltd	1714 Kanakanui St	R / 984466540						SQG		mixed industrial/business
Hirota Painting Co	2188 Kamehameha Hwy	R / 984469502						CEG		mixed industrial/business
HMSA	1438 Rycroft St	U / 9-102479					gas	500 gal	1 removed 9/91	mixed industrial/business
Holiday Action Gas—see Firestone Holiday Mart/Store										
Honeywell	250 Ward Ave	R / 984468579						SQG		mixed industrial/business
Honolulu Body & Fender Shop	131 Mokauea St	U / 9-101544					unknown	800 gal	1 temporarily out of use	automotive

Summary—*Continued*

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Honolulu Cellular	1161 Kapiolani Blvd	U / 9-101857 R / 984469080					diesel	CEG; 300 gal	1 removed 3/92	mixed industrial/business
Honolulu City & County Corp Yard	160 Ahui St	U / 9-100124 R / 981439581					gas, diesel	SQG; 20,000 gal	3 in use	government
Honolulu Community Action	337 N King St	U / 9-101814					gas, diesel	8,000 gal	2 temporarily out of use	mixed industrial/business
Honolulu Community College	601 Kokea St	R / 982442386						SQG		government
Honolulu Corp Yard—see Honolulu City & County Corp Yard										
Honolulu Equipment Co/Pac X Warehouse	120 Puuhale Rd	R / 981654098 R / 984468389						LQG; SQG		mixed industrial/business
Honolulu Federal Savings	1361 Kapiolani Blvd	U / 9-101231					unknown	unknown	1 removed 1/78	mixed industrial/business
Honolulu Ford	711 Ala Moana Blvd	U / 9-100937 R / 981652043					used oil	SQG; 3,500 gal	1 in use, 2 removed 10/88	automotive
Honolulu Fueling Facilities	4 Sand Island Access Rd	U / 9-100871					kerosene	300 gal	1 in use	mixed industrial/business
Honolulu Fueling Facilities—see Shell Oil Sand Island										
Honolulu GTE Sprint	737 Bishop St	U / 9-101803					diesel	1,000 gal	1 in use	mixed industrial/business
Honolulu Harbor Island Movers	414 Kuwili St	U / 9-100936								mixed industrial/business
Honolulu Laundry Co	438 Kamakee St	U / 9-100786					gas, diesel	7,650 gal	5 closed in ground	mixed industrial/business
Honolulu Marine Terminal Chevron	777 N Nimitz Hwy	U / 9-101104					foam	750 gal	1 in use	mixed industrial/business
Honolulu Medical Group	550 S Beretania St	R / 984469833						SQG		mixed industrial/business
Honolulu Municipal Bldg	650 S King St	U / 9-100122					diesel	10,000 gal	1 in use	government
Honolulu Nissan/Rainbow Chevrolet	630 Piikoi St	U / 9-101279 R / 981621659 R / 981651649					gas, new oil, used oil	LQG; SQG; 4,500 gal	5 temporarily out of use	automotive
Honolulu Plumbing	1909 Home Rule St	L / 9-100246 U / 9-100246	Rank 3	500–5,000 gal	Pb-gas	soil contamination	gas	1,100 gal	2 removed 8/90	mixed industrial/business
Honolulu Police Department/Station Pawaa	1455 S Beretania St	U / 9-100114 R / 982495871					gas	SQG; 15,000 gal	3 in use	government
Honolulu Shell Plant/Oil Co	789 N Nimitz Hwy	C / 000631655 L / 9-101355 U / 9-101355	Rank 3, no further remedial action	10,000–25,000 gal	Pb-gas	FP on gw	gas	7,000 gal	2 removed 4/90	gasoline station/fuel
Honolulu Shipyard Inc/Ship Supply	506 Ahui St	U / 9-100248 R 990675704					gas	LQG; transporter; 2,000 gal	2 in use	mixed industrial/business
Honolulu Asphalt Plant	795 N Nimitz Hwy	U / 9-101548					hazardous DBCP	25,000 gal	2 closed in ground	mixed industrial/business
Hopaka Auto Repair	1141 Hopaka St	R / 981978844						SQG		automotive

Summary—*Continued*

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Horace & Rachel Tao—see Sign Design/Horace & Rachel Tao										
Hose Service Inc	1807 Home Rule St	U / 9-100798					gas	1,000 gal	1 in use	mixed industrial/business
HPC Foods Ltd Repair Shop	1612 Democrat St	U / 9-102495					gas	2,000 gal	1 in use	mixed industrial/business
HPC Foods Ltd Warehouse	1603 Republican St	U / 9-100800					gas, diesel	1,500 gal	2 in use	mixed industrial/business
HSI Mechanical	239 Puuhale Rd	U / 9-100356					gas	1,000 gal	1 permanently out of use	mixed industrial/business
I. Steven Sunada—see Takamiya Property/I. Steven Sunada/Remediation Specialists										
Imperial Plaza	Kapiolani Blvd & Cooke St	L / 9-102177 U / 9-102177	no ranking listed	unknown	unknown	unknown	heating oil	unknown	1 removed 4/90	mixed industrial/business
IMPS Environmental	607 Ala Moana Blvd	R / 981613094						LQG; transporter		mixed industrial/business
IMPS Inc	2298 Alahao Pl	R / 980893119						transporter only		mixed industrial/business
Intelect Inc	925 Dillingham Blvd	R / 982483018						SQG		mixed industrial/business
International Plumbing Inc	2003 Waterhouse St	U / 9-102430					gas	2,000 gal	1 removed 3/91	mixed industrial/business
Island Movers	Auiki St & Libby St	R / 981654023					unknown	CEG; unknown	2 in use	mixed industrial/business
Island Painting/Paint Supply	1353 Mookaula St	L / 9-102161 U / 9-102161 R / 984466862	Rank 3	500–5,000 gal	gas, oil	FP on gw, soil contamination	used oil	SQG; 500 gal	1 removed 7/91	mixed industrial/business
ITT Word Communications	1164 Bishop St	U / 9-100250					Jet-A fuel	2,000 gal	1 in use	mixed industrial/business
Iwilei Fire Station	840 Iwilei Rd	U / 100067					gas	550 gal	1 removed 12/88	government
Iwilei Tank Yard HECO—see HECO Iwilei Tank Yard										
J's Automotive	721 Auahi St	R / 981660962						SQG		automotive
J.T. Chevron	743 N King St	U / 9-101113					gas	60,000 gal	3 in use, 3 removed 12/90	gasoline station/fuel svc
Jas W Glover Ltd	1046 Waimanu St	U / 9-100835 R / 981637861					gas	SQG; 1,000 gal	1 removed 11/90	mixed industrial/business
JBL Hawaii Ltd	905 Kokea St	L / 9-701856 U / 9-102462	Rank 3	500–5,000 gal	gas	FP on gw, soil contamination	gas	1,000 gal	1 removed 12/60	mixed industrial/business
Johiro Brothers Inc.	1240 Mookaula St	L / 9-100258	Rank 3	500–5,000 gal	gas	soil contamination				mixed industrial/business
June Otaka	1714 Colburn St	U / 9-102519					diesel, unknown	1,100 gal	2 removed 12/71	mixed industrial/business
K & Y Service Chevron	571 Queen St	U / 9-101107					gas, used oil	31,000 gal	4 in use	gasoline station/fuel svc
K. Miura Plumbing	1718 Hau St	U / 9-100259					gas	800 gal	1 removed 9/91	mixed industrial/business
Kaiser Hospital	1091 Young St	U / 9-101235					unknown	unknown	1 removed 1/82	mixed industrial/business

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Kakaako Fire Station	555 Queen St	U / 9-100075					gas, diesel	1,500 gal	2 in use	government
Kakaako Mechanic Shop	620 South St	U / 9-100074					gas, used oil	2,000 gal	2 in use, 1 temporarily out of use	automotive
Kalakaua Transmission Inc	1665 Kalakaua Ave	L / 9-100763 U / 9-100763 R / 981637564	Rank 3	500–5,000 gal	unknown	FP on gw	used oil	SQG; 1,000 gal	2 removed 5/90	automotive
Kalihi Central Office GTE—see GTE Kalihi Central Office										
Kalihi Chevron Self Serve	1715 N King St	L / 9-101236 U / 9-101236	Rank 3	5,000–10,000 gal	Pb-gas, gas	FP on gw	gas	30,000 gal	3 in use	gasoline station/fuel svc
Kalihi Fire Station	1742 N King St	U / 9-100079					gas	1,000 gal	1 in use	government
Kalihi Pump Station BWS—see BWS Kalihi Pump Station										
Kapalama Military Reservation	1699 Auiki St	C / 214522214 U / 9-100051 R / 214522214	no further remedial action				gas	LQG; 550 gal	1 in use	government
Kapiolani Bowl—see Symphony Park/Kapiolani Bowl										
Keeaumoku Superblock N—see Superblock N Keeaumoku										
Kewalo Incin Ash Dump/ Marine Services/ McWayne Marine Supply	1125 Ala Moana Blvd	C / 980497226 U / 9-100857 U / 9-101369	no further remedial action				gas, diesel	2,000 gal	2 in use	mixed industrial/business
King Street Carwash	809 S King St	L / 9-102451 U / 9-102451	Rank 3	5,000–10,000 gal	Pb-gas	soil contamination	gas	30,000 gal	3 removed 8/92	automotive
King's Chevron Service	1070 N King St	L / 9-101111 U / 9-101111	Rank 3	500–5,000 gal	gas	FP on gw	gas, used oil	58,000 gal	4 in use, 5 removed 9/86	gasoline station/fuel svc
Kingsgate Plaza	Dillingham Blvd & N King St	L / 9-102172 U / 9-102172	Rank 2	25,000–50,000 gal	Pb-gas	dissolved in gw	unknown	21,000 gal	6 removed 1/90	mixed industrial/business
Kirby Sales & Service	428 McNeill St	R / 981654833						SQG		mixed industrial/business
KSC Service L-4210—see Unocal 76 SS4210/KSC										
Kyle's Service	869 Kawaiahao St	R / 981972375						SQG		gasoline station/fuel svc
Lee's Dillingham Chevron—see Hal's City Chevron/Lee's Dillingham Chevron										
Leroy's Chevron	444 Waiakamilo Rd	U / 9-101244					gas, diesel, used oil	22,550 gal	5 removed 12/89	gasoline station/fuel svc
Lex Brodie's Tire Co	701 Queen St	L / 9-102200 U / 9-102200	Rank 2	10,000–25,000 gal	?gas	FP on gw	gas	85,000 gal	3 in use, 3 removed 2/91	automotive
Lexus of Hawaii	744 Ala Moana Blvd	L / 9-102163 U / 9-102163 R / 982488033	Rank 2	500–5,000 gal	?gas	FP on gw	gas, used oil	LQG; 1,550 gal	2 removed 4/85	automotive
Liberty House—see Ala Moana Center										
Lionel's Unocal—see Unocal 76/Lionel's										

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Look Laboratory (UH)	811 Olomehani St	U / 9-102414					methane	8,000 gal	1 in use	government
Loomis Armored Inc	1540 Kalani St	U / 9-100268					gas	8,000 gal	1 removed 12/90	mixed industrial/business
M. Nakai Repair Service	288 Mokauea St	U / 9-101550 R / 981655939					unknown	SQG; 1,000 gal	1 in use	automotive
Maaco Auto Painting	400 N Nimitz Hwy	R / 982496150						SQG		automotive
Magic Island Enterprises	1440 Kapiolani Blvd	U / 9-100820					heating oil	500 gal	1 in use	mixed industrial/business
Mail Well Envelope	150 Puuhale Rd	R / 096010087						SQG		mixed industrial/business
Makena Hawaii Ltd—see Ala Moana Volkswagen/Makena Hawaii Ltd										
Makiki Shell	1436 S Beretania St	L / 9-100833 U / 9-100833	Rank 3	<500 gal	oil	soil contamination	gas, used oil	22,550 gal	6 in use	gasoline station/fuel svc
Malama Pacific Corp/ Prestige Auto Care	759 S King St	L / 9-102158 U / 9-102158 R / 981652704	Rank 3	500–5,000 gal	?gas, oil	FP on gw, soil contamination	gas, used oil	SQG; 27,500 gal	4 removed 6/89	mixed industrial/business, automotive
Manna Pro Corp	699 Nimitz Hwy	R / 981653512						SQG		mixed industrial/business
Mark's Piikoi Unocal Service	1180 S King St	U / 9-100038					gas, used oil, hydraulic oil	12,630 gal	6 in use	gasoline station/fuel svc
Market Center Service Station—see Affinity Inc/Market Center Service Station										
Masa's Foreign Car Service	706 Sheridan St	R / 981651706						SQG		automotive
Master Sheet Metal	1648 Auiki St	U / 9-100271					gas	4,000 gal	1 in use	mixed industrial/business
Maui Divers of Hawaii Ltd	1545 Liona St	R / 009116757						LQG		mixed industrial/business
Maunawili Produce Inc	914 Kaaahi Pl	L / 9-100272 U / 9-101518 R / 984469627	Rank 3	<500 gal	gas, diesel	FP on gw, dissolved in gw, soil contamination	gas, diesel	SQG; 4,000 gal	3 removed 11/92	mixed industrial/business
McKesson Wine & Spirits	80 Sand Island Access Rd	U / 9-100277					gas, diesel	14,000 gal	3 in use	mixed industrial/business
McKinley Car Wash	1139 Kapiolani Blvd	U / 9-100278					gas, diesel	33,500 gal	4 in use	automotive
McKinley Motor Service	333 Kalihi St	U / 9-100279					gas	30,000 gal	3 in use	automotive
McWayne Marine Supply—see Kewalo Incin Ash Dump/Marine Services/McWayne Marine Supply										
Meadow Gold Dairies	824 Sheridan St	U / 9-100817 U / 9-100865 R / 982428997					gas, diesel, used oil	SQG; 43,000 gal	1 in use, 4 removed 9/89	mixed industrial/business
Meadow Gold Dairy	925 Cedar St	R / 981653058						SQG		mixed industrial/business
Meadow Gold Transportation—see Meadow Gold Dairies										
Melim Bldg	333 Queen St	L / 9-100812 U / 9-100812	Rank 3	10,000–25,000 gal	Pb-gas, gas, oil	FP on gw, soil contamination	gas, used oil	8,350 gal	3 temporarily out of use	mixed industrial/business
Mercantile Trucking	2280 Alahao Pl	U / 9-100273					gas, diesel	6,000 gal	2 in use	mixed industrial/business

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Midas	1335 S Beretania St	R / 981638778						SQG		automotive
Midas	1415 Dillingham Blvd	R / 981638836						no longer engaged in activity		automotive
Mike's Auto Supply—see Shell Oil/Mike's										
Mike's Chevron Service	1260 Ala Moana Blvd	U / 9-101115					gas, used oil	13,550 gal	5 in use	gasoline station/fuel svc
Mike's Kalihi Shell Service Station	1029 Houghtailing St	L / 9-100783 U / 9-100783	no ranking listed	>50,000 gal	unknown	unknown	gas, used oil	60,100 gal	4 in use, 5 removed 9/91	gasoline station/fuel svc
MK Equipment Corp	1814 Home Rule St	U / 9-102681 R / 981653256					gas, diesel	SQG; 3,000 gal	2 in use, 1 removed 5/89	mixed industrial/business
Motor Imports Service Department	609 South St	U / 9-100879 R / 981654262					used oil	SQG; 500 gal	1 in use	automotive
Motor Supply Ltd	726 Sheridan St	U / 9-101451					gas	3,000 gal	1 in use	automotive
MTL Bus Facility	1133 Alapai St	L / 9-100150 U / 9-100150 R / 981990047	Rank 2	25,000–50,000 gal	Pb-gas, gas, diesel, oil, hazardous-PCB	FP on gw	gas, diesel, used oil, unknown	LQG; 59,000 gal	11 removed 6/90	automotive
Nakamura Investment Group	979 Robello Ln	U / 9-101147					gas	1,000 gal	1 closed in ground	mixed industrial/business
Nauru Phosphate Royalties	404 Piikoi St	L / 9-102168 U / 9-102168 R / 981656812	Rank 2	500–5,000 gal	unknown	FP on gw	unknown	SQG; unknown	1 permanently out of use	mixed industrial/business
Neon Electric Service	1821 Republican St	U / 9-102455					unknown	unknown	1 in use	mixed industrial/business
Nexus Environmental Group	1142 Auahi St	R / 984469056						transporter only		mixed industrial/business
Noble S Transmission Auto	602 Kokea St	R / 982507188						LQG		automotive
NY Technical Institute	1375 Dillingham Blvd	R / 981652894						SQG		mixed industrial/business
Oahu A/C Service/Plumbing & Sheet Metal	938 Kohou St	U / 9-101367 R / 982525347					gas	SQG; 1,000 gal	1 in use	mixed industrial/business
Oahu Bindery	2278 Hoonee Pl	U / 9-100749					gas	500 gal	1 removed 12/82	mixed industrial/business
Oahu Metal & Supply	204 Sand Island Access Rd	R / 033201245						LQG		mixed industrial/business
Oahu Plumbing & Sheet Metal—see Oahu A/C Service/Plumbing & Sheet Metal										
Oahu Sales Inc	1724 Kalani St	R / 982435281						CEG		mixed industrial/business
Okada Trucking Co	818 Moowaa St	L / 9-100285 U / 9-100285	Rank 3	10,000–25,000 gal	?gas, diesel	dissolved in gw, soil contamination	gas, diesel	24,000 gal	2 in use, 2 closed in ground	mixed industrial/business
Okuda Metal Inc	1804 Kahai St	R / 033201831						LQG		mixed industrial/business
Old World Products of Hawaii Inc	717 N King St	R / 982320301						SQG		mixed industrial/business

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One Waterfront Plaza (ATT)	500 Ala Moana Blvd	U / 9-101732					diesel	6,000 gal	unknown	mixed industrial/business
Oto's Service Inc	345 Mokauea St	U / 9-101375 R / 981638539					gas, diesel, used oil	SQG; 15,000 gal	5 in use	automotive
Pac X Warehouse—see Honolulu Equipment Co/Pac X Warehouse										
Pacific Auto Service	1229 N King St	U / 9-100930					gas	2,000 gal	2 temporarily out of use	automotive
Pacific Heavy Equipment	1618 Silva St	R / 981624349						LQG		mixed industrial/business
Pacific Marine & Supply Co Ltd	Smith St & N Nimitz Hwy	C / 980880736	no further remedial action							mixed industrial/business
Pacific Nissan	670 Auahi St	R / 984466524						SQG		automotive
Pacific Oldsmobile—see Shelly Nissan/Pacific Oldsmobile										
Pacific Resources Inc/BHP/Aloha Petroleum	739 N Nimitz Hwy or 600 Iwilei Rd	C / 982392367 U / 9-101194 U / 9-100928 R / 980735443	low priority				gas, ethanol	LQG; 14,200 gal	1 in use, 3 permanently out of use	mixed industrial/business
Pacific Tire	1955 N King St	U / 9-101450					gas	20,600 gal	4 in use	automotive
Pacific Warehouse	801 Moowaa St	U / 9-100290					gas, diesel	12,000 gal	2 in use	mixed industrial/business
Pawaa Fire Station	1610 Makaloa St	U / 9-100087					gas	1,000 gal	1 in use	government
Pflueger Acura	1450 S Beretania St	U / 9-100192 R / 981630700					gas, new oil, used oil	SQG; 8,000 gal	3 removed 9/91	automotive
Phillips 66 Co	1096 S King St	U / 9-101781					gas, used oil	10,550 gal	3 removed 7/76	gasoline station/fuel svc
PHT Polynesian Hospitality—see Polynesian Hospitality										
Pioneer Ventures Inc	999 Robello Ln	R / 984468330						CEG		mixed industrial/business
Pneumatic Equipment	1806 Home Rule St	U / 9-100295					gas, diesel	4,000 gal	1 in use, 3 removed 3/92	mixed industrial/business
Pohulani Elderly Project	677 Queen St	L / 9-101396 U / 9-101396	no ranking listed	<500 gal	diesel	soil contamination	diesel	500 gal	1 removed 11/90	mixed industrial/business
Polynesian Hospitality	330 Pacific St	L / 9-101379 U / 9-101379	Rank 3	500–5,000 gal	oil	soil contamination	gas, diesel, used oil	13,000 gal	3 in use, 1 removed 3/91	mixed industrial/business
Pony Express Courier—see Transcend Inc/Pony Express Courier										
Prestige Auto Care—see Malama Pacific Corp/Prestige Auto Care										
Prince Kuhio Federal Bldg	300 Ala Moana Blvd	U / 9-101930					diesel	5,000 gal	1 in use	government
Produce Center Development Ltd	651 Ilalo St	U / 9-101735					gas, diesel	15,000 gal	3 in use	mixed industrial/business
Puna Bug	555 South St	R / 981654908						SQG		automotive
Punahou Repair Shop	1558 S King St	U / 9-101387					gas, used oil	5,550 gal	3 removed 6/92	automotive

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Qualex Inc	760 Halekauwila St	R / 049981996						SQG		mixed industrial/business
Qualex Inc	1065 Kapiolani Blvd	R / 077672889						LQG		mixed industrial/business
Queen Emmalani Tower	Queen St & South St	C / 984466698 R / 982442394	no ranking listed					LQG		mixed industrial/business
Queen's Medical Center	1301 Punchbowl St	L / 9-100901 U / 9-100901	Rank 3	10,000–25,000 gal	diesel	soil contamination	diesel	34,000 gal	3 in use	mixed industrial/business
Queen's Physician's Bldg	1329 Lusitana St	U / 9-102622					diesel	500 gal	1 in use	mixed industrial/business
Quick Wash Chevron	909 Waiakamilo Rd	U / 9-101238 R / 981628894					gas, used oil	SQG; 31,000 gal	3 in use, 1 removed 4/91	automotive
R & L Auto Service	1924 Home Rule St	R / 981967318						SQG		automotive
Rainbow Chevrolet—see Cutter Mitsubishi/Rainbow Chevrolet										
Rainbow Chevrolet—see Honolulu Nissan/Rainbow Chevrolet										
Ray's Auto Services	959 Queen St	L / 9-102612 U / 9-102612	Rank 3	500–5,000 gal	oil	soil contamination	used oil	550 gal	1 removed 3/92	automotive
Raymond's Painting	738 Queen St	R / 981425317						LQG		mixed industrial/business
Rego's Purity Foods	942 Kawaiahao St	U / 9-100303					gas	1,000 gal	1 removed 9/88	mixed industrial/business
Remediation Specialists—see Takamiya Property/I. Steven Sunada/Remediation Specialists										
Richard Tom Unocal	963 Robello Ln	U / 9-101574					gas, diesel	2,000 gal	2 in use	gasoline station/fuel svc
Richard's Chevron	1509 S Beretania St	U / 9-101122					gas, used oil, GST46	31,090 gal	7 removed 10/87	gasoline station/fuel svc
Richard's Union Service—see Unocal 76 SS0471/Richard's										
Roberts Hawaii Tours	759 Kelikoi St	L / 9-100893	Rank 3	10,000–25,000 gal	?gas, diesel, oil, hazardous-solvents	FP on gw, soil contamination				mixed industrial/business
Rod's Auto Service	1489 Punchbowl St	L / 9-100889 U / 9-100889 R / 981693160	Rank 3	10,000–25,000 gal	Pb-gas, gas, oil	soil contamination	gas, used oil	SQG; 13,000 gal	3 removed 3/91	automotive
Roger's Repair Inc	1687 Kalakaua Ave	R / 981615222						SQG		automotive
Ron's Auto Service	306 Kalihi St	R / 981655491						SQG		automotive
Ronwill Inc	1232 Kaumualii St	U / 9-100854					gas	1,000 gal	1 removed 11/89	mixed industrial/business
RT Ozaki Roofing	121 Puuhale Rd	R / 981656754						SQG		mixed industrial/business
Sadd Laundry & Dry Cleaning Supplies	210 Puuhale Rd	R / 980886485						transporter only		mixed industrial/business
Salvation Army	806 Iwilei Rd	U / 9-100310					gas	1,000 gal	1 removed 10/89	mixed industrial/business
Sam's Supply	1824 Auiki St	U / 9-101463					gas	3,000 gal	2 removed 12/88	mixed industrial/business

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Sand Island Unocal Service—see Unocal 76 SS5068/Sand Island										
Sasamoto Union Service—see Unocal 76 SS5005/Sasamoto										
Schuman Carriage Co	1234 S Beretania St	L / 9-101276 U / 9-101276 R / 981663750	Rank 3	5,000–10,000 gal	Pb-gas, oil, hazardous-solvents	soil contamination	gas, new oil, used oil	SQG; 5,100 gal	4 in use	automotive
Schuman Carriage Co/ H. Hironaka Trucking	2099 Auiki St	U / 9-100906 R / 984469122					gas, diesel, used oil, solvent	SQG; 7,050 gal	3 in use, 3 temporarily out of use	automotive
Sears Automotive Center	1450 Ala Moana Blvd	L / 9-101837 U / 9-101837 R / 981653154	Rank 3	5,000–10,000 gal	oil	FP on gw, dissolved in gw, soil contamination	new oil, used oil	SQG; 23,000 gal	2 in use, 5 temporarily out of use	automotive
Shell Oil	737 Nimitz Hwy	R / 000631655						LQG; transporter		gasoline station/fuel svc
Shell Oil Co—see Honolulu Shell Plant/Oil Co										
Shell Oil Sand Island	50 Sand Island Access Rd	U / 9-100870 R / 000631838					kerosene	LQG; transporter; 2,000 gal	2 removed 11/89	gasoline station/fuel svc
Shell Oil/Gushi Kuma's	605 Puuhale Rd	U / 9-100313 R / 981653561					gas, used oil	SQG; 25,050 gal	4 in use, 1 removed 6/90	gasoline station/fuel svc
Shell Oil/Mike's	225 S Vineyard Blvd	U / 9-101034 R / 982445876					gas, used oil	LQG; 23,550 gal	5 in use	gasoline station/fuel svc
Shell Oil/Wes's	1204 Kapiolani Blvd	L / 9-101021 U / 9-101021 R / 981657307	no ranking listed	10,000–25,000 gal	gas, oil, unknown	FP on gw	gas, used oil, unknown	LQG; 21,300 gal	6 removed 5/92	gasoline station/fuel svc
Shelly Mazda Service Center	Kapiolani Blvd & Chapin St	L / 9-102704	Rank 3	5,000–10,000 gal	Pb-gas, unknown	FP on gw				automotive
Shelly Motors	830 Kapiolani Blvd	L / 9-101826 U / 9-101826					unknown	unknown	2 removed 5/92	automotive
Shelly Motors Auto Sales—see Lexus of Hawaii										
Shelly Motors Body Shop	720 Ilalo St	R / 984469684						SQG		automotive
Shelly Nissan/Pacific Oldsmobile	900 Ala Moana Blvd	L / 9-100929 U / 9-100929 R / 981983844	Rank 3	500–5,000 gal	oil	FP on sw, soil contamination	gas, used oil	SQG; 6,000 gal	2 removed 10/91	automotive
Shimaya Shoten Ltd	710 Kohou St	L / 9-101425 U / 9-101425	Rank 3	500–5,000 gal	?gas	dissolved in gw	gas	1,000 gal	unknown	mixed industrial/business
SIC Partners	2170 Auiki St	U / 9-102412					gas	8,000 gal	1 removed 2/91	mixed industrial/business
Sign Design/Horace & Rachel Tao	1805 Republican St	L / 9-101997 U / 9-101997 U / 9-100952	Rank 3	500–5,000 gal	Pb-gas	soil contamination	gas	1,450 gal	1 removed 12/84, 1 removed 8/90	mixed industrial/business
SJD Radiator Service	1218 Makiki St	R / 981664634						SQG		automotive

Summary—*Continued*

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Smith Service Hawaii	350 Ward Ave	R / 980880884						transporter only		automotive
Snappy Wheel Align	527 Puuhale Rd	R / 981656036						SQG		automotive
Sonny's Auto Repair	818 Iwilei Rd	R / 981629280						LQG		automotive
Standard Plumbing	894 Waimanu St	U / 9-101382					gas	500 gal	1 removed 12/89	mixed industrial/business
Star Service	1414 Rycroft St	U / 9-102480					gas	550 gal	1 removed 9/91	gasoline station/fuel svc
State Capitol	235 S Beretania St	U / 9-102692					unknown	2,000 gal	2 temporarily out of use	government
State of Hawaii Department of Agriculture	1428 S King St	U / 9-101926					gas	2,000 gal	1 in use	government
State of Hawaii/DAGS Automotive Management Division	869 Punchbowl St	L / 9-100189 U / 9-100189 R / 982354136	Rank 3	5,000–10,000 gal	Pb-gas, oil	soil contamination	gas, used oil	CEG; 6,250 gal	2 in use	government
State Poultry Processors	2132 Kaliawa St	U / 9-101473					gas, diesel	4,500 gal	1 in use, 1 removed 11/91	mixed industrial/business
State T.L. Equipment Corp	1729 Home Rule St	U / 9-102408					diesel	4,000 gal	1 in use, 3 removed 6/91	mixed industrial/business
Steven S. Nagamine—see Flamingo Enterprises/Steven S. Nagamine										
STI Industries	120 Mokauea St	R / 982497281						SQG		mixed industrial/business
Straub Clinic	888 S King St	U / 9-100814					diesel	2,800 gal	1 in use, 1 removed 7/92	mixed industrial/business
Superblock N. Keeaumoku	705 Sheridan St	R / 984466847						LQG		mixed industrial/business
Superblock N4	898 Keeaumoku St	U / 9-102592					gas	2,000 gal	2 removed 11/91	mixed industrial/business
Superblock N8	Keeaumoku St & Rycroft St	L / 9-102594 U / 9-102594		10,000–20,000 gal	?gas, oil	soil contamination	gas, used oil	16,250 gal	3 removed 7/91	mixed industrial/business
Superblock N12	1350 Kamaile St	U / 9-102593					diesel	550 gal	1 removed 8/91	mixed industrial/business
Superblock N15	Sheridan St & Rycroft St	L / 9-102595 U / 9-102595					used oil	500 gal	1 removed 1/92	mixed industrial/business
Superblock S1	Sheridan St & Kamaile St	L / 9-102596 U / 9-102596					gas	1,000 gal	1 removed 10/91	mixed industrial/business
Superblock S6	1450 Kamaile St	U / 9-102596					gas, diesel	1,000 gal	2 removed 12/91	mixed industrial/business
Superblock S9	666 Keeaumoku St	U / 9-101271					gas	17,800 gal	2 removed 6/80	mixed industrial/business
Superblock S10	850 Keeaumoku St	U / 9-102599					gas	4,000 gal	2 removed 10/91	mixed industrial/business
Superblock S11	800 Keeaumoku St	U / 9-102605					gas	1,000 gal	1 removed 12/91	mixed industrial/business

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Superblock S13	Sheridan St & Makaloa St	L / 9-102600 U / 9-102600					diesel	500 gal	1 removed 11/91	mixed industrial/business
Superblock S14	1350 Makaloa St	U / 9-102601					diesel	500 gal	1 removed 11/91	mixed industrial/business
Superblock S20	1400 Makaloa St	L / 9-102602 U / 9-102602					used oil	1,000 gal	1 removed 10/91	mixed industrial/business
Superblock S22	1375 Makaloa St	U / 9-102604					gas	550 gal	1 removed 10/91	mixed industrial/business
Superblock S24	1500 Makaloa St	U / 9-102606					gas	1,000 gal	1 removed 12/91	mixed industrial/business
Superblock S25	Keeaumoku St & Makaloa St	L / 9-102603 U / 9-102603					gas	10,000 gal	2 removed 11/91	mixed industrial/business
Symphony Park/Kapiolani Bowl	Ward Ave & Kapiolani Blvd	C / 984467654 L / 9-102703 U / 9-102703	Rank 2	500–5,000 gal	?gas, diesel, oil, hazardous-solvent, unknown	dissolved in gw, soil contamination	unknown	unknown	1 removed 5/92	mixed industrial/business
Tagami Auto Service	1733 Kahai St	U / 9-100321					gas, used oil	7,100 gal	2 in use, 2 temporarily out of use	automotive
Tai Hing Co	1023 Kawaiahao St	U / 9-100831					gas	900 gal	1 in use	mixed industrial/business
Takamiya Property/I. Steven Sunada/Remediation Specialists	850 Moowaa St	C / 984468371 L / 9-100251 U / 9-100251 R / 984468603	Rank 3	500–5,000 gal	?gas, diesel	FP on gw	gas, diesel	transporter only; 3,000 gal	2 removed 12/90	mixed industrial/business
Tenney's Bishop Union—see Unocal 76 SS0346/Tenney's										
Texaco Station	1701 Dillingham Blvd	U / 9-100322					gas	30,000 gal	3 in use	gasoline station/fuel svc
Texaco Station	215 Vineyard Blvd	U / 9-100343					gas	30,000 gal	3 in use	gasoline station/fuel svc
Texaco Station	1239 S King St	U / 9-100340 R / 984467852					gas, used oil	SQG; 40,550 gal	5 in use	gasoline station/fuel svc
Texaco Station/Yamasaki	1010 N King St	U / 9-100339 R / 981629132					gas, diesel, used oil	SQG; 40,550 gal	5 in use	gasoline station/fuel svc
Theo Davies Euromotors	704 Ala Moana Blvd	L / 9-101329 U / 9-101329 R / 981674476	Rank 3	500–5,000 gal	Pb-gas	dissolved in gw, soil contamination	gas, diesel, used oil	LQG; 4,500 gal	3 removed 5/92	automotive
Thoht Construction	636 Laumaka St	U / 9-101437					gas, unknown	2,500 gal	3 removed 11/89	mixed industrial/business
Todoki Machine & Marine Works Inc	810 Halekauwila St	U / 9-100490					gas	550 gal	1 permanently out of use	mixed industrial/business
Toguchi Service Station	825 N Vineyard Blvd	U / 9-100348 R / 981665466					gas, used oil	SQG; 20,500 gal	3 in use, 2 removed 2/90	gasoline station/fuel svc

Summary—*Continued*

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Tongg Publishing Co/American Scientific Prod	274 Puuhale Rd	R / 000626911 R / 982033482						SQG; LQG; transporter		mixed industrial/business
Trane Pacific Service	2298 Alahao Pl	R / 982459950						SQG		mixed industrial/business
Trans Hawaiian Oahu	124 Puuhale Rd	L / 9-100804 U / 9-100804	no ranking listed	500–5,000 gal	gas	unknown	gas, diesel	12,550 gal	1 in use, 2 removed 11/92	mixed industrial/business
Trans Pacific Textiles	1930 Kahai St	U / 9-102642					gas	1,000 gal	1 removed 2/81	mixed industrial/business
Transcend Inc/Pony Express Courier	1321 Moonui St	U / 9-100296 R / 984469098					gas	transporter only; 6,000 gal	1 in use	mixed industrial/business
Transmission Service of Hawaii	972 Kawaiahao St	R / 982049637						SQG		automotive
Transport Express Inc	1320 Hart St	R / 981966104						transporter only		mixed industrial/business
Travel Plaza Transportation Inc	818 Pine St	R / 984468637						CEG		mixed industrial/business
Treasures of the East	1310 Makaloa St	U / 9-101168					gas	1,000 gal	1 removed 12/81	mixed industrial/business
Trends of Hawaii	1804 Hart St	U / 9-101664 R / 984469619					gas	1,000 gal	1 in use	mixed industrial/business
Tropical Fruits Distributors of Hawaii Inc—see DMC Waiakamilo/Tropical Fruits Distributors										
TW Systems	955 Waimanu St	U / 9-101936					unknown	550 gal	1 removed 4/90	mixed industrial/business
Typehouse Hawaii	250 N Beretania St	R / 981162647						LQG; transporter		mixed industrial/business
UH Marine Center—see USDOC NOAA Ship Townsend Cromwell										
Union Oil—see Unocal/Iwilei Tank Farm										
Uniq Distributing Corp	2020 Auiki St	L / 9-102676 U / 9-102676	no ranking listed	500–5,000 gal	?gas, diesel	soil contamination	gas, diesel	1,100 gal	2 removed 3/92	mixed industrial/business
United Auto Service	2242 Kamehameha Hwy	R / 981652985						SQG		automotive
United Tech Otis Elevator	793 S Hotel St	R / 982433856						SQG		mixed industrial/business
Universal Sheet Metal	1711 Kalani St	U / 9-100358					gas	1,000 gal	1 permanently out of use	mixed industrial/business
Unocal 76 Center—see Unocal/Iwilei Tank Farm										
Unocal 76 SS0344/Don's	1406 S Beretania St	L / 9-100035 U / 9-100035 R / 984468728	no ranking listed	>50,000 gal	gas, diesel, oil	unknown	gas, diesel, used oil	LQG; 54,100 gal	4 in use, 5 removed 12/87	gasoline station/fuel svc
Unocal 76 SS0346/Tenney's	169 S Beretania St	L / 9-100015 U / 9-100015 R / 984468751	Rank 3	10,000–25,000 gal	gas	soil contamination	gas, used oil, unknown	LQG; 24,550 gal	6 removed 5/92	gasoline station/fuel svc
Unocal 76 SS0471/Richard's	1136 N King St	L / 9-100028 U / 9-100028 R / 984468702	Rank 3	10,000–25,000 gal	gas	FP on gw, dissolved in gw, soil contamination	gas, used oil	LQG; 11,550 gal	3 in use	gasoline station/fuel svc

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Unocal 76 SS2877/A-1/ Ala Moana	1322 Kapiolani Blvd	L / 9-100037 U / 9-100037 R / 984468710	Rank 3	10,000–25,000 gal	Pb-gas	FP on gw	gas, used oil	LQG; 40,800 gal	6 in use	gasoline station/fuel svc
Unocal 76 SS3282/Alii 1	540 Nimitz Hwy	L / 9-100017 U / 9-100017 R / 984468876	Rank 3	10,000–25,000 gal	Pb-gas	dissolved in gw, soil contamination	gas, used oil	LQG; 45,500 gal	6 in use	gasoline station/fuel svc
Unocal 76 SS3667	1012 Piikoi St	R / 984468694						LQG		gasoline station/fuel svc
Unocal 76 SS3941/Academy	882 S Beretania St	U / 9-100040 R / 984468967					gas, used oil	LQG; 37,600 gal	3 in use, 3 removed 12/86	gasoline station/fuel svc
Unocal 76 SS4210/KSC	2295 N King St	L / 9-100031 R / 984468793	Rank 3	5,000–10,000 gal	Pb-gas	FP on gw		LQG		gasoline station/fuel svc
Unocal 76 SS5005/Sasamoto	33 S Vineyard Blvd	L / 9-100022 U / 9-100022 R / 984468835	no ranking listed	500–5,000 gal	oil	soil contamination	gas, used oil	LQG; 36,830 gal	6 removed 5/92	gasoline station/fuel svc
Unocal 76 SS5068/Sand Island	165 Sand Island Access Rd	U / 9-100023 R / 984468744					gas, diesel, used oil	LQG; 48,050 gal	8 in use	gasoline station/fuel svc
Unocal 76 SS5583	1801 Kapiolani Blvd	R / 984468769						LQG		gasoline station/fuel svc
Unocal 76/Lionel's	1505 S King St	L / 9-100041 U / 9-100041 R / 984468736	Rank 3	10,000–25,000 gal	gas	dissolved in gw, soil contamination	gas, used oil	LQG; 13,050 gal	3 in use	gasoline station/fuel svc
Unocal/Iwilei Tank Farm	411 Pacific St	C / 000633081 R / 000633981 R / 981652696 U / 9-100108	no ranking listed				diesel, used oil	LQG; SQG; 9,590 gal	5 in use	gasoline station/fuel svc
US Postal Service Downtown	710 Richards St	U / 9-101767					unknown	unknown	2 in use	government
US Postal Service Kapalama	1271 N King St	L / 9-101773 U / 9-101773	Rank 3	5,000–10,000 gal	gas	soil contamination	gas	12,000 gal	1 in use, 1 removed 7/90	government
US Postal Service Merchant St	335 Merchant St	U / 9-101768					gas	6,000 gal	unknown	government
USDOC NOAA Ship Townsend Cromwell	1 Sand Island Access Rd	U / 9-201058 R / 130090065					gas	SQG; 6,500 gal	1 in use, 2 removed 12/73	government
VHT Inc	912 Ilaniwai St	R / 984469494						CEG		mixed industrial/business
Victor & Jeanette Lee	2010 Democrat St	U / 9-102706					gas	1,000 gal	1 closed in ground	mixed industrial/business
Victoria Ward Ltd	955 Kawaiahao St	U / 9-102507					unknown	1,000 gal	1 in use	mixed industrial/business
W.B. Venture	742 Auahi St	U / 9-100360					gas	3,000 gal	3 in use	mixed industrial/business
Waimanu Sash & Door	815 Waimanu St	U / 9-100361 R / 009152059					gas	LQG; 550 gal	1 permanently out of use	mixed industrial/business

Ward Ave Complex HECO—see HECO Ward Ave Complex

Facility Name	Street Address	Site List / Facility Identification Number	Hazard Ranking	Released Amount	Type of Substance Released	Extent of Contamination	Tank Contents	Total Potential Contaminants On-site	Storage Tank Status	Site Classification
Washington Place	300 S Beretania St	U / 9-102613					gas	250 gal	1 removed 9/92	government
Waterfront Fire Station	111 N Nimitz Hwy	L / 9-100097 U / 9-100097	Rank 3	500–5,000 gal	gas	FP on gw	diesel	1,000 gal	1 removed 2/91	government
Wayne's Auto Electric	858 Queen St	R / 981652340						SQG		automotive
Wens Life Co	808 Sheridan St	U / 9-101330					gas, alcohol	7,000 gal	4 in use	mixed industrial/business
Wes's Kapiolani Shell Service Station—see Shell Oil/Wes's										
Western Transmission	1717 Republican St	R / 981439177						no longer engaged in activity		automotive
Weyerhaeuser Paper Co	900 N Nimitz Hwy	L / 9-100743 U / 9-100743 R / 982339194	Rank 3	<500 gal	unknown	dissolved in gw, FP on gw	fuel oil, used oil, unknown	SQG; 11,550 gal	1 in use, 2 removed 6/91	mixed industrial/business
WH Fiddler Co	611 Cooke St	R / 984469734						SQG		mixed industrial/business
WRAF Hawaiian Tuna Packers	1011 Ala Moana Blvd	L / 9-102690 U / 9-102690	no ranking listed	unknown	unknown	unknown	gas, diesel	unknown	2 in use	mixed industrial/business
Yajima Oil Convenience	600 Dillingham Blvd	U / 9-101873					gas, used oil, GST46	37,090 gal	2 temporarily out of use, 7 removed 8/86	gasoline station/fuel svc
Yajima Oil of USA	1375 S King St	L / 9-100832 U / 9-100832	no ranking listed	10,000–25,000 gal	unknown	unknown	gas	24,000 gal	3 in use	gasoline station/fuel svc
Yamada Plumbing	1827 Republican St	U / 9-100365					gas	1,000 gal	1 removed 12/89	mixed industrial/business
Yamasaki Service Inc—see Texaco Station/Yamasaki										
Yick Lung Co	580 Dillingham Blvd	L / 9-101500 U / 9-101499	Rank 3	500–5,000 gal	diesel	soil contamination	gas, used oil, unknown	10,600 gal	3 in use, 1 permanently out of use, 1 removed 7/91	mixed industrial/business
Young Brothers Ltd	711 N Nimitz Hwy	U / 9-101155 R / 006927123					gas, used oil	SQG; transporter; 2,285 gal	3 removed 7/88	mixed industrial/business
Zep Manufacturing Co	1601 Kalani St	R / 000626705						no longer engaged in activity		mixed industrial/business
Ziroli Co	905 Waimanu St	U / 9-102449					gas	550 gal	1 removed 1/86	mixed industrial/business

SOURCES: CERCLA, LUST, UST, and RCRA lists maintained by the Hawai'i Department of Health.
NOTE: See "Results" section in Chapter 6 for explanation of hazard rankings, groupings, and other data provided in this table.