Final Report
Subsurface Fuel Contamination Study

for United States Navy

Naval Air Station
Alameda, California

Contract N62474 - 79 - C - 5320
FY 1979 Special Project C18 - 77

January 1980

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Attention: Mr. James Washington
Project Coordinator

Subject: Final Report
Contract N62474-79-C-5320
Naval Air Station, Alameda, California
FY 1979 Special Project C18-77
Subsurface Contamination/Fuel Tank Leak
KE 9055

Gentlemen:

In accordance with our agreement dated 25 July 1979, we are pleased to submit herewith ten copies of the final report on the investigation of subsurface fuel contamination at the Alameda Naval Air Station.

If we can be of any further assistance regarding this investigation, please do not hesitate to contact us.

Very truly yours,

KENNEDY ENGINEERS

Theodore G. Erler

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Project Engineer

TGE:cdg

Enclosures: 10 copies Final Report

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(4 copies Final Report)

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CHAPTER I

INTRODUCTION

BACKGROUND

This report describes the examination and evaluation of subsurface contamination resulting from fuel tank leaks at the Fuel Storage Area 97, Naval Air Station, Alameda, California.

The project study area is illustrated on Figure 1. Area 97 contains five fuel storage tanks. Tanks A, B, C, and D are concrete tanks lined with carboline. These tanks were constructed in 1943. Tank E is a steel tank and was constructed in 1962. NAS Fuel Division personnel have stated that all five tanks were used exclusively for the storage of aviation gasoline (115-Avgas).

Navy personnel detected the loss of fuel from Storage Tank A and the contamination by leaked fuel of the subsurface soil in the vicinity of the fuel storage area. Tanks B, C, and D, because they are the same age and type as Tank A, were also suspected to be leaking. For this reason, Tanks A, C, and D were abandoned and sealed off in October 1975. At that time, these tanks were drained, cleaned, and filled with water. In December 1978, Tanks B and E were also abandoned, sealed off, drained, and filled with water. Because Tanks B and E were not cleaned, a small amount of avgas remains on the water surface in these two tanks.

The quantity of fuel lost from the fuel tanks is not known, but has been estimated by Navy personnel to be as much as 100,000 gallons per year over several years.

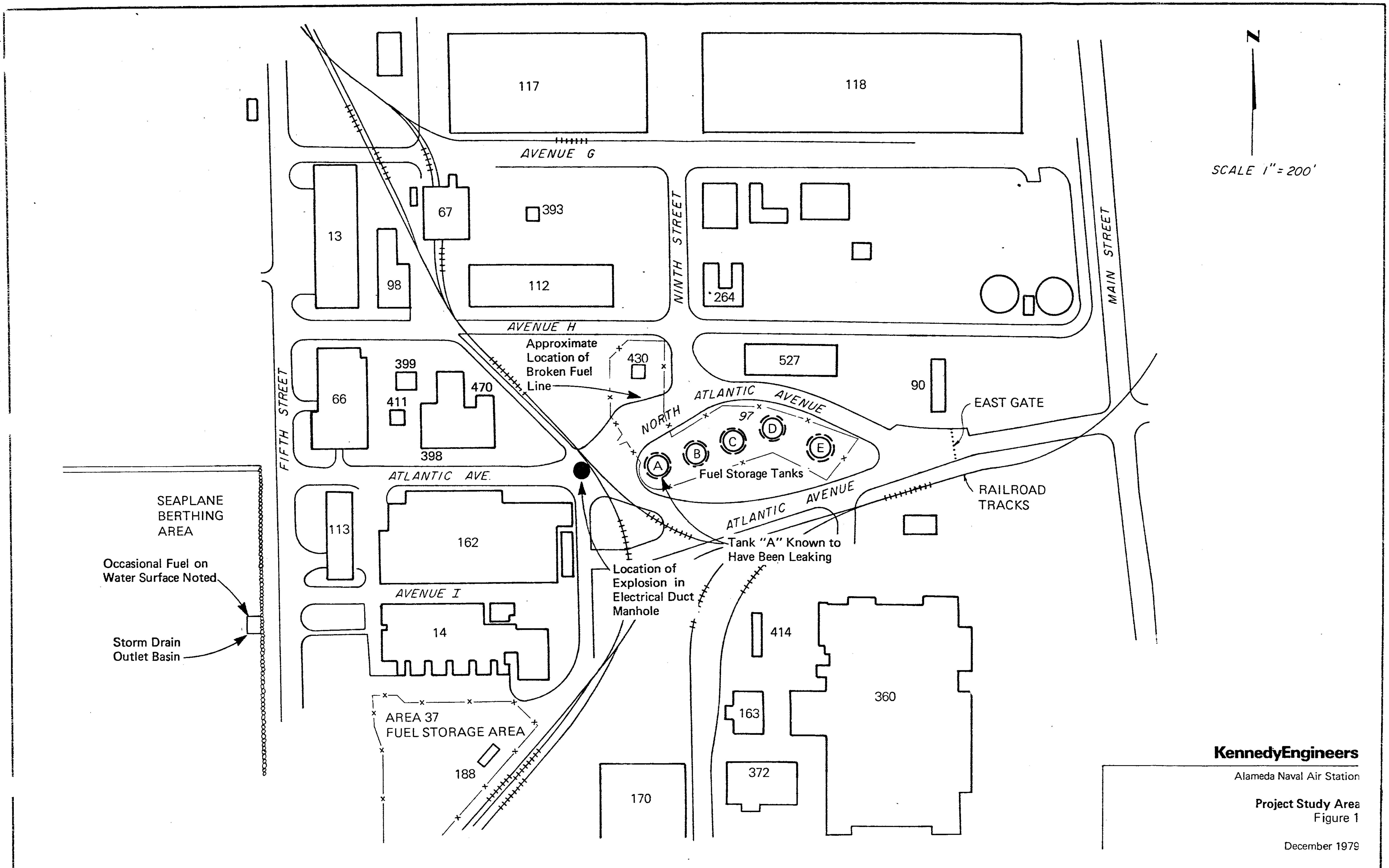
In addition to the leakage from the storage tanks, a fuel line in Area 97 burst in 1972, releasing an undetermined quantity of avgas into the surrounding soil. The approximate location of this fuel line break is shown on Figure 1.

Fuel has been found in electrical duct access manholes just west of Area 97. Fuel has also reportedly accumulated at a storm drain outlet basin at the Seaplane Berthing Lagoon, especially during periods of unusually low tide.

Objectives and Scope

In July 1979, the Western Division of the Naval Facilities Engineering Command authorized Kennedy Engineers to proceed with a study with the following objectives:

1. Determine the extent of subsurface fuel contamination in the vicinity of Area 97.



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Project Study Area
Figure 1

December 1979

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2. Recommend a program to eliminate or mitigate the adverse conditions resulting from the subsurface fuel.

The tasks required to meet these objectives are as follows:

1. Obtain pertinent subsurface utility maps for the study area.
2. Bore eighteen observation and sampling wells and take soil samples.
3. Determine the characteristics of the predominant soils in the study area, including fuel content.
4. Determine the depth of pooled fuel, depth of groundwater, and the characteristics of the groundwater, including fuel content.
5. Determine concentration of fuel vapors in subsurface utility lines.
6. Assess the extent of fuel contamination of subsoil, groundwater, and utility lines.
7. Develop alternatives for the elimination or mitigation of the adverse conditions resulting from the subsurface fuel.
8. Evaluate alternatives based on safety, environmental, and economic cost factors.
9. Identify a recommended project strategy.
10. Report the results of the investigation in a preliminary report and final report.

CHAPTER II

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Field and laboratory investigations indicate that an area of approximately 5-1/2 acres is affected by some degree of fuel contaminated subsoil. The fuel in the subsoil was determined to be aviation gasoline (avgas) from Area 97.

The two possible types of fuel contamination in the subsoil were pooled fuel and pellicular fuel. Pooled fuel is free liquid fuel "floating" on the groundwater surface. It occupies the pore spaces in the soil and is free to move through the soil. Pellicular fuel is fuel which adheres to the soil particles and cannot move through the soil. Pellicular fuel is that fuel which remains tied up with the soil particles once the pooled fuel has drained away.

No pooled fuel was found in the study area, indicating that the fuel from Area 97 which entered the soil has drained away, probably through infiltration in subsurface utility lines. The remaining pellicular fuel was found in highest concentrations in the vicinity of Tank A and Building 430. The concentration of fuel in the soil and the depth of the contaminated soil zone decreases with the distance from these structures, with the majority of fuel movement having occurred to the north and west as shown in Figures 5, 6, and 7.

The only situation which has been found to present a potential hazard associated with the fuel contaminated subsoil is the accumulation of fuel vapors in subsurface utilities. Fuel vapor concentrations in the explosive range were found in a sanitary sewer line along the Seaplane Berthing Lagoon just south of the storm drain trash fence. It was determined that fuel vapors in this line were not due to avgas from Area 97. Additional study is required to determine the source of these fuel vapors.

In the vicinity of Area 97, an electrical duct, a storm drain, and a sanitary sewer all contained fuel vapors. The vapor concentrations in these lines were not in the explosive range, but the electrical and storm drain lines exhibited fuel vapor concentrations in excess of 500 ppm (vol.), the threshold limit value for gasoline. The threshold limit value is a measure of health hazard of toxic compounds. Exposure of personnel entering areas with fuel vapors in excess of the threshold limit value can result in permanent neurological damage. It is possible, under extreme conditions, that fuel vapors could accumulate in these subsurface utility lines in explosive concentrations.

Four alternatives were considered for mitigation of the adverse effects of the fuel contaminated subsoil:

1. Excavation of fuel contaminated subsoil and replacement with clean, uncontaminated soil.

2. Bio-stimulation of the fuel utilizing bacteria in the subsoil to increase the rate of fuel decomposition.

3. Venting of selected utility lines exhibiting high fuel vapor concentrations to remove the potentially harmful or explosive fuel vapors.

4. No project.

The estimated costs of these alternatives are tabulated in Table 1.

TABLE 1

ESTIMATED COSTS FOR ALTERNATIVES

	Alternative	Estimated Cost
1.	Excavation of Fuel Contaminated Subsoil	$3,200,000
2.	Bio-Stimulation	420,000
3.	Venting of Utilities	60,000
4.	No Project	-

The apparent best alternative for mitigation of the adverse effects of the subsurface fuel is venting of selected utility lines. The lines which would require venting are the electrical duct, storm drain, and sanitary sewer in the vicinity of Area 97. This alternative is illustrated in Figure 10. The estimated installed cost for the three utility vents is $60,000.

The advantages of venting the utility lines are the elimination of the potential health and explosion hazards at a relatively low capital cost and in a relatively short time period when compared with Alternatives 1 and 2. This alternative will not reduce or eliminate the concentration of fuel in the subsoil as would the first two alternatives. However, the fuel contaminated subsoil does not, of itself, constitute an explosion or health hazard.

The groundwater in the study area is saline and is therefore not used as a potable water source. Thus, the small amount of fuel which becomes dissolved in the groundwater does not endanger any potable water supply. However, dissolved fuel in the groundwater will reach the Bay at the Seaplane Berthing Lagoon. It is estimated that some fourteen pounds of fuel per year reach the Bay in this manner. This quantity of fuel release does not appear significant. Therefore, it is our opinion that the presence of the fuel in the subsoil and groundwater and the minor quantity of fuel entering the Bay via the groundwater constitute a negligible environmental impact.

Venting the utility lines will eliminate the potential health and explosion hazards during the estimated 50 years it will take for natural biodegradation to eliminate the majority of fuel contained in the subsoil. It is therefore recommended that the electrical duct, the storm drain, and the sanitary sewer in the vicinity of Area 97 be vented to eliminate the potential health and explosion hazard. It is further recommended that investigations be instigated to determine the source and extent of the explosive concentrations of fuel vapors which were found in the sanitary line south of the storm drain outlet basin along the Seaplane Berthing Lagoon, and that measures be taken to eliminate this hazardous condition.

CHAPTER III

METHODOLOGY

FIELD TEST METHODS

Borings and Soil Sampling

A total of eighteen observation wells were drilled to an average depth of approximately fourteen feet using an eight-inch hollow-stemmed auger. The wells were cased with slotted four-inch PVC pipe. During the drilling operation, undisturbed soil samples were obtained using a split spoon sampler. Samples were taken in the vicinity of the water table and near the bottom of the well. These samples were used for sieve analysis and to determine soil density and permeability. Details of the drilling and soil sampling operations are contained in the soils report in Appendix A.

In addition to the split spoon samples, grab samples were taken from the soil brought up by the auger. These samples were used to determine soil moisture content and fuel content and to determine the effectiveness of chemical agents in removing the pellicular fuel. Pellicular fuel is that fuel which is held in the soil by adhering to the soil particles.

Water Sampling and Measurement

Water samples from the observation wells were obtained using a messenger-type sampler. Water samples were tested in the field for temperature, pH, conductivity, dissolved oxygen, and oxidation reduction potential.

Groundwater depths were measured by lowering a conductivity probe into the well. The conductivity meter registered when the probe touched the groundwater surface and the depth was then measured from the top of the well casing. A survey was conducted to determine the horizontal and vertical locations of the tops of the well casings.

Pooled fuel is free liquid fuel which "floats" on the groundwater surface. It occupies the pore spaces in the soil and is free to move through the soil. Testing for pooled fuel was accomplished by coating a plastic rod with water sensitive paste on one side and fuel sensitive paste on the other and lowering the rod into the well. Presence of water or fuel is denoted by a change in color of the respective paste. The depth of pooled fuel is indicated by the distance between the groundwater surface and the fuel surface as indicated by the pastes.

Fuel Vapor Survey

Electrical duct manholes, sanitary sewer manholes, and storm drain manholes in the study area were tested for the presence of fuel vapors. The instrument used for testing was a portable fuel vapor "sniffer" with the vapor intake tube inserted through a vent hole in the manhole cover.

LABORATORY TEST METHODS

Soil Characteristics

The determination of soil density and permeability and the sieve analyses are described in the soils report in Appendix A.

Groundwater Characteristics

The total Kjeldahl nitrogen, nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, and phosphate concentrations were determined in order to evaluate the groundwater characteristics in relation to bacterial nutrient requirements.

Fuel Concentrations in Soil and Groundwater

Fuel was extracted from the groundwater samples with pentane. The pentane was then analyzed with a gas chromatograph for the presence and concentration of fuel.

The curves produced by the gas chromatograph were also used to identify the type of fuel present in the samples by comparison with standard curves produced by analysis of known fuel types.

Chemical Dispersant Test

A test was performed to evaluate the effectiveness of chemical dispersants in emulsifying and removing fuel from the soil.

A three-inch column was filled to a depth of one foot with representative soil which was saturated with avgas. A two percent solution of Exxon Corexit 9527 chemical dispersant was prepared. The solution was added to the column to a depth of three feet above the soil. The solution was allowed to percolate down through the soil. After treatment with the dispersant, soil samples were taken at the top and bottom of the soil column, the procedure was then repeated, and two more soil samples were taken.

The concentration of fuel in a fuel saturated soil sample and in the four column soil samples was then determined using the fuel extraction method previously described.

Presence of Fuel Utilizing Bacteria

To test for the presence of fuel utilizing bacteria, two groundwater samples were cultured on nutrient agar plates. Avgas was added to one plate and the other plate received no avgas. Food and nutrients were available to the bacteria on both plates from the agar. The plate with the avgas, however, made available the fuel as an additional food source to those special bacteria that are able to decompose fuel. Normal bacteria populations would not be expected to be stimulated by fuel. Initial bacterial counts were compared to counts taken at two and four days. The presence of avgas utilizing bacteria would be shown by increased bacterial counts in the sample to which avgas was added.

CHAPTER IV

FIELD TEST RESULTS AND DISCUSSION

OBSERVATION WELLS

On 28, 29, and 30 August and 12 September 1979, a total of eighteen observation wells were drilled. The locations of the wells are shown in Figure 2. The boring logs for the observation wells are included in the soils report in Appendix A.

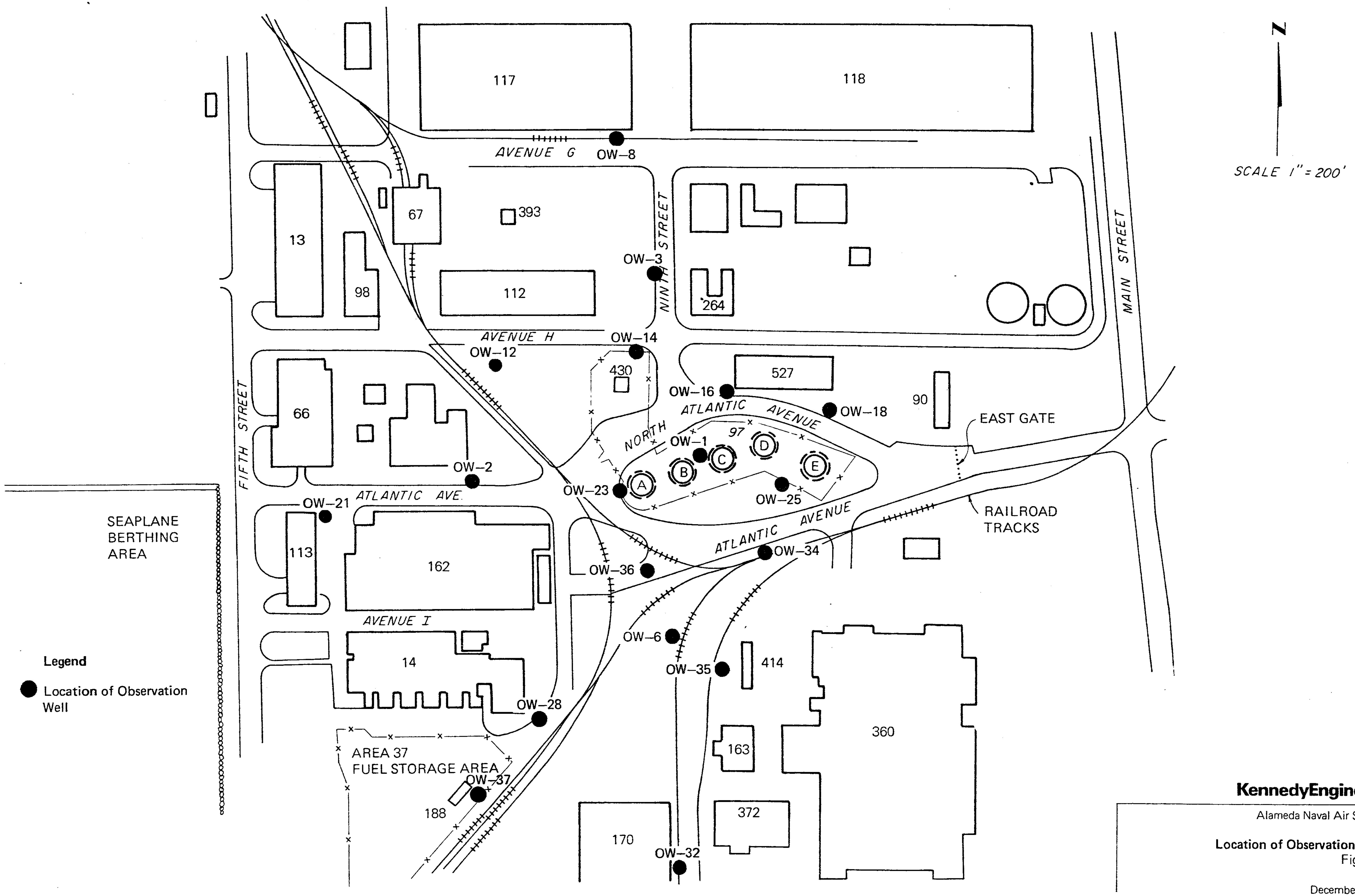
In general, the soil investigations show the study area to be covered by a relatively uniform layer of sandy hydraulic fill. The fill was typically about 8 feet thick; however, at specific locations, thicknesses of 6 and 12 feet were recorded. The fill consists primarily of loose, clean sands and silty and clayey sands containing from about 4 to 35 percent silt and clay sized material. Numerous, relatively thin, discontinuous layers of soft, silty clay were encountered within the fill. Beneath the fill is a thin layer of soft to medium stiff clayey silt which appears to thin toward the east. This material is locally referred to as "bay mud," and is a highly impermeable marsh deposit which frequently contains large quantities of organic matter. Underlying the bay mud are stiff, sandy clays and dense silty and clayey sands. A more detailed description of the subsurface conditions is contained in the soils report in Appendix A.

Fuel odor was noted in soil samples from several of the observation wells during the drilling operations. These soil samples were transported to the laboratory for analysis. The results of the analyses are described in Chapter V.

Tests conducted to determine the depth of pooled fuel at the groundwater table showed that no pooled fuel is present in the study area. This indicates that the fuel from Area 97 which entered the soil has for the most part drained away, probably through infiltration into sewer and storm drain lines. A pellicular fuel residual does, however, exist in the subsoil. Field investigations indicate that a portion of the spilled fuel has also entered electrical duct, storm drain, and sanitary sewer lines in the vicinity.

WATER TABLE LOCATION

The horizontal and vertical locations of the observation wells were determined by location survey. The results of this survey are shown in Table 2. Groundwater elevations at each observation well were obtained using groundwater depths measured on 12 September and 24 October 1979. Groundwater was encountered in the wells at depths ranging from 4 to 7-1/2 feet below the ground surface. These data are summarized in Table 4. Groundwater contours interpolated from groundwater depths in the wells are shown on Figure 3.



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● Location of Observation Well

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Location of Observation Wells

Figure 2

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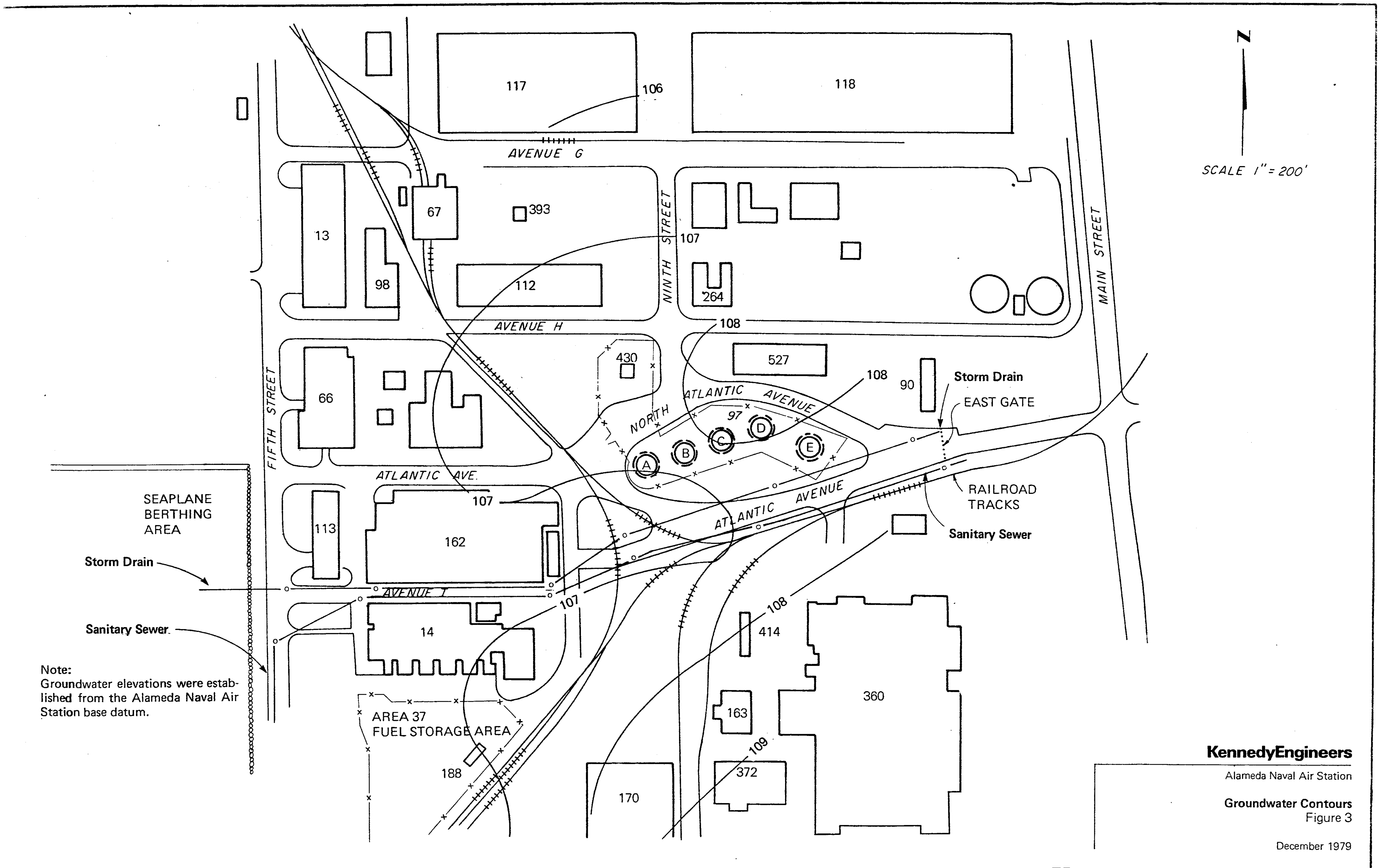

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Groundwater Contours
Figure 3

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TABLE 2

OBSERVATION WELL COORDINATES AND ELEVATIONS

Observation Well No.	Coordinates		Elevation of Top of Well Casing
1	S 1736.52	E 2472.99	113.14
2	S 1787.04	E 2013.20	112.81
3	S 1361.65	E 2380.09	113.11
6	S 2165.05	E 2406.90	113.51
8	S 1082.75	E 2335.35	113.78
12	S 1542.19	E 2020.90	113.51
14	S 1540.15	E 2344.55	113.28
16	S 1617.03	E 2552.41	113.01
18	S 1676.70	E 2769.10	112.39
21	S 1897.96	E 1659.57	112.65
23	S 1807.85	E 2301.89	113.25
25	S 1812.37	E 2663.75	113.07
28	S 2287.03	E 2148.11	113.81
32	S 2678.22	E 2412.70	114.24
34	S 1993.95	E 2541.59	112.64
35	S 2230.99	E 2500.37	113.62
36	S 1981.97	E 2357.20	113.37
37	S 2471.79	E 1962.13	112.98

Note:

Elevations and coordinates based on Naval Air Station coordinate system and base datum.

A storm drain and a sanitary sewer run along Atlantic Avenue and down Avenue I, as shown in Figure 3. It appears that groundwater is entering these lines, thereby creating a depression in the groundwater table in the vicinity of the lines. Aside from this localized depression, the direction of groundwater movement through the study area is in a generally westerly direction.

Based on the interpolated contours in Figure 3, the groundwater slope in the study area ranges from 0.002 to 0.008 feet per 100 feet. Based on these gradients and the permeability of the soil as determined in the laboratory, the estimated velocity of groundwater movement through the soil ranges from a maximum of 0.1 feet per day to a minimum of 0.02 feet per day.

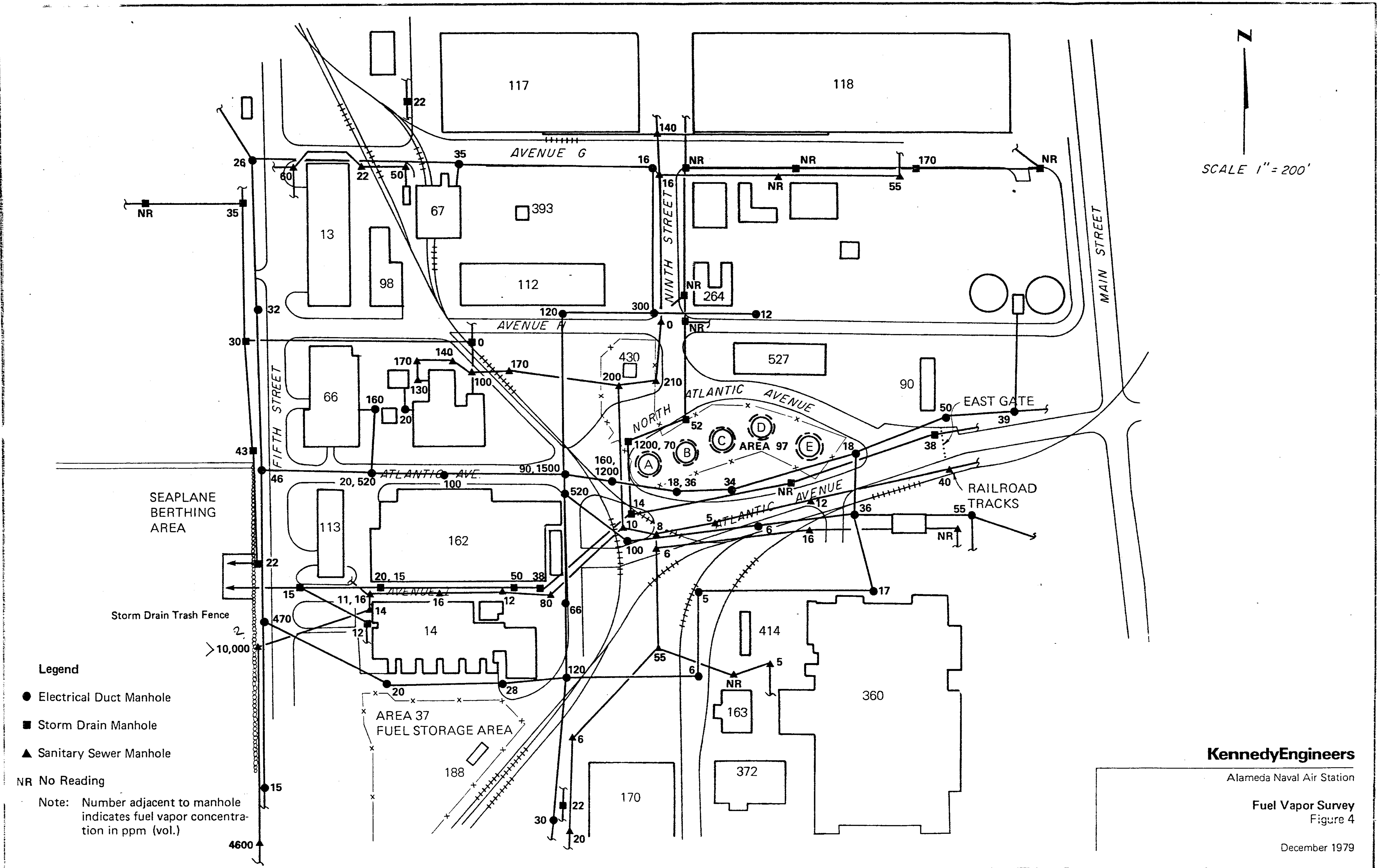
FUEL VAPOR SURVEY

On 28 August and 19 and 24 October 1979, electrical duct manholes, storm drain manholes, and sanitary sewer manholes were tested for the presence of fuel vapors. The results of this survey are illustrated on Figure 4. The vapor concentrations, in parts per million (volume) hydrocarbons as hexane, are shown on Figure 4 adjacent to each manhole. Most manholes were tested just once for fuel vapors. Those manholes that were tested twice have both readings shown adjacent to the manhole.

The threshold limit value for gasoline is 500 ppm (vol.). Prolonged exposure by personnel to gas vapors in excess of this threshold concentration can result in permanent neurological damage. The explosive limits for gasoline are 10,000 ppm - 80,000 ppm (1% - 8%) fuel vapor in air. Fuel vapors in this range of concentration will explode in the presence of an open flame or spark.

As shown on Figure 4, the highest vapor readings were obtained in a sanitary line adjacent to the Seaplane Berthing Lagoon along Fifth Street. A sanitary sewer manhole just south of the storm drain outlet basin contained a fuel vapor concentration in excess of 10,000 ppm (vol.), which is above the lower explosive limit. An adjacent electrical duct manhole had a reading of 470 ppm (vol.). In the same sanitary sewer, the next two manholes to the south exhibited fuel vapor concentrations of 4600 ppm (vol.) and 850 ppm (vol.). The manholes immediately west (towards Area 97) all exhibited fuel vapor concentrations of less than 100 ppm (vol.); thus, it is highly unlikely that fuel leakage from Area 97 is the source of contamination in this sanitary line. The investigations which would be required to determine the source and extent of contamination in this line are beyond the scope of this study.

Vapor readings as high as 1500 ppm (vol.) were obtained in the electrical duct manholes along Atlantic Avenue immediately west of Area 97. Along this same electrical line further west on Atlantic Avenue, a vapor reading of 520 ppm (vol.) was obtained. In addition, a storm drain manhole immediately northwest of Tank A exhibited a vapor reading of 1200 ppm (vol.). Due to the proximity to Area 97, there is little



Legend

- ● Electrical Duct Manhole
- ■ Storm Drain Manhole
- ▲ Sanitary Sewer Manhole
- NR No Reading

Note: Number adjacent to manhole indicates fuel vapor concentration in ppm (vol.)

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Fuel Vapor Survey

Figure 4

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doubt that fuel contamination in these lines is due to the fuel contaminated soil in the vicinity of Area 97. Although none of these readings indicate an explosion hazard, the fuel vapor readings in excess of the threshold limit value of 500 ppm (vol.) indicate that a health hazard to personnel who must enter these areas does exist.

CHAPTER V

LABORATORY RESULTS AND DISCUSSION

FUEL IN SOIL AND GROUNDWATER

Soil and groundwater samples from all of the eighteen observation wells were tested for the presence of fuel. The results of these analyses are shown in Table 3. The laboratory analyses showed the fuel present in the soil and groundwater to be aviation gasoline (115-avgas).

Figure 5 illustrates the approximate extent of soil and groundwater contamination by avgas from Area 97 based on field and laboratory data and observations. It is estimated that approximately 100,000 gallons of avgas remain in the subsoil in the fuel contaminated area shown on Figure 5. The area affected comprises approximately 5-1/2 acres.

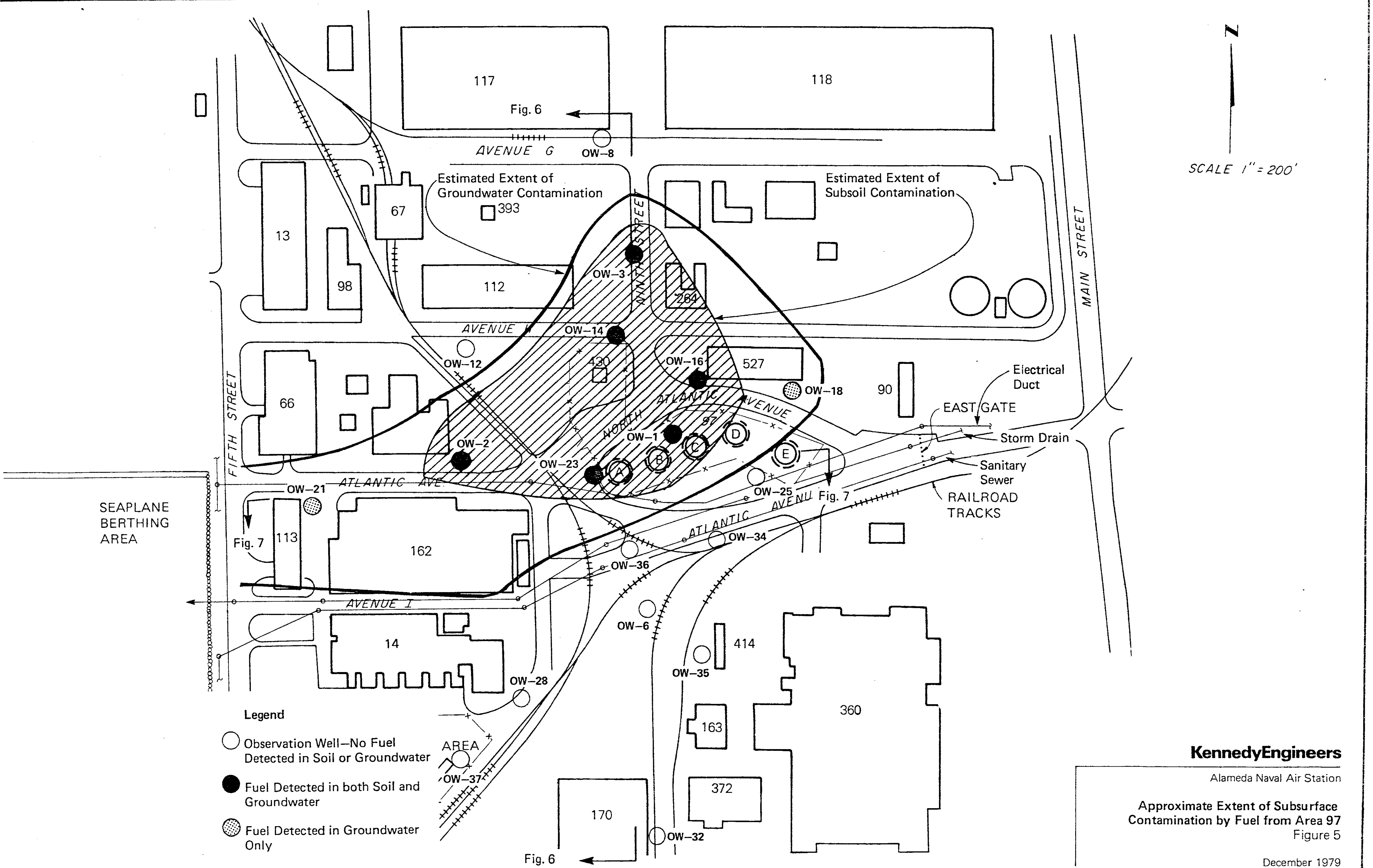
It appears that the underground utilities along Atlantic Avenue, shown on Figure 5, have prevented fuel from moving to the south. This could be explained by fuel actually flowing into the utility lines, by the utility lines acting as a physical barrier to fuel movement, or a combination of both of these possibilities.

The majority of fuel movement has occurred to the west and the north in the soil and to the west in the groundwater. The natural flow of groundwater to the west accounts for the extent of groundwater contamination in that direction.

It is likely that fuel contamination of the groundwater is limited to the groundwater above the layer of bay mud due to the relatively high impermeability of the bay mud. The groundwater contamination would then be limited to the layer of groundwater between the groundwater surface, at an average depth of 5-1/2 feet from the ground surface, and the bay mud, at an average depth of 8 feet from the ground surface.

As shown on Figure 5, fuel contaminated groundwater containing dissolved fuel eventually flows into the Seaplane Berthing Lagoon, which is a small inlet off San Francisco Bay. Based on fuel concentrations found in the groundwater at observation well no. 21 (the well closest to the lagoon) and the estimated flow rate of groundwater into the lagoon, it is estimated that a maximum of 14 pounds per year of fuel enters the lagoon via the groundwater.

Figures 6 and 7 illustrate two sections through the study area as indicated on Figure 5. These sections show the approximate extent of fuel contamination of the subsoil based on field and laboratory observations and data. Shown in Figure 6 is the depression in the groundwater table created by the utility lines along Atlantic Avenue. The electrical duct in which the explosion occurred is shown in both sections to be well within the fuel contaminated area; thus, if liquid fuel were



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Approximate Extent of Subsurface Contamination by Fuel from Area 97

Figure 5

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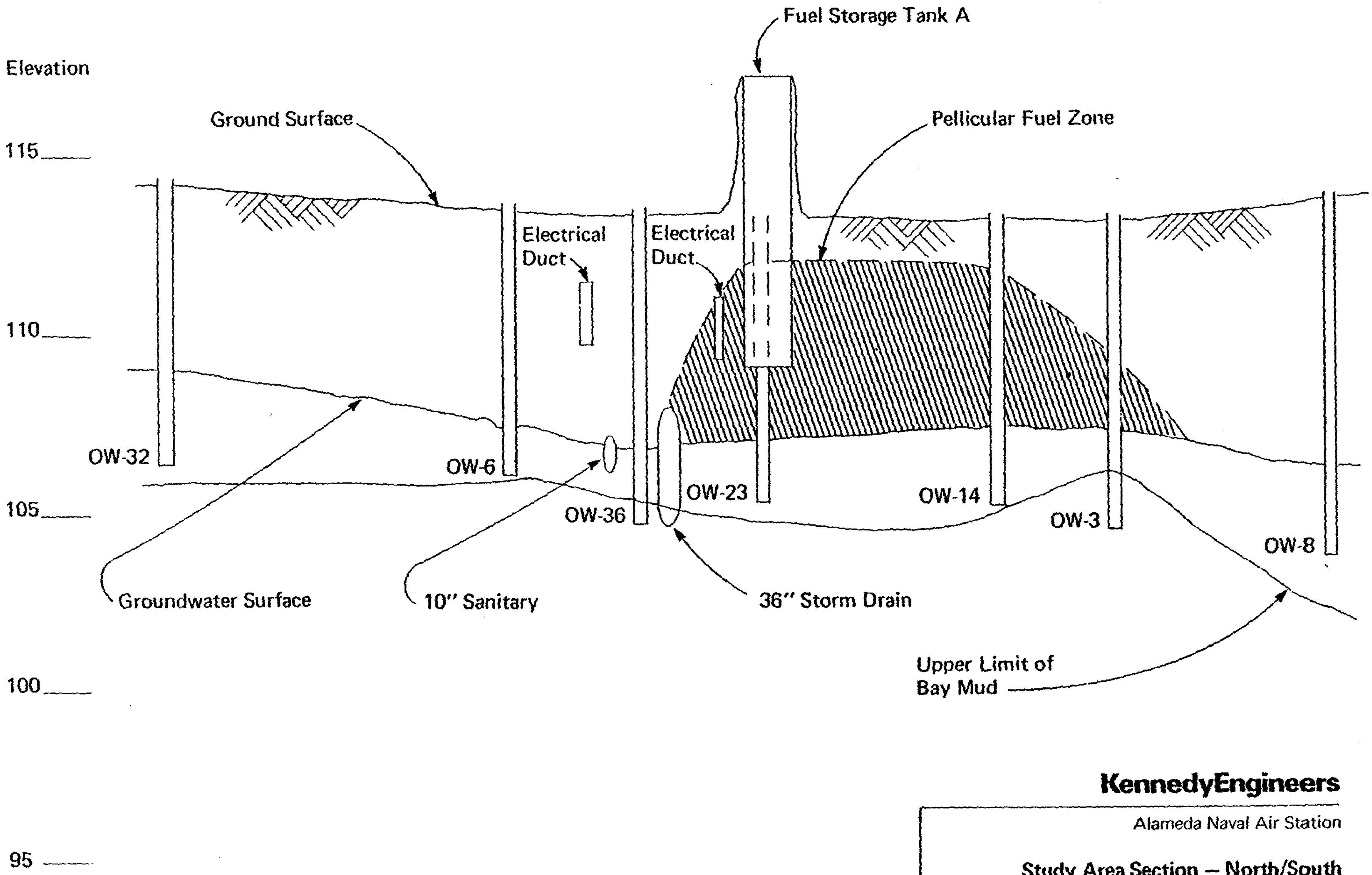

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Study Area Section – North/South
Figure 6

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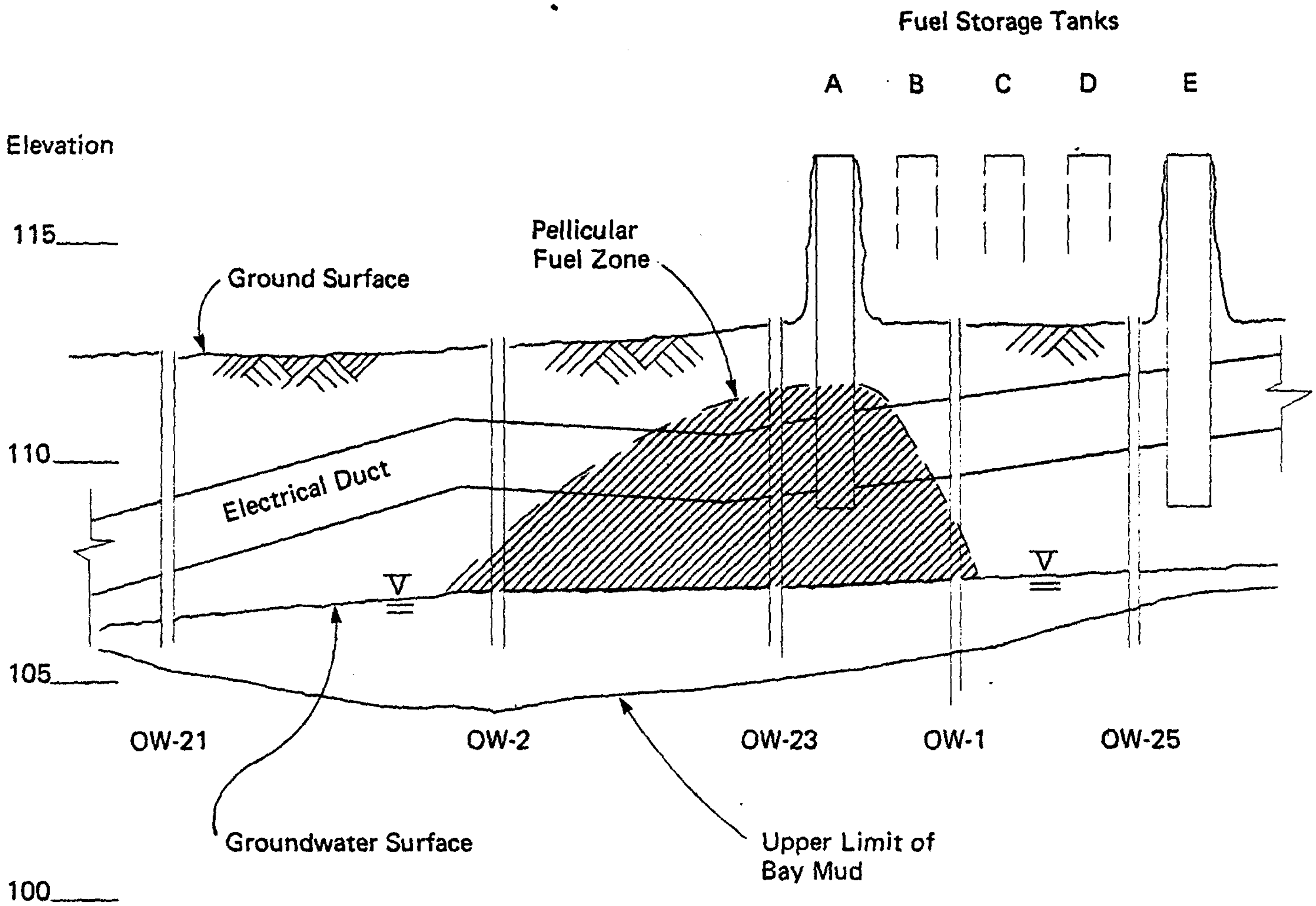

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Study Area Section — East/West
Figure 7

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TABLE 3

FUEL CONCENTRATION IN SOIL AND GROUNDWATER SAMPLES

Observation Well No.	Avgas Concentration in Soil[1] mg/kg	Avgas Concentration in Groundwater[2] mg/l
1	1100	5.0
2	D[3]	4.0
3	<720	<3
6	<720	<3[4]
8	<720	<3
12	<720	<3
14	D[3]	27
16	9200	D[3]
18	<720	<1.5
21	<720	5.0
23	7600	41
25	<720	<3
28	<720	11.0
32	<720	<3
34	<720	<3
35	<720	<3
36	<720	<3
37	<720	<3

1. From samples collected on 28, 29, 30 August and 12 September 1979.
2. From samples collected on 19 September and 17 October 1979.
3. "D" indicates that a fuel odor was detected from the sample but the concentration was not determined.
4. Analysis of the groundwater from observation well no. 6 showed an oil and grease concentration of 1,410 mg/l.

present in the soil, it could easily enter the duct through any openings. Fuel vapors formed by the gradual vaporization of the pellicular fuel could also enter the duct through any openings. In the same fashion, fuel liquid and vapor could enter any utility line with which it came in contact. This process accounts for the presence of fuel vapors in subsurface utilities as described in Chapter IV.

Soil samples from observation well no. 6 bore a very strong fuel odor but laboratory analyses indicated no avgas present. Subsequent investigations suggest that contamination at this location is not due to avgas. Soil and water analyses of samples collected from this well indicate the contaminant to be a heavy, dark, highly viscous oil. It has been suggested by NAS Alameda Facilities Management personnel that this contaminant may be bunker oil from a previous spill.

Soil samples from observation well no. 28 bore a very faint fuel odor, but no fuel was detected during laboratory analyses. However, a slight amount of avgas was detected in a groundwater sample from this well. It is highly doubtful that this slight contamination is due to avgas from Area 97 due to the distance involved and the fact that observation wells nos. 6 and 36, which are situated between Area 97 and observation well no. 28, had no fuel detected in either soil or groundwater samples. It is more likely that contamination at this location is due to fuel from Area 37 to the southwest. Determination of the source and extent of contamination at this location would require additional investigation and is beyond the scope of this study.

SOIL AND GROUNDWATER CHARACTERISTICS

Tables 4 and 5 present the soil and groundwater characteristics as determined in the field and laboratory.

The conductivity readings in the study area varied from 880 to 21,000 umho/cm. A review of these results indicates that the groundwater in the project area is predominantly saline bay water, with fresh water entering the groundwater at various points in the study area. The observed fresh water influence may be the result of sewage exfiltration from sanitary sewers, leakage from water lines, or a combination of processes.

Low dissolved oxygen concentrations were measured in the groundwater throughout the project area. The low dissolved oxygen levels probably result from bacterial activity indicated by the presence of organic matter in the soil fill and from the fuel.

Oxidation-reduction potentials are of interest in determining the conditions which exist in biological systems, in this case the fuel decomposing bacteria-fuel system in the fuel leak area. In any system undergoing biological oxidation, there is a continual change in the ratio between materials in the reduced form and the materials in the oxidized form. The oxidation-reduction potential reflects this ratio with negative values

TABLE 4

SOIL CHARACTERISTICS

Observation Well No.	Sample Depth[2] ft.	Moisture Content % by wt.	Depth to Groundwater[3] ft.	Groundwater Elevation NAS Alameda Base Datum	Estimated Depth of Pellicular Fuel Zone Above Groundwater[1] ft.
1	5	19.98	5.1	108.0	1
1	10	14.22	-	-	1
1	15	16.38	-	-	1
2	2-5	8.75	5.5	107.4	1-2
3	7	16.97	5.7	107.5	2-3
6	5	15.06	5.9	107.6	-
6	8	21.16	-	-	-
8	7	17.29	7.5	106.3	-
12	2-5	11.69	5.7	107.9	-
14	2-5	5.24	5.9	107.5	5
16	2-4	7.75	4.3	108.7	2
18	3	7.75	4.0	108.4	-
21	5-7	10.9	6.1	106.7	-
23	2-5	18.46	6.1	107.2	5
23	5-8	12.51	-	-	5
25	2-5	21.85	5.4	107.7	-
28	2-5	5.55	6.1	107.8	-
32	0-5	-	5.2	109.0	-
34	2-5	11.27	5.5	107.2	-
35	2-5	5.29	5.5	-	-
35	9	12.9	-	108.0	-
36	2-5	5.32	6.6	-	-
36	6-7	11.14	-	106.8	-
37	6-7	3.65	6.2	-	-
37	6-7	11.45	-	106.8	-

1. Pellicular fuel zone ends at groundwater surface. Depth shown is from beginning of pellicular fuel zone down to groundwater surface.

2. Soil samples were obtained during drilling operations on 28-30 August 1979 and 12 September 1979.

3. Average depth of measurements obtained on 12 December 1979 and 24 October 1979.

TABLE 5

GROUNDWATER CHARACTERISTICS

Observation Well No.	Total Conductivity umho/cm	Dissolved Solids mg/l	Dissolved Oxygen mg/l	Oxidation-Reduction Potential mv	pH	Temperature °C	Depth to Groundwater ft.
1	1,480	-	1.9	-60	8.2	23.0	5.1
2	3,670	2,170	0.9	-40	8.2	22.5	5.5
3	3,930	-	1.0	-180	8.0	22.0	5.7
6	-	-	0.5	-220	8.3	22.0	5.9
8	7,270	-	1.0	-20	8.1	23.0	7.5
12	5,400	3,600	1.0	+40	7.4	22.0	5.7
14	15,200	9,250	0.9	-210	8.0	23.0	5.9
16	1,110	-	1.8	0	8.2	23.0	4.3
18	20,500	-	1.2	-140	7.1	22.5	4.0
21	2,500	-	0.8	+80	8.0	22.5	6.1
23	1,550	-	1.0	-125	7.6	23.0	6.1
25	3,800	-	1.1	-20	7.2	22.5	5.4
28	1,050	-	0.9	-230	8.0	21.5	6.1
32	880	-	0.6	+90	8.0	21.5	5.2
34	9,750	-	1.5	-40	8.0	22.0	5.5
35	900	-	0.7	+90	8.1	22.0	5.5
36	3,270	-	2.4	+80	7.9	22.0	6.6
37	1,320	-	2.7	+50	8.1	21.5	6.2

	N I T R O G E N							
Observation Well No.	TOTAL as N mg/l	ORGANIC as N mg/l	NO_3 as N mg/l	NO_2 as N mg/l	NH_3 as N mg/l	PHOSPHORUS PO_4 as P mg/l	ORGANIC CARBON TOTAL mg/l	ORGANIC CARBON VOLATILE mg/l
2	5.88	5.04	0.12	0.04	0.7	0.36	21	1.0
6	4.02	2.24	0.10	0.01	1.68	0.02		
8	8.76	2.80	0.33	0.03	5.60	0.02		
14	10.64	8.68	0.02	0.01	1.96	1.0	78	3.9
23	6.56	3.36	0.26	0.01	2.94	0.06	65	5.9

indicating a predominance of reductants and positive values indicating a predominance of oxidants. Negative oxidation-reduction potentials indicate conditions generally unfavorable for biological oxidation.

A review of the oxidation-reduction potential data tabulated in Table 5 indicates generally negative oxidation-reduction potential values. It can be inferred from these data that bacterial decomposition of the fuel in the leak area is oxidant limited and is probably only proceeding at a slow rate.

The nitrogen concentrations observed in the groundwater are relatively high and may result from the decomposition of proteinaceous organic material in the soil.

Organic nitrogen concentrations are higher than that normally expected. The total organic carbon concentrations are also higher than would be expected for groundwater.

Phosphorus concentrations in the groundwater are typical for groundwater.

PRESENCE OF FUEL UTILIZING BACTERIA

The procedures used to test for the presence of fuel utilizing bacteria in the fuel contaminated subsoil are described in Chapter III. The culture to which avgas was added increased from the initial plate count of $3x10^6$ cells per ml to approximately $1x10^8$ cells per ml after two days and to approximately $1x10^{10}$ cells per ml after four days. The culture without avgas added exhibited no growth after two days and a decline in bacterial count after four days. The presence of fuel (avgas) utilizing bacteria in the fuel contaminated subsoil is definitely indicated by the increase in the cell counts over time.

This test shows that fuel utilizing bacteria are present in the soil and groundwater in the vicinity of Area 97. Given enough time, the bacteria would eventually consume the contaminating fuel in both the soil and groundwater.

CHEMICAL DISPERSANT TEST

A test was performed to evaluate the effectiveness of using a chemical dispersant to emulsify and remove pellicular fuel from the soil, as described in Chapter III.

The test results showed that approximately 70% of the pellicular fuel at the top of a one-foot soil column was removed by allowing the 4.2 liters of dispersant solution to flow through the column. No additional removal was accomplished by a second dispersant application. Soil samples taken from the bottom of the soil column after the first dispersant application indicate that only about 2% of the pellicular fuel was removed. Soil analyses after the second dispersant application are inconclusive since the soil column became clogged before the dispersant could drain through the column.

The laboratory tests indicate that the application of a chemical dispersant to fuel contaminated soil is not significantly effective in emulsifying and removing the fuel. For this reason, the use of chemical dispersants for removal of fuel from the soil received no further consideration.

CHAPTER VI

ANALYSIS OF ALTERNATIVES

The four alternatives which have been formulated and are evaluated in this chapter are excavation of the fuel contaminated soil, biostimulation of the fuel utilizing bacteria, venting of the subsurface utility lines, and no project. The following sections describe each of these alternatives, present cost estimates, and discuss the advantages and disadvantages of the alternatives.

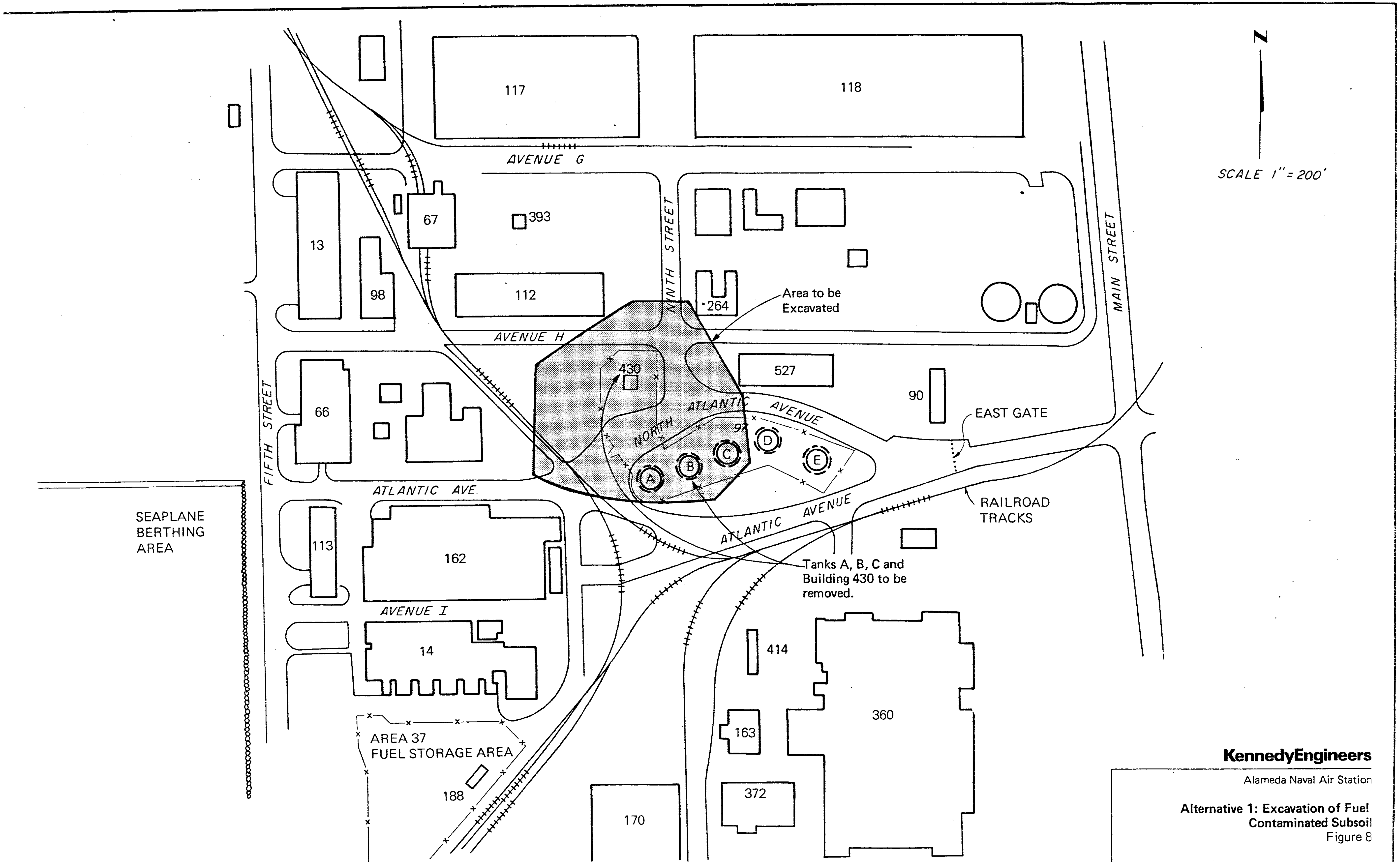
ALTERNATIVE 1
EXCAVATION OF FUEL CONTAMINATED SOIL

This alternative involves excavating all fuel contaminated soil in the study area and transporting it to a suitable disposal site, importing a suitable fill material, and resurfacing the area with asphalt. Because fuel contaminated soil constitutes a hazardous waste, State regulations dictate that at least a portion of the excavated soil would have to be transported to a Class I Disposal Site.

The closest Class I Disposal Site in the San Francisco Bay Area is the West Contra Costa Sanitary Landfill in Richmond. Personnel at this landfill have stated that they have capacity to accommodate up to approximately 25,000 cubic yards of fuel contaminated soil, which is probably adequate for disposal of the anticipated quantity of fuel contaminated soil. For purposes of estimating costs, it was assumed that 25,000 cubic yards of fuel contaminated soil would be taken to the Class I Disposal Site in Richmond. The remaining excavated uncontaminated soil would be stored in a spoil area near the project site and used to refill the pit at the completion of excavation operations. The regulatory agencies which would be involved in determining the final disposal of the fuel contaminated soil are the Regional Water Quality Control Board and the State Health Department. Experience in work with these agencies has shown them to be willing to work with the public in reaching a disposal solution that is both environmentally and economically reasonable. It would, therefore, be necessary to consult with these agencies in order to identify an actual disposal solution and to determine the cost for disposal of fuel contaminated soil.

This alternative also requires the removal of Fuel Storage Tanks A, B, and C, Building 430, and some fuel lines in order to excavate the fuel contaminated soil beneath and surrounding these facilities. The tanks, building, and fuel lines are no longer in use. Figure 8 shows the area which would require excavation.

The total estimated cost for this alternative is $3,200,000. A cost breakdown is provided in Table 6. In preparing this cost estimate, it was assumed that the entire excavated area would be resurfaced with



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Alameda Naval Air Station

Alternative 1: Excavation of Fuel Contaminated Subsoil

Figure 8

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asphalt. If landscaping is desired, the estimate will have to be increased accordingly.

The advantage of this alternative is that it would remove almost all fuel contaminated soil from the study area and thereby significantly reduce the possibility of associated hazards, in a relatively short period of time. Some soil, supporting electrical, sanitary, and storm sewers within the area to be excavated, will remain and therefore total removal cannot be achieved without unreasonable costs.

The disadvantages of this alternative are the costs involved and the disruption of traffic in the vicinity that would be caused by the excavation operations.

TABLE 6

ALTERNATIVE 1 - EXCAVATION OF FUEL CONTAMINATED SUBSOIL

COST ESTIMATE

Locate and protect subsurface utilities	$ 30,000
Relocate subsurface utilities	195,000
Remove and dispose of asphalt	98,000
Excavate and dispose of soil	275,000
Sanitary Landfill charges	1,125,000
Remove abandoned subsurface fuel lines	5,000
Import fill material	250,000
Demolish Tanks A, B, C, and Building 430	44,000
Remove and replace fencing	14,000
Repave	162,000
Curb and gutter	11,000
Striping	2,000
Traffic control	6,000
20% contingency	443,000
Subtotal	2,660,000
20% overhead and profit	540,000
TOTAL	$3,200,000

ALTERNATIVE 2
BIO-STIMULATION

This alternative involves the stimulation of the fuel utilizing bacteria present in the soil to speed up their rate of fuel utilization. This stimulation is accomplished by injecting water containing oxygen and nutrients into the soil. The increased oxygen and nutrient concentrations will allow the bacteria to increase to a significantly larger population which will utilize the fuel at a significantly higher rate. Studies have shown that the time required to biologically degrade the fuel can be shortened from an estimated 50 years for natural biodegradation to approximately 12 to 18 months using bio-stimulation methods.

Figure 9 illustrates the bio-stimulation system. The system consists of 14 injection trenches, spaced every 35 feet, with each trench containing a length of perforated 3-inch distribution piping. Water which contains oxygen and nutrients is conveyed, via a common header, to the distributing piping in each trench, from which it percolates into the subsoil. The elevations of the distribution piping in each trench are designed to create a slope in the groundwater table as shown in the section in Figure 9.

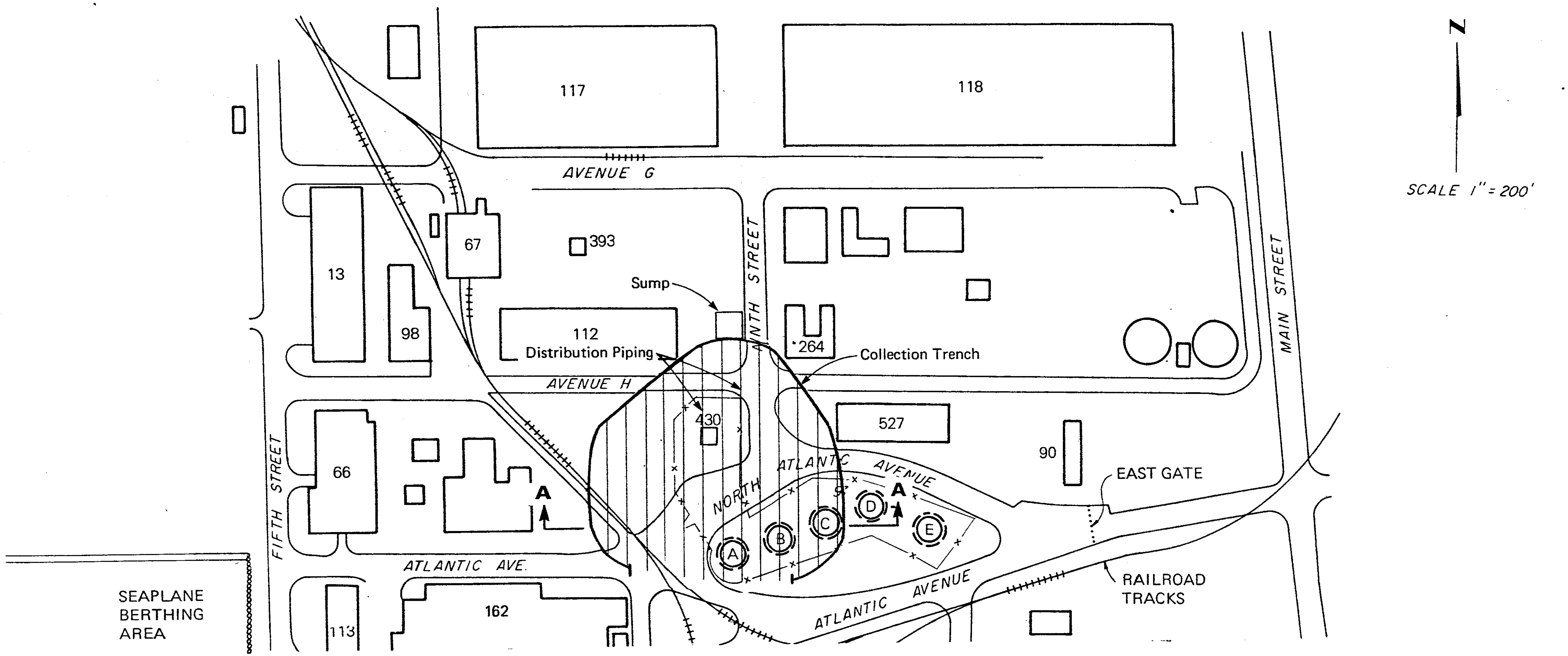
The recovery trench collects the water which has percolated through the soil and conveys it to a sump. The water in the sump is aerated and pumped back to the distribution piping. A batch tank is used to prepare a solution containing the necessary nutrients and a sidestream of this solution is added to the water pumped to the distribution piping.

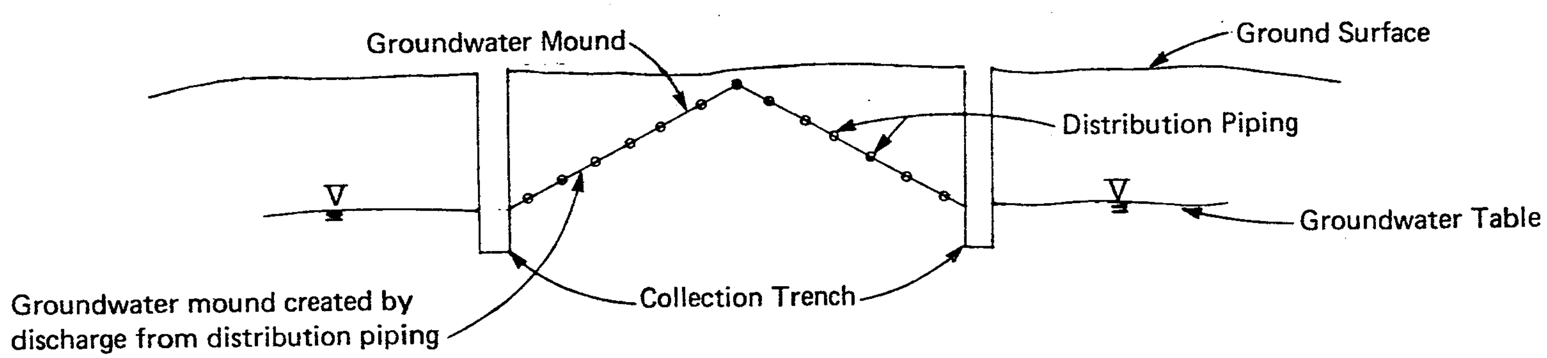
The laboratory analyses indicate that the nutrients required for biostimulation include nitrogen and phosphorus. These nutrients would be added to the batching tank in the form of ammonium sulfate and potassium phosphate.

It is estimated that operation of this system for approximately 18 months will degrade the majority of the fuel contained within the subsoil.

The estimated cost for installation, operation, and final closing down of the bio-stimulation system is $390,000. An additional $30,000 would be required for a thorough and detailed analysis of the study area in order to determine the parameters necessary to design and implement the system. The total estimated cost is $420,000. A cost breakdown is provided in Table 7.

The advantages of the bio-stimulation alternative are that it can be installed and operated without the expense and inconvenience of extensive excavation operations. A disadvantage of the system is the relatively long period of time required for operation of the system and the constant monitoring which would be necessary for effective and efficient system operation.





Section A

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Alternative 2: Bio-~~Simulation~~ Stimulation

Figure 9

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TABLE 7

ALTERNATIVE 2 - BIO-STIMULATION

COST ESTIMATE

1. Preliminary Study		
Total Cost		$ 30,000
2. Bio-Stimulation System		
Remove and replace paving	43,200	
Excavation and backfill	51,200	
Location and protection of utilities	50,000	
Piping and valves	30,400	
Sump	12,000	
Pump	5,000	
Aeration and chemical feed	5,000	
Batching tank and mixer	4,000	
Chemicals	3,000	
Potable water connection	3,000	
Electrical	3,500	
Monitoring	11,000	
Operation and maintenance	25,000	
Shutdown	25,000	
20% contingency	54,300	
Subtotal	325,600	
20% overhead and profit	64,400	
Total cost		390,000
TOTAL COST (items 1 and 2)		$420,000

ALTERNATIVE 3
VENTING OF UTILITIES

This alternative involves venting those subsurface utility lines which have exhibited high fuel vapor concentrations. Although no subsurface utilities in the vicinity of Area 97 exhibited fuel vapor concentrations in the explosive range, some readings were obtained above the threshold limit value. In addition, it is possible that fuel vapors could accumulate in some utility lines in concentrations in excess of the explosive limit under exceptional conditions. Since the only apparent danger associated with the fuel contamination in the subsoil is the potential for high concentrations of fuel vapors accumulating in the subsurface utility lines, venting the utility lines would eliminate the possibility of an explosion or adverse health effects resulting from breathing the vapors.

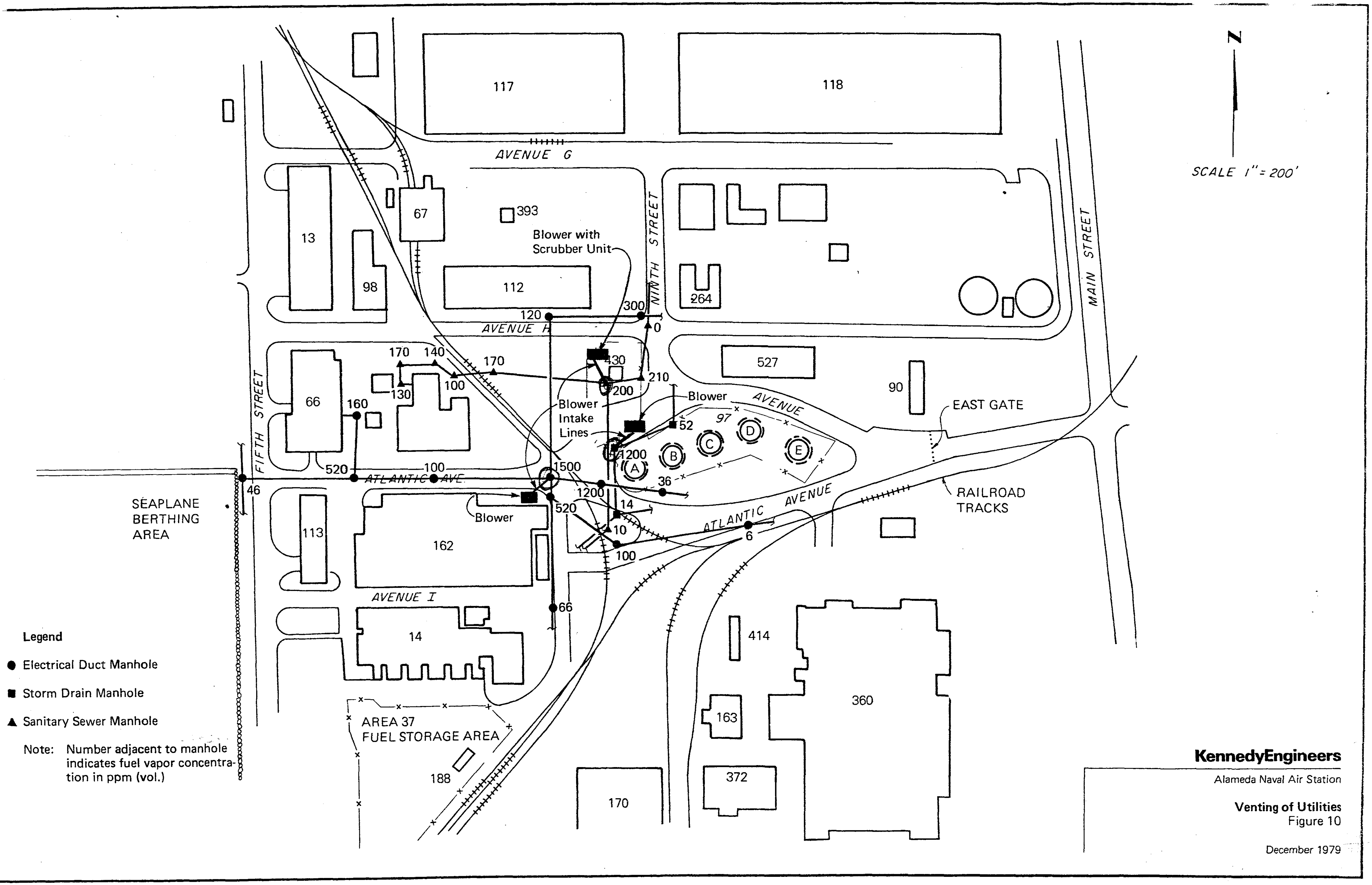
The utility lines which would require venting are the electrical duct immediately west of Area 97 and the storm drain and sanitary sewer lines immediately north of Tank A.

Fuel vapor concentrations have been detected in the electrical duct and storm drain lines in excess of the threshold limit value for gasoline and therefore present a health hazard to anyone breathing the vapors for a prolonged period of time. The sanitary sewer did not exhibit vapor readings in excess of the 500 ppm (vol.) threshold limit value; however, readings ranging from 100 to 210 ppm (vol.) were recorded over a significant reach of the sewer. This indicates a definite potential for the accumulation of vapors in concentrations exceeding the threshold limit value. The proximity of the sewer line to Area 97 also suggests a high potential for the accumulation of excessive vapor concentrations.

Each of the three utility lines would require a separate venting unit as illustrated in Figure 10. A venting unit consists of a blower to remove the vapors from the utility line and an exhaust stack to discharge the vapors to the atmosphere. The venting unit with scrubber for the sanitary line is approximately 5 by 7 feet by 6 feet in height and is mounted on an 8 by 10 foot concrete slab. Each blower inlet is connected to the utility line by an underground pipe.

The total estimated installed cost for three venting units is $60,000. A cost breakdown is provided in Table 8.

The advantages of this alternative are the elimination of the potential health and explosion hazard at a relatively low cost and in a relatively short period of time compared to Alternatives 1 and 2. A disadvantage of this alternative is that it will not eliminate the fuel contamination present in the subsoil, but will only eliminate the associated hazards until the fuel in the subsoil undergoes natural biodegradation over a period of years. However, investigations indicate that the presence of fuel in the subsoil and groundwater and the minor quantities of fuel entering the Bay via the groundwater constitute a negligible environmental impact.



Legend

- ● Electrical Duct Manhole
- ■ Storm Drain Manhole
- ▲ Sanitary Sewer Manhole

Note: Number adjacent to manhole indicates fuel vapor concentration in ppm (vol.)

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Venting of Utilities
Figure 10

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TABLE 8

ALTERNATIVE 3 - VENTING OF UTILITIES

COST ESTIMATE

500 CFM blower with scrubber unit	$16,000
Structural slab	1,000
500 CFM blower with pad, 2 each @ $2,000	4,000
Excavation, backfill, paving	3,700
Piping, tie-ins	10,500
Electrical	7,000
Fencing	1,000
15% contingency	7,000
Subtotal	50,200
20% overhead and profit	9,800
TOTAL	$60,000

ALTERNATIVE 4
NO PROJECT

A fourth alternative for dealing with the fuel contamination problem is to do nothing. No pooled fuel was found in the study area and there is no indication that the fuel remaining in the subsoil will spread beyond its present boundary. Fuel vapor readings for the subsurface utilities in the vicinity of Area 97 indicate that an explosion hazard does not exist, although the possibility remains that fuel vapors could accumulate in explosive concentrations under an exceptional set of circumstances. The fuel vapor concentration in five of the manholes exceeded the threshold limit value of 500 ppm (vol.) and therefore constitutes a health hazard to a person entering one of these manholes. This hazard could be overcome by venting the manhole using a portable blower if it became necessary to enter the manhole, and posting warning signs in the vicinity of the affected manholes.

The pellicular fuel contained in the subsoil will eventually, over a period of years, be degraded by the fuel utilizing bacteria in the soil and the potential health and explosion hazards will gradually diminish with time.

This alternative is, of course, the least expensive of the four alternatives, but leaves open the potential for personal injury due to explosion or breathing of fuel vapors.

APPARENT BEST ALTERNATIVE

The apparent best alternative for dealing with the fuel contamination problem is Alternative 3, venting of the utility lines. The total estimated cost for this alternative is $60,000.

This alternative combines the advantages of a relatively low cost with an effective means for eliminating potential hazards due to explosion or the breathing of fuel vapors.

This alternative will not promote the removal of fuel from the subsoil in the study area. However, the fuel will eventually be removed by the fuel utilizing bacteria in the soil over an estimated 50-year period. In the meantime, the presence of the fuel in the soil does not present an adverse environmental impact. The pellicular fuel is stationary and therefore does not threaten any adjacent areas which may be more environmentally sensitive. The groundwater in the study area is saline and is not used as a potable water source. Thus, the small amount of fuel which does become dissolved in the groundwater does not threaten a potable water source. It is estimated that the amount of fuel which will enter San Francisco Bay via the groundwater is a maximum of 14 pounds per year. Due to the relatively impermeable nature of the bay mud, it is highly probable that groundwater containing dissolved fuel will be limited to the layer of groundwater between the bay mud (average depth from ground surface of 8 feet) and the groundwater surface (average depth from ground surface of 5-1/2 feet).

APPENDIX A

SOIL INVESTIGATIONS

SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
ALAMEDA, CALIFORNIA

HLA Job No. 2176,044.04

Prepared for

Naval Facilities Engineering Command, Western Division
c/o Kennedy Engineers, Inc.
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San Francisco, California 94105

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December 4, 1979

INTRODUCTION

This report presents the results of our geotechnical investigation to evaluate the extent of subsurface fuel contamination near Area 97 at the Alameda Naval Air Station in Alameda, California. The area in which our investigation was conducted is shown on Plate 1, Site Plan. Background information was obtained from discussions with representatives from various utilities on the post and a set of utility drawings provided by the Navy.

The investigation was performed for Kennedy Engineers, Inc. The scope of our services was to explore the subsurface conditions in the area, define the extent of subsurface fuel contamination, and assist Kennedy Engineers, Inc. in developing a program which could be used to "clean up" the contaminated area. Specifically, we were to:

1. Drill 15 test borings, 10 to 15 feet deep, and install observation wells in each;

2. Perform sieve analyses, percent passing the #200 sieve, and permeability tests on undisturbed samples obtained from the test borings (the permeability tests were to be conducted using water and fuel typical of the contaminate encountered during our investigation);

3. Excavate three backhoe test pits at selected locations and obtain undisturbed samples of the soils encountered.

After drilling the 15 test borings, it was concluded that (1) more usefull information could be obtained from additional wells rather than from the proposed test pits and (2) since no pooled fuel was encountered, there was no need to perform permeability tests using fuel. Consequently, our scope was ammended to incorporate three additional observation wells and delete the fuel permeability tests.

BACKGROUND

Area 97 contains five, above-ground fuel storage tanks which have had fill placed around their perimeter. These tanks have been used principally for the storage of aviation gasoline (Avgas). The location of the tanks, labled A through E, are shown on Plate 1. Tanks A, B, C, and D were constructed in 1943 of reinforced concrete; tank E is of steel construction and was bult in 1962. Significant fuel leakage was detected by Navy personnel (estimated to be as high as 100,000 gallons per year for several years) which resulted in the abandonment of tanks A, C, and D in 1975 and tanks B and E in 1978. In 1972, approximately 200 feet north of tank A, a fuel line ruptured discharging an undetermined quantity of Avgas into the surrounding soils.

Evidence of this subsurface contamination has been observed west of Area 97 in several utility man holes and on the water surface near a storm drain outlet in the Seaplane Berthing Area. In addition, west of Area 97, two explosions have occurred in the past.

EXPLORATION AND TESTING

The subsurface conditions were explored by drilling 18 test borings ranging from 10 to 17 feet deep at the locations shown on Plate 1. Initially, approximately 33 tentative boring locations were approved by the Navy. Because only 18 borings were ultimately drilled, a discontinuous boring numbering system was necessary. Each boring was positioned and logged by one of our engineers. Detailed logs were prepared based upon a visual examination of the samples and laboratory test results. They are presented on Plates 2 through 10. All of the soils encountered were classified in accordance with the Unified Soil Classification System described on Plate 11.

Observation wells were constructed by inserting sections of three inch diameter PVC pipe in each boring. The lower section of the pipe was slotted in a manner which allowed groundwater and fuel to enter the pipe at any elevation. Individual slots were approximately five inches long and 1/8 inch wide. Installation of the wells was complicated by the loose sands beneath the area which caved into the hole as the auger was removed. Consequently, it was necessary to insert the PVC pipe into the hollow stem of the auger and then withdraw the auger sections, allowing the sand to collapse around the pipe. The upper portions of the borings which did not cave in were backfilled with pea gravel.

Undisturbed samples were tested for percent passing the #200 (0.074 mm) sieve, grain size distribution, and falling head permeability. The grain size distribution test results are presented on Plates 2 through 15, Particle Size Analyses; the other test results are summarized on the Boring Logs. All tests were performed in accordance with current ASTM standards* except for the falling head permeability tests for which no standard exists. These tests were performed in accordance with currently accepted soil engineering practice.

SUBSURFACE CONDITIONS

Our investigation indicates that the area is covered by a layer of sandy hydraulic fill ranging from 6 to 12 feet thick and averaging about 8 feet thick. The fill consists primarily of loose clean sand, and silty and clayey sands containing from 4 to 35 percent silt and clay size material. However, in some areas the fill consisted of medium stiff sandy clays and medium dense clayey gravels (Borings 34 and 21). Permeability tests performed on representative samples of the sandy fill indicate permeabilities ranging from about 4×10^{-3} to 4×10^{-4} centimeters per second (cm/sec). The sandy fill often contained relatively thin, discontinuous layers of silty clay. Beneath the fill is a relatively thin layer of soft to medium stiff clayey silt locally referred to as "Bay Mud". The Bay Mud is a marsh deposit which typically contains an abundant amount of organic matter and is highly impermeable.

*percent passing the #200 sieve, ASTM D1140-54
grain size distribution, ASTM D422-63

These marsh deposits were not observed in borings 18 and 35 which may mark the eastern extent of the marsh that once occupied the area. Underlying the Bay Mud are stiff sandy clays and dense clayey and silty sands.

Groundwater was encountered in all test borings at depths ranging from 4 to 7-1/2 feet below the ground surface. Groundwater elevations reveal that in general, flow is occurring toward the west and that a relative "low" exists along Atlantic Avenue near Area 97.

A distinct fuel odor was detected in six borings during drilling (borings 2, 3, 6, 14, 16 and 23). In all cases, the fuel odor eminated from the soil above the groundwater. The depths between which fuel odor was detected in the samples and cuttings are summarized below:

Observation Well/Test Boring Number	Approximate Depth Interval in Which Fuel Odor Was Detected (feet)
2	4-1/2 - 5-1/2*
3	3-1/2 - 5-1/2*
6	2 - 6*
14	1-1/2 - 5-1/2*
16	2 - 4*
23	3 - 6*

*Approximate depth to groundwater surface

In addition to a fuel odor, boring 6 encountered a black, tarry substance not typical of the contaminate found in the other borings.

CONCLUSIONS

The results of our investigation indicate that contamination of the subsurface soils exists in an area extending to the west and north of Area 97. Our estimate of the extent of contamination, as revealed by fuel odors, is shown on Plate 1. It is likely that the contaminated region is somewhat greater than that indicated. Chemical analyses of the groundwater and soils performed by Kennedy Engineers will better establish the extent of contamination.

We estimate, based upon measured groundwater elevations and permeability test results, that groundwater seepage is occurring toward the west at velocities less than 0.1 feet per day. This slow, but steady seepage is probably responsible for transporting the liquid fuel away from Area 97 as no pooled fuel was found near the tanks nor in the vicinity of the pipeline rupture. What appears to remain are relatively high concentrations of fuel suspended in the soil above the groundwater in the form of a coating on the soil particles. Fuel removal from the area may have been accelerated by seepage into leaking utility pipe joints along Atlantic Avenue. If the contamination has entered the groundwater, we believe that only the water situated above the bay mud would be affected because of the low permeability of these marsh deposits.

We understand that three alternatives are being considered to clean up the contamination problem. They are:

1. Excavation and removal of the contaminated soil;
2. Biodegradation of the contaminant;
3. Venting of the underground utilities in the area.

The excavation and biodegradation alternatives will in effect eliminate the contaminated soils; the venting alternative will not remove the contaminate but rather prevent high concentrations of fuel vapor from accumulating in utility manholes, underground plumbing, etc. We have consulted with Kennedy Engineers, Inc. throughout the study regarding the geotechnical aspects of these alternatives, particularly with regard to the biodegradation scheme. In addition, we have talked with Groundwater Associates, Inc. of Westerville, Ohio, a firm that is experienced in the groundwater hydraulics of the biodegradation system.

The excavation and removal alternative is an option that could be accomplished using conventional earthmoving equipment; however, excavation would be complicated by the presence of numerous underground utilities. Temporary cut slopes in the sandy fill should be 1:1 (horizontal to vertical) or flatter.

Biodegradation of the contaminant can be accomplished using bacteria capable of consuming the fuel. To do so, the groundwater table in the area would be raised to inundate the contaminated soils; typically this is done using injection wells, lines, or by ponding. Oxygen and nutrients are mixed with the injection water to insure a large active bacteria community. Subdrains or wells are typically positioned around the perimeter of the area to recover the bacteria laden groundwater and re-inject it into the system.

Based upon analyses we have performed and our discussions with Groundwater Associates, Inc., our conclusions regarding the geotechnical aspects of the biodegradation scheme are:

1. Raising the groundwater surface can most economically be accomplished using a series of injection wells or linear injection lines. From a practical standpoint, well or line spacings between 25 and 50 feet will probably be required.

2. The wells and/or drains should be backfilled with a well graded sand/gravel mix to reduce the liklihood of the sandy fill infiltrating and clogging the injection and collection systems.

3. Relatively large quantities of injection water will be required to continually inundate the contaminated soils. Sufficient quantities can probably be recovered from a continuous drain around the perimeter of the treated area.

4. By increasing the height of the groundwater table, the gradient under which flow occurs will increase. The seepage flow velocities will vary, primarily depending upon the distance from the injection points and the local soil conditions. Based upon our judgement and the site conditions, we believe that average seepage velocities on the order of 0.3 to 0.5 feet per day will be generated.

We emphasize that these conclusions are general ones and should only be used in conceptual planning. Detailed field, laboratory, and engineering analyses should be performed to develop final design criteria.

LIST OF ILLUSTRATIONS

DISTRIBUTION

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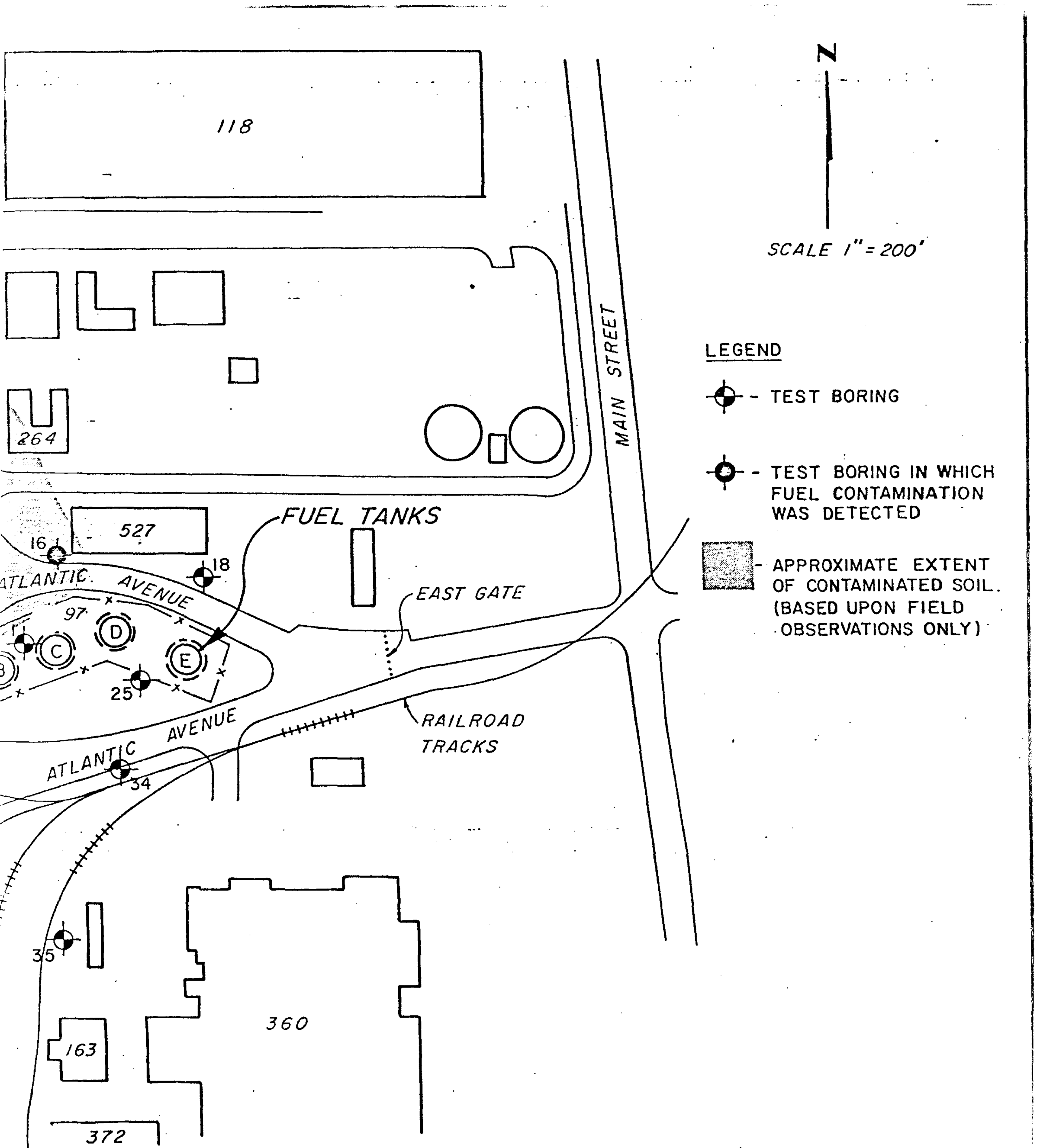

HARDING - LAWSON ASSOCIATES

Consulting Engineers and Geologists

Job No. 2176,044.04 Appr: [signature] Date 9-13-79

SITE PLAN

SUBSURFACE FUEL CONTAMINATION STUDY

ALAMEDA NAVAL AIR STATION

Alameda California

PLATE

1

RF 15

LOG OF BORING 1

Equipment: 8" Hollow Auger
Elevation: 113.1 Feet* Date: 8/28/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot**	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Description
						0	BROWN SILTY SAND(SM) loose to medium dense, moist (FILL)
							GRAY GREEN SILTY SAND(SM) loose, wet, occasional thin clay lenses (FILL)
						5	water level 10/19/79
			1				DARK GRAY CLAYEY SILT(MH) soft, saturated (Bay Mud)
						10	GREEN BROWN SILTY SAND(SM) loose, saturated
			6				
						15	
20% - #200			29				color change to brown; becomes dense below 15 Feet

LOG OF BORING 2

Equipment: 8" Hollow Auger
Elevation: 112.8 Feet Date: 8/28/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot**	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Description
						0	BROWN SILTY SAND(SM) medium dense, moist (FILL)
							water level 10/19/79
			15			5	BROWN CLAYEY GRAVELLY SAND(SC) medium dense, saturated gravel to 3" (FILL)
			12				GRAY CLAYEY SILT(MH) soft, saturated (Bay Mud)
						10	
			10				BLUE GRAY CLAYEY SAND(SC) medium dense, saturated
						15	

NOTE: Slight Fuel Odor Detected Near the Ground Water Surface.

*Alameda NAS Datum

**Blow counts have been converted to standard penetration values.

HARDING - LAWSON ASSOCIATES
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Job No. 2176,044.04 Appr: [signature] Date 10/15/79

LOG OF BORINGS 1 & 2
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE 2

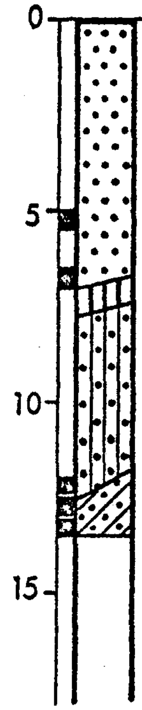
RF 15

LOG OF BORING 3

Equipment 8" Hollow Auger

Elevation 113.1 Feet Date 8/29/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
			4			5	
			2				
			7				



BROWN SAND(SP)
medium dense, moist, with occasional gravel and clay pockets

FILL

▽ water level 10/19/79

GRAY CLAYEY SILT(MH)
soft, saturated (Bay Mud?)

DARK GRAY SILTY SAND(SM)
loose, saturated

DARK BROWN CLAYEY SAND(SC)
loose, saturated

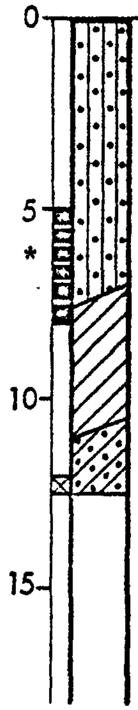
NOTE: Fuel Odor Detected
Between 2.5 and 5.5 Feet

LOG OF BORING 6

Equipment 8" Hollow Auger

Elevation 113.5 Feet Date 8/29/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
SIEVE ANALYSIS* 25% - #200			5			5 *	
			2				



BROWN SILTY SAND(SM)
loose to medium dense, moist

interbedded layers of light gray silty clay

FILL

▽ water level 10/19/79

black oily substance mixed with sand @ 6 Feet

LIGHT GRAY-BLACK SILTY CLAY(CL)
soft, saturated (Bay Mud ?)

GREEN BROWN CLAYEY SAND(SC)
medium dense, saturated

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LOG OF BORINGS 3 & 6
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE 3

RF 15

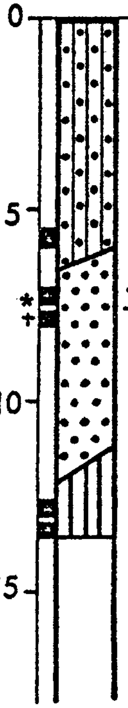
LOG OF BORING 8

Equipment 8" Hollow Auger

Elevation 113.8 Feet Date 8/29/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	Description
						0		ORANGE BROWN SILTY SAND(SM) medium dense to loose, moist
			8			5		
SIEVE ANALYSIS* 35% - #200			4	18.0	104		* +	BLUE GRAY SAND (SM-SP) loose, saturated, with interbedded layers of gray silty clay
PERMEABILITY* $k = 4 \times 10^{-3}$ cm/sec.						10		water level 10/19/79
SIEVE ANALYSIS+ 13% - #200			1					BLUE GRAY CLAYEY SILT(MH) soft, saturated (Bay Mud)
						15		

FILL (0 to approx. 11.5 ft)



LOG OF BORING 12

Equipment 8" Hollow Auger

Elevation 113.5 Feet Date 8/30/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	Description
						0		BROWN CLAYEY SAND(SC) loose to medium dense, moist
			5			5		water level 10/19/79
								saturated below 6.5 Feet
						10		BLUE GRAY CLAYEY SILT(MH) soft, saturated (Bay Mud)
			6					BLUE GRAY CLAYEY SAND(SC) medium dense, saturated
						15		

FILL (0 to approx. 9 ft)

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LOG OF BORINGS 8 & 12
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE 4

RF 15

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample

LOG OF BORING 14

Equipment 8" Hollow Auger
Elevation 113.3 Feet Date 8/28/79

Laboratory Tests	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)
				0
12% - #200*	8			5
PERMEABILITY† k = 3.8 X 10^{-4} cm/sec. SIEVE ANALYSIS† 21% - #200	3	24.3	97	
				10
	8			
				15

ORANGE BROWN SILTY SAND(SM-SP)
loose to medium dense, moist
GRAY SILTY CLAY(CL)
soft, wet
ORANGE BROWN SAND(SP)
medium dense, moist
ORANGE BROWN CLAYEY SAND(SC)
medium dense, saturated
GRAY CLAYEY SILT(MH)
soft, saturated (Bay Mud)
water level 10/19/79
BROWN SILTY SAND(SM)
medium dense, saturated

FILL

NOTE: Fuel Odor Detected
Between 1.5 and 5.5 Feet

LOG OF BORING 16

Equipment 8" Hollow Auger
Elevation 113.0 Feet Date 8/29/79

Laboratory Tests	Blows/foot	Depth (ft)
		0
		5
	2*	
	2*	
SIEVE ANALYSIS 18% - #200	8	10
		15

ORANGE BROWN SILTY SAND(SM)
medium dense, moist
water level 10/19/79
BLUE GRAY CLAYEY SAND(SC)
loose, saturated
BLUE GRAY CLAYEY SILT(MH)
soft, saturated (Bay Mud)
BROWN CLAYEY SAND(SC)
loose to medium dense, saturated

FILL

NOTE: Fuel Odor Detected
Between 2 and 4 Feet

*Attempted to sample, no recovery

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LOG OF BORINGS 14 & 16
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE 5

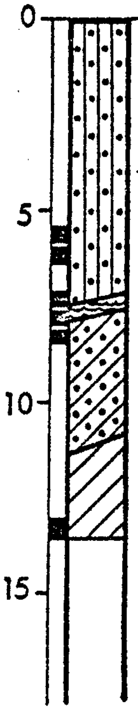
RF 15

LOG OF BORING 18

Equipment 8" Hollow Auger

Elevation 112.4 Feet Date 8/30/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)
30% - #200			3			
			3			
			8			



BROWN SILTY SAND(SM-SP)
medium dense, moist with interbedded layers of blue-gray clay
water level 10/19/79

FILL

BROWN CLAYEY PEAT(Pt)
soft, saturated

BLACK CLAYEY SAND(SC)
loose, saturated, contains organic material, color change to green-brown at 9 Feet

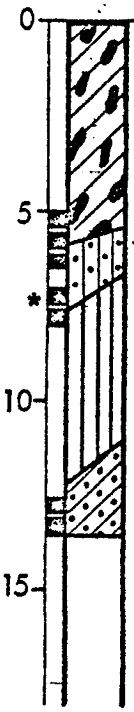
MOTTLED ORANGE-BROWN SANDY CLAY(CL)
medium stiff to stiff, saturated

LOG OF BORING 21

Equipment 8" Hollow Auger

Elevation 112.7 Feet Date 8/30/79

Laboratory Tests	Blows/foot
	14
SIEVE ANALYSIS* 27% - #200	4
	24



BROWN GRAY CLAYEY SANDY GRAVEL(GC)
medium dense, moist

FILL

water level 10/19/79

BROWN SILTY SAND(SM)
medium dense, saturated

GRAY CLAYEY SILT(MH)
soft, saturated (Bay Mud)

ORANGE BROWN CLAYEY SAND(SC)
medium dense, saturated

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LOG OF BORINGS 18 & 21
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE 6

RF 15

LOG OF BORING 23

Equipment: 8" Hollow Auger

Elevation: 113.3 Feet Date: 8/28/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	Description
						0		BROWN SILTY SAND(SM) loose, dry, becomes moist @ 1.5 Feet
								color change to blue-gray
						5		water level 10/19/79
			25					ORANGE BROWN SILTY SAND(SM) dense, moist
16% - #200			1					BLUE GRAY SILTY SAND(SM) loose, saturated, fine grained, contains occasional thin layers of gray clay
						10		
25% - #200*			15				*	ORANGE BROWN SANDY CLAY(CL) stiff, saturated
						15		

FILL (0 to approx. 8 ft)

NOTE: Fuel Odor Detected Between 3 and 6 Feet

LOG OF BORING 25

Equipment: 8" Hollow Auger

Elevation: 113.1 Feet Date: 8/29/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	Description
						0		BROWN CLAYEY SAND(SC) medium dense, moist
						5		water level 10/19/79
			3					
31% - #200*			4				*	DARK GRAY CLAYEY SILT(MH) soft, saturated (Bay Mud)
						10		
								ORANGE BROWN CLAYEY SAND(SC) medium dense to dense, saturated
			20					
						15		

FILL (0 to approx. 6 ft)

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LOG OF BORINGS 23 & 25

SUBSURFACE FUEL CONTAMINATION STUDY

ALAMEDA NAVAL AIR STATION

Alameda California

PLATE 7

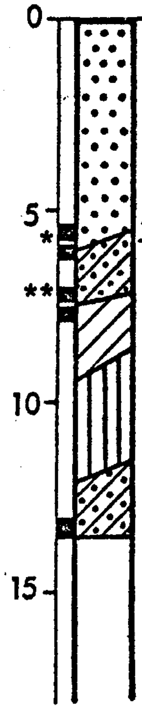
RF 15

LOG OF BORING 28

Equipment 8" Hollow Auger

Elevation 113.8 Feet Date 8/30/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
5% - #200*			5				*
18% - #200**			8				**
			15				



ORANGE BROWN SAND(SP)
medium dense to loose, moist

water level 10/19/79

ORANGE BROWN CLAYEY SAND(SC)
loose to medium dense, moist

BLUE GRAY GRAVELLY SANDY CLAY(CL)
medium stiff, saturated

FILL

BLUE GRAY CLAYEY SILT(MH)
soft, saturated (Bay Mud)

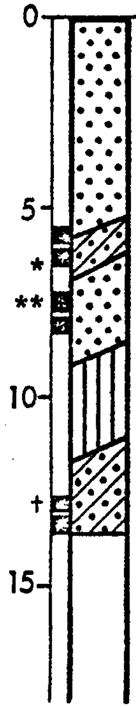
ORANGE BROWN CLAYEY SAND(SC)
medium dense, saturated

LOG OF BORING 32

Equipment 8" Hollow Auger

Elevation 114.2 Feet Date 8/29/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
SIEVE ANALYSIS* 4% - #200			12				*
15% - #200**			13				**
22% - #200+			23				+



ORANGE BROWN GRAVELLY SAND(SP)
medium dense, moist, gravel to 1"

water level 10/19/79

BLUE GRAY CLAYEY SAND(SC)
medium dense, saturated

BROWN SAND(SP-SM)
medium dense, saturated

FILL

BLUE GRAY CLAYEY SILT(MH)
soft, saturated (Bay Mud)

ORANGE BROWN CLAYEY SAND(SC)
medium dense to dense, saturated

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Job No. 2176,044.04 Appr: [signature] Date 10/15/79		

RF 15

LOG OF BORING 34

Equipment: 8" Hollow Auger

Elevation: 112.6 Feet Date: 8/30/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	Description
						0		BROWN GRAVELLY SANDY CLAY(CL) medium stiff, moist, gravel to 1/2 Inch occasional sandy layers (FILL)
						5		water level 10/19/79
40% - #200			4					thin layer of organic matter @6.5 Feet
			push					GRAY CLAYEY SILT(MH) soft, saturated (Bay Mud)
						10		ORANGE BROWN CLAYEY SAND(SC) dense, saturated
			22					
						15		

LOG OF BORING 35

Equipment: 8" Hollow Auger

Elevation: 113.6 Feet Date: 9/13/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample	Description
						0		ORANGE BROWN CLAYEY SAND(SC) medium dense, moist, with occasional gravel (FILL)
								GREEN BROWN SAND(SP) medium dense, moist (FILL ?)
						5		BLACK SILTY SAND(SM) loose to medium dense, moist; water level 10/19/79
			6					
						10		
			13					color change to brown @ 11.5 Feet
						15		

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LOG OF BORINGS 34 & 35
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE 9

RF 15

LOG OF BORING 36

Equipment: 8" Hollow Auger
Elevation: 113.4 Feet Date: 9/13/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
9% - #200			20				

Depth scale: 0, 5, 10, 15

- ORANGE BROWN CLAYEY SAND(SC) medium dense, moist
- BROWN SAND(SP) medium dense, moist with occasional gravel
- ▽ water level 10/19/79
- GREEN BROWN SILTY SAND(SM) moderately dense, saturated
- GRAY CLAYEY SILT(MH) soft, saturated,(Bay Mud)

FILL

LOG OF BORING 37

Equipment: 8" Hollow Auger
Elevation: 113.0 Feet Date: 9/13/79

Laboratory Tests	Drill Rate (min/ft)	Drill Pressure (psi)	Blows/foot	Moisture Content (%)	Dry Density (pcf)	Depth (ft)	Sample
			14*				

Depth scale: 0, 5, 10, 15

- ORANGE BROWN SILTY SAND(SM) loose to medium dense, moist with occasional gravel
- BROWN SAND(SP) medium dense, moist, fine grained
- ▽ water level 10/19/79
- GRAY GREEN SILTY SAND(SM) medium dense, saturated
- GRAY CLAYEY SILT(MH) soft, saturated (Bay Mud)

FILL

*Attempted to sample, no recovery

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LOG OF BORINGS 36 & 37
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE 10

MAJOR DIVISIONS				TYPICAL NAMES
COARSE GRAINED SOILS (MORE THAN HALF IS LARGER THAN #200 SIEVE)	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE SIZE	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW	WELL GRADED GRAVELS, GRAVEL - SAND MIXTURES
			GP	POORLY GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH OVER 12% FINES	GM	SILTY GRAVELS, POORLY GRADED GRAVEL - SAND - SILT MIXTURES
			GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL - SAND - CLAY MIXTURES
	SANDS MORE THAN HALF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS - WITH LITTLE OR NO FINES	SW	WELL GRADED SANDS, GRAVELLY SANDS
			SP	POORLY GRADED SANDS, GRAVELLY SANDS
		SANDS WITH OVER 12% FINES	SM	SILTY SANDS, POORLY GRADED SAND - SILT MIXTURES
			SC	CLAYEY SANDS, POORLY GRADED SAND - CLAY MIXTURES
FINE GRAINED SOILS (MORE THAN HALF IS SMALLER THAN #200 SIEVE)	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS, OR CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC CLAYS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS, AND CLAYS LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACIOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS

UNIFIED SOIL CLASSIFICATION SYSTEM

Consol — Consolidation	*Tx	320	(2600)	Unconsolidated Undrained Triaxial	
LL — Liquid Limit (in %)	TxCU	320	(2600)	Consolidated Undrained Triaxial	
PL — Plastic Limit (in %)	DS	2750	(2000)	Consolidated Drained Direct Shear	
G_s — Specific Gravity	FVS	470		Field Vane Shear	
SA — Sieve Analysis	*UC	2000		Unconfined Compression	
■ "Undisturbed" Sample	LVS	700		Laboratory Vane Shear	
⊠ Bulk Sample					

(Column values: Shear Strength, psf; Confining Pressure, psf)

Notes: (1) All strength tests on 2.8" or 2.4" diameter samples unless otherwise indicated.

(2) * Indicates 1.4" diameter sample.

KEY TO TEST DATA

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SOIL CLASSIFICATION CHART AND KEY TO TEST DATA
ALAMEDA NAVAL AIR STATION

PLATE 11

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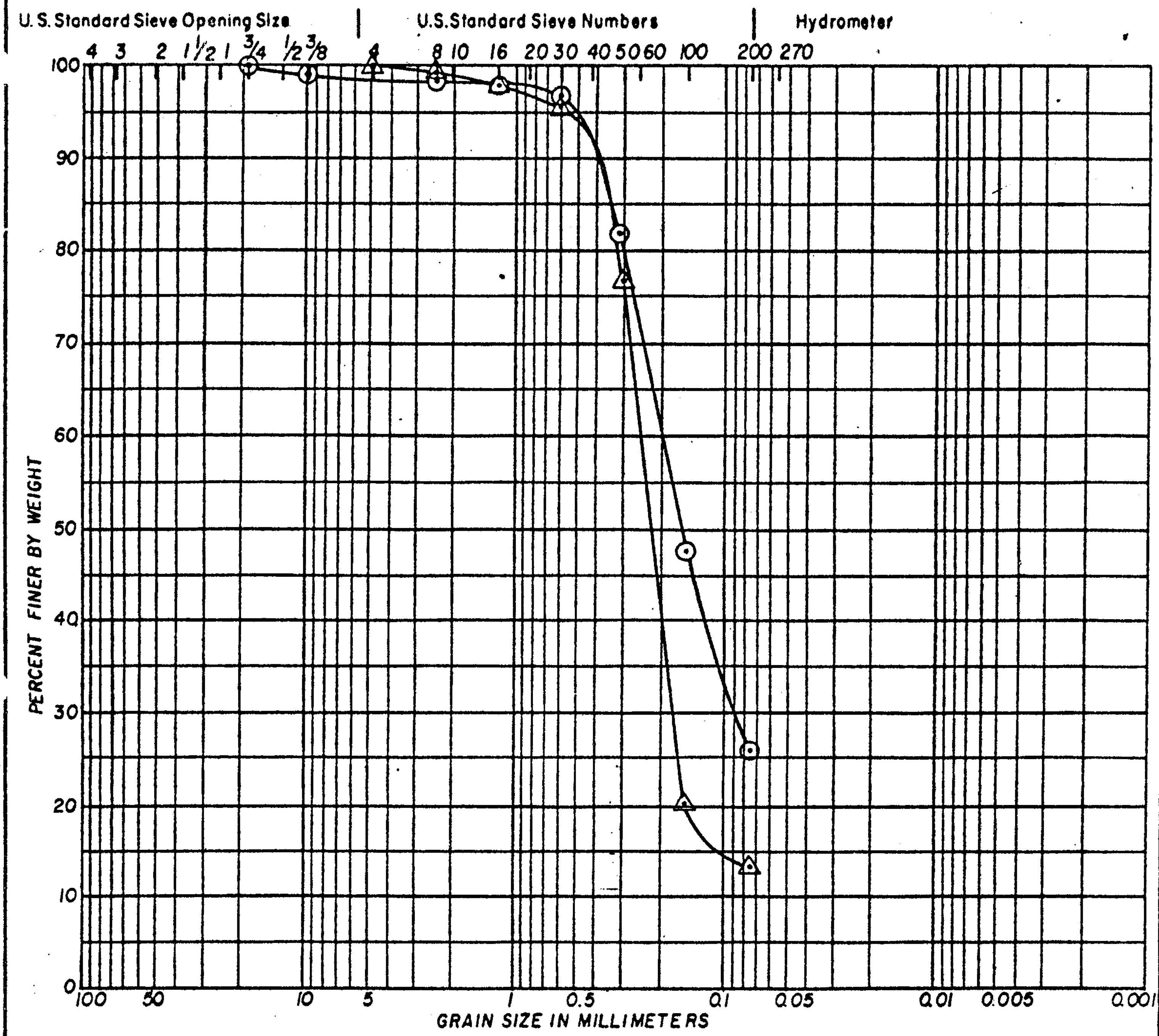

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
⊙	BORING 6 @ 6.5'	BROWN SILTY SAND (SM)
△	BORING 8 @ 7.0'	GRAY SILTY SAND (SM)

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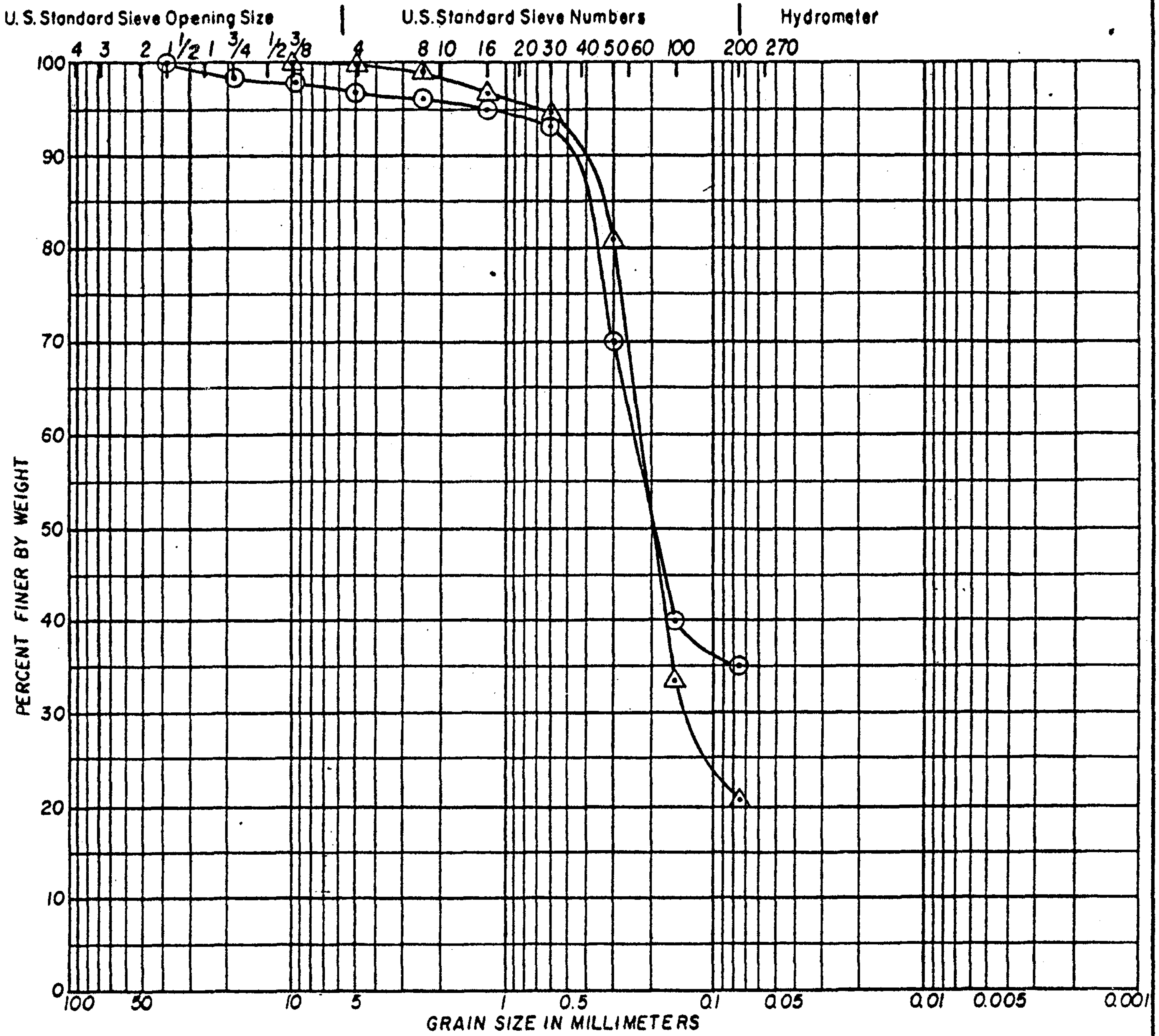
PARTICLE SIZE ANALYSIS
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE **12**



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
⊙	BORING 8 @ 7.5'	BROWN GRAVELLY CLAYEY SAND (SC)
△	BORING 14 @ 6.8'	GRAY CLAYEY SAND (SC)

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PARTICLE SIZE ANALYSIS

SUBSURFACE FUEL CONTAMINATION STUDY

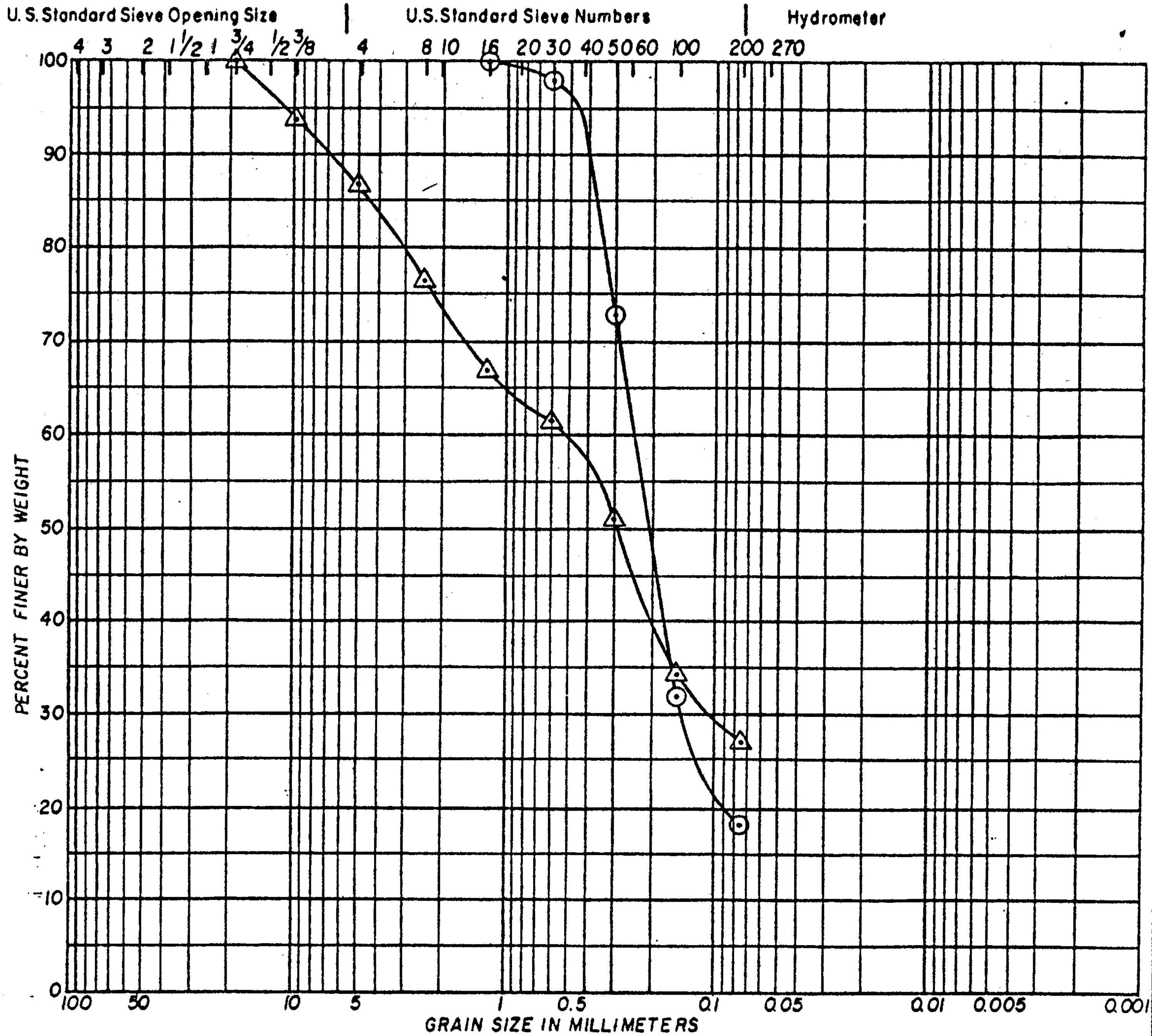
ALAMEDA NAVAL AIR STATION

Alameda California

PLATE

13

Rr 24



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
⊙	BORING 16 @ 10.5'	BROWN CLAYEY SAND (SC)
△	BORING 21 @ 7.0'	BROWN GRAVELLY SILTY SAND (SM)

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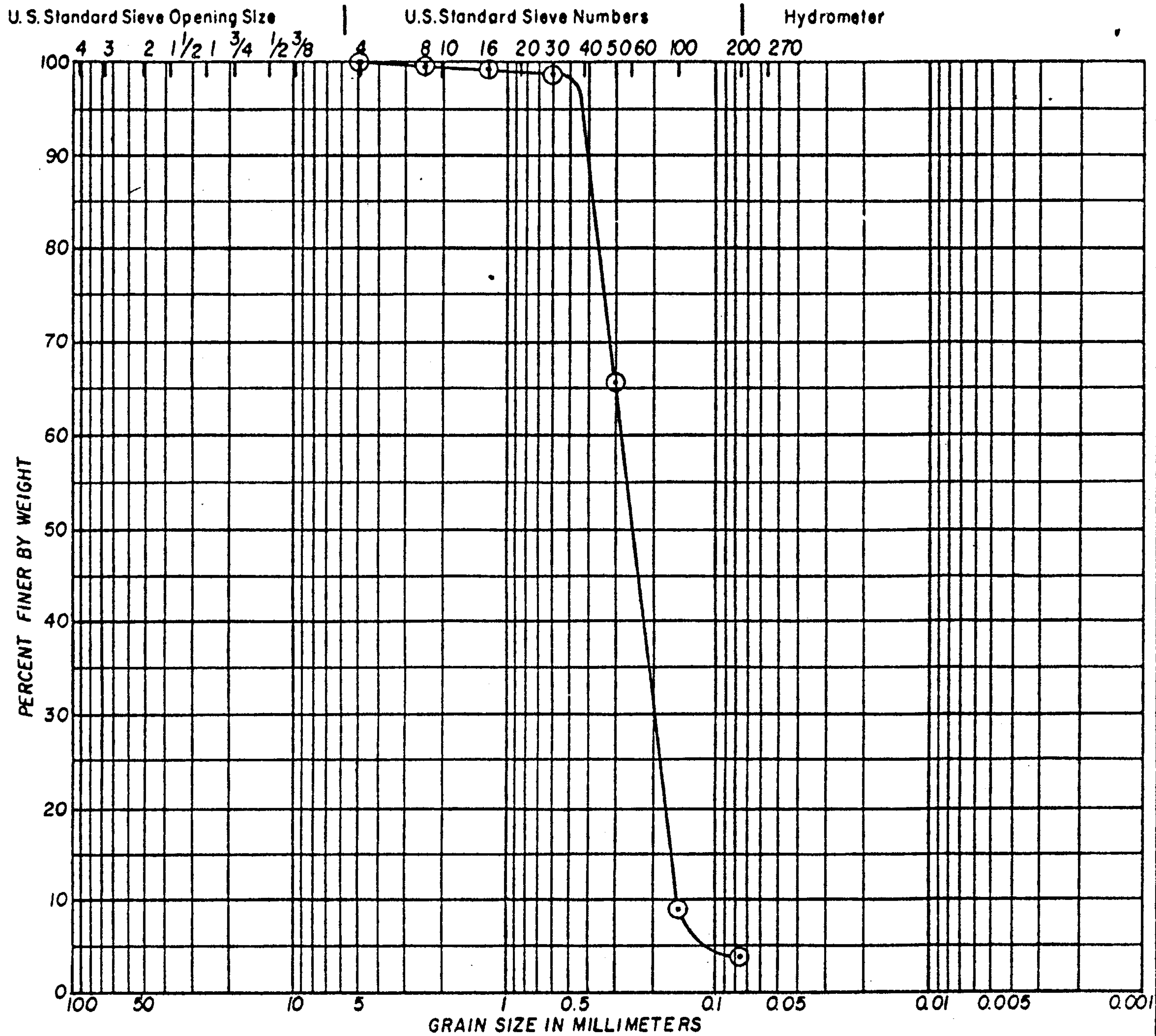
PARTICLE SIZE ANALYSIS
SUBSURFACE FUEL CONTAMINATION STUDY
ALAMEDA NAVAL AIR STATION
Alameda California

PLATE 14



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Symbol	Sample Source	Classification
⊙	BORING 32 @ 6.0'	BROWN SAND (SP)

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PARTICLE SIZE ANALYSIS

SUBSURFACE FUEL CONTAMINATION STUDY

ALAMEDA NAVAL AIR STATION

Alameda California

PLATE 15