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EXTENT OF SUB-SURFACE FUEL CONTAMINATION
OCEANA NAVAL AIR STATION

FOR:

NAVAL AIR STATION, OCEANA
VIRGINIA BEACH, VIRGINIA

BY:

R. E. WRIGHT ASSOCIATES, INC.
3240 SCHOOLHOUSE ROAD
MIDDLETOWN, PENNSYLVAIA 17057

FEBRUARY, 1983

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February 1983

Respectfully submitted,

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TABLE OF CONTENTS

Figures

Appendices

EXTENT OF SUB-SURFACE FUEL CONTAMINATION
OCEANA NAVAL AIR STATION

Contract N62470-82-B7800

INTRODUCTION

This report describes a hydrogeologic investigation which was conducted to delineate the extent of subsurface fuel contamination at the Oceana Naval Air Station, and to determine appropriate response procedures. The investigation was initiated in part because of the suspected occurrence of fuel in the subsurface near certain fuel facilities at the base, resulting from leaks and spills. The actual extent and environmental threat posed by such fuel has not been previously known, however.

Thus, it was desired to determine the following things about those facilities where some potential for subsurface fuel occurrence was thought to exist:

* If and where fuel does occur in the subsurface.
* Whether it is mobile or potentially mobile.
* Whether the occurrence of such fuel poses any short-term risk to safety and health.
* Whether the occurrence of fuel poses any other significant environmental threat.
* What remedial actions are appropriate.

The locations of the investigated fuel facilities are shown in Figure 1. Above-ground and underground leakage is known to have occurred at the Day Tank, Test Cells, and Tank Farm. Some potential for periodic leakage was thought to exist at the Fire Training Area. Also, some potential was thought to remain at the Abandoned North Station Tank Farm (Figure 1).

The approach of this study has been to acquire as much existing information as possible regarding subsurface conditions at each of these five sites. Based on this, field investigations were conducted to gather more definitive information. The results of these investigations were then evaluated in order to characterize the significant conditions at each site. In light of the results, possible remedial actions were evaluated for those areas where substantial subsurface fuel does occur.

The following section of this report will describe in more detail the methods of investigation that were employed at each of the sites. Subsequent sections will describe the following for each site:

* The history of pertinent operations and known fuel leaks and spills.

* Methods of investigation that were unique to each site.

* Results of the subsurface investigation.

* The degree to which fuel occurs in the subsurface, how mobile it is, and what type of threat it poses.

* What remedial action is warranted.

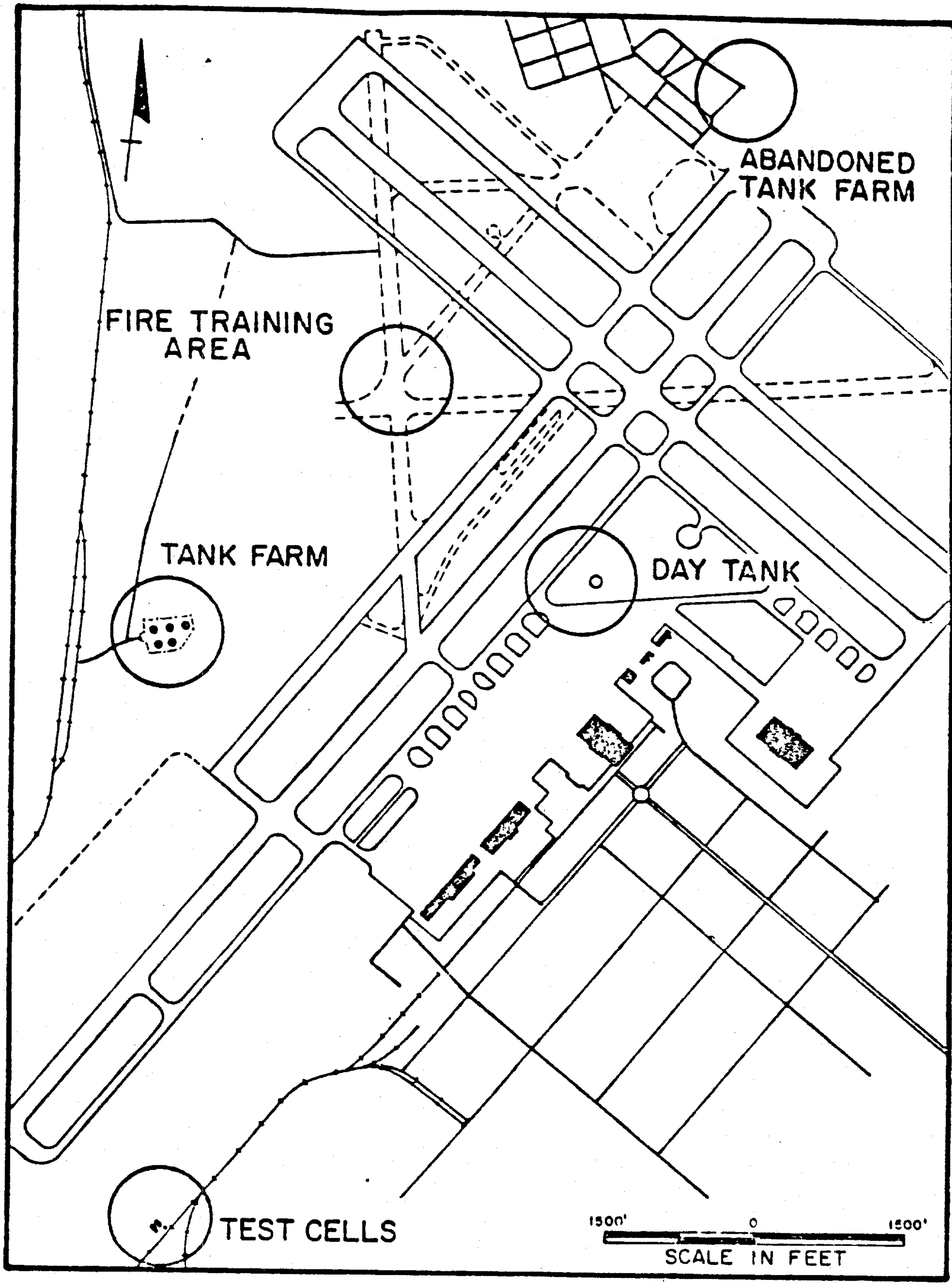

Figure 1: Fuel facilities at the Oceana Naval Air Station which were investigated for subsurface fuel occurrence.

METHODS OF SUBSURFACE INVESTIGATION

Based on prior knowledge of site conditions, backhoe pits, test borings and monitoring wells were installed at selected points at the five sites. These facilitated the direct observation of subsurface conditions and provided the means by which to measure and sample.

Backhoe Pits

Backhoe pits are simple excavations that are typically about 10 feet long, 4 feet wide and as deep as subsurface or machine limitations permit. They are a rapid, inexpensive means to qualitatively determine subsurface conditions; results from them were used in the early part of the investigation to guide the location of test borings and monitoring wells. Additionally, they permitted the description of some subsurface conditions that cannot be determined with test borings and monitoring wells. These typically included the nature of layer interfaces, soil structure, and perched groundwater conditions.

In this investigation 13 backhoe pits were dug at the five sites based on the anticipated locations of potentially occurring subsurface fuel. The locations were largely based on the position of specific fuel facilities such as tanks and buried pipelines. Subsurface conditions were described from the visual observation of pit walls, grab samples, and groundwater. Descriptive logs from each backhoe pit are provided in Appendix A.

Standpipes were installed in some backhoe pits prior to backfilling. The standpipes consisted of 4-inch seepage-bed pipe which was constructed of thin-wall perforated PVC. Each was capped at the bottom and wrapped with burlap in an attempt to prevent an excessive influx of sediment through the perforations. The standpipes were placed vertically in open backhoe pits; the pits were then backfilled to the surface. Two standpipes were installed near the Day Tank, two in the Fire Training Area, and two near the Test Cells.

Test Borings and Monitoring Wells

In this investigation, it is assumed that test borings are drilled holes where sediment samples have been taken; monitoring wells are the small diameter well screens and casings (pipes) that are placed in the borings to permit sampling and measurements to be made of subsurface fluids. Monitoring wells were installed in all of the test borings made during this investigation.

Test borings and monitoring wells were located based on the anticipated occurrence of subsurface fuel, as indicated by the results of the backhoe pit investigations. The borings were advanced to a depth of approximately 20 feet with hollow-stem augers and continuous split-spoon sampling. All split-spoon samples were described immediately after recovery in terms of sediment characteristics, moisture content, and degree of fuel odor. Test boring logs are presented in Appendix B.

A schematic monitoring well design is illustrated in Figure 2. In the initial part of well construction, after the hollow-stem augers had been removed from the borehole, a 4-inch diameter pipe was inserted to keep the hole open. Each boring was then backfilled with well-sorted coarse sand to a depth that permitted the well to be screened above and below the expected high water table level. A 10-foot-long by 2-inch diameter

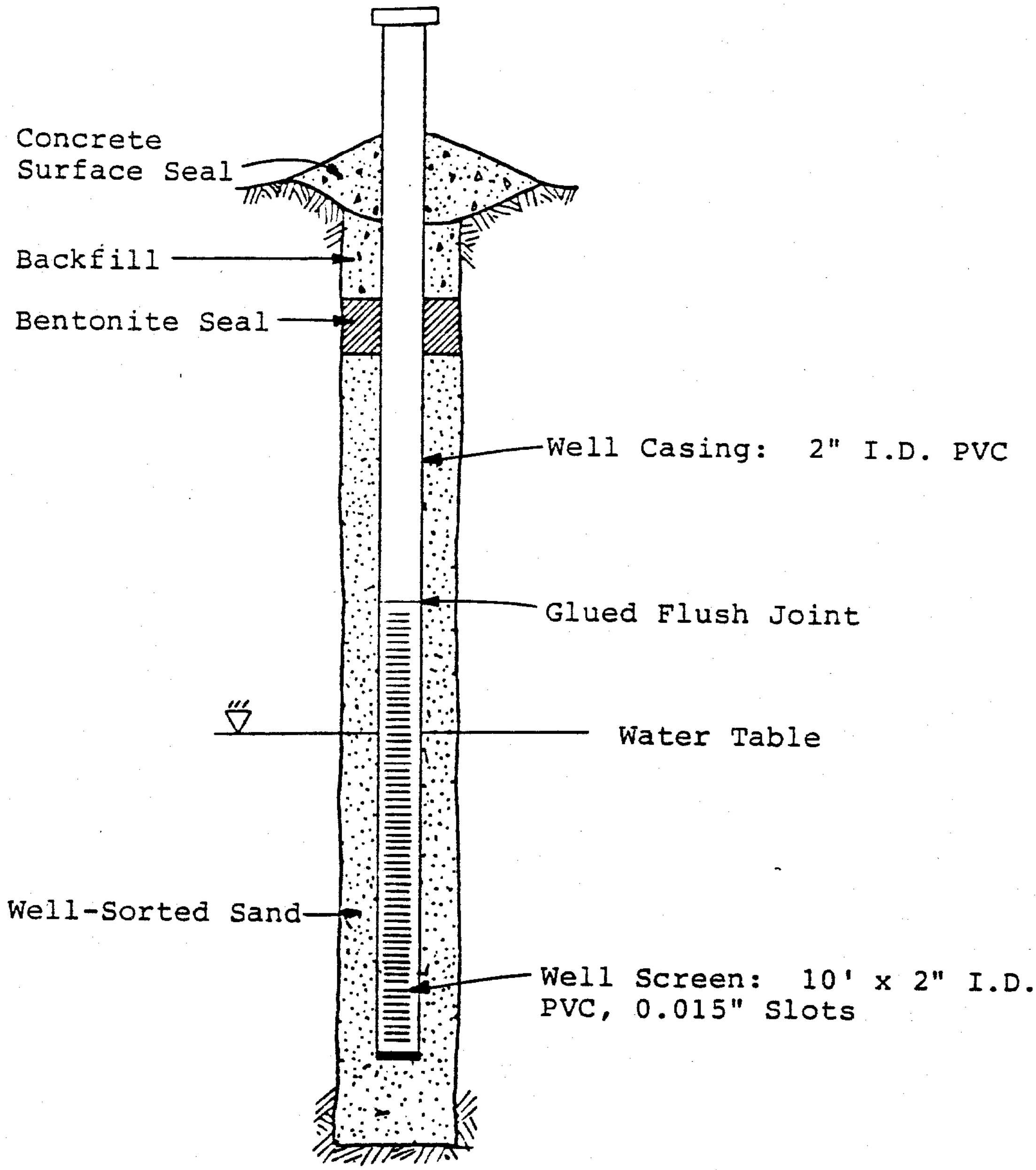

Figure 2: Schematic Monitoring Well Design

section of well screen was then installed in the borehole and backfilled with well-sorted coarse sand.

During the backfilling process, the 4-inch casing was removed gradually to prevent the collapse of natural sediments onto the well screen. Approximately 0.5-foot of well-sorted sand was placed above the top of the screen. A bentonite seal was then installed and the remainder of the hole was backfilled with concrete. The monitoring wells installed near the Test Cells were covered with 6-inch protective steel casings with locking caps, which were concreted in. At other monitoring wells, the 2-inch PVC casing sticks up one to 2 feet above the ground surface.

Monitoring Well Testing

The occurrence of fuel in backhoe-pit sediments and split-spoon samples was checked visually and by smelling the samples. Generally, odor is a more reliable qualitative indicator since small amounts of fresh fuel in soil tend to appear like water. Sediment containing small amounts of fuel commonly cannot be visually distinguished from those containing water. Five split-spoon samples and one water sample were analyzed quantitatively for fuel concentration by a local laboratory. The results will be discussed in a subsequent part of this report.

The occurrence of free-floating fuel on the water table was determined with a transparent bailer and with fuel and water-sensitive paste. The paste changes color in response to the occurrence of water and fuel, permitting the measurement of fuel thickness on a tape measure which has been lowered into the well.

Water-table depths were measured with a wire recorder and with water-sensitive paste. The elevations of the tops of selected well casings were surveyed (Appendix C) to permit the standardization of water-table levels.

TANK FARM

History of Fuel Leakage

Information regarding the loss of fuel at the Tank Farm was obtained from Mr. Troxler (Watch Office) and Mr. White (Fuel Supervisor).

Buried tanks were installed at the Tank Farm (Figure 1) in the early 1950s and have stored aviation gasoline, JP-3, and JP-5. They are known to have leaked for more than a decade, although the volumes lost are unknown. Leakage has apparently been from both above and below the water table. Vegetation damage indicates that fuel has emanated from several points on the sides of the embankment at the Tank Farm, and accumulated around the perimeter of the embankment (Figure 3).

At the time of this investigation, a project is underway to repair leaks from all five buried tanks at the Tank Farm. Repairs have been completed on Tank F-15, and are currently underway on F-12 and F-14. They will subsequently be made to Tanks F-13 and F-16.

It has been necessary to repair the bottoms of the tanks, which are situated below the normal water-table elevation. Because of this, well points are being used to dewater the tank area. Additionally, ten observation wells were installed around the perimeter of the tank area, as shown in Figure 3. These are presumably used to monitor the effectiveness of dewatering.

Construction plans indicate that these observation wells are screened approximately 10 feet below the static water-table level. Since the water-table level has been cased off, floating fuel cannot enter the wells under static conditions. If the

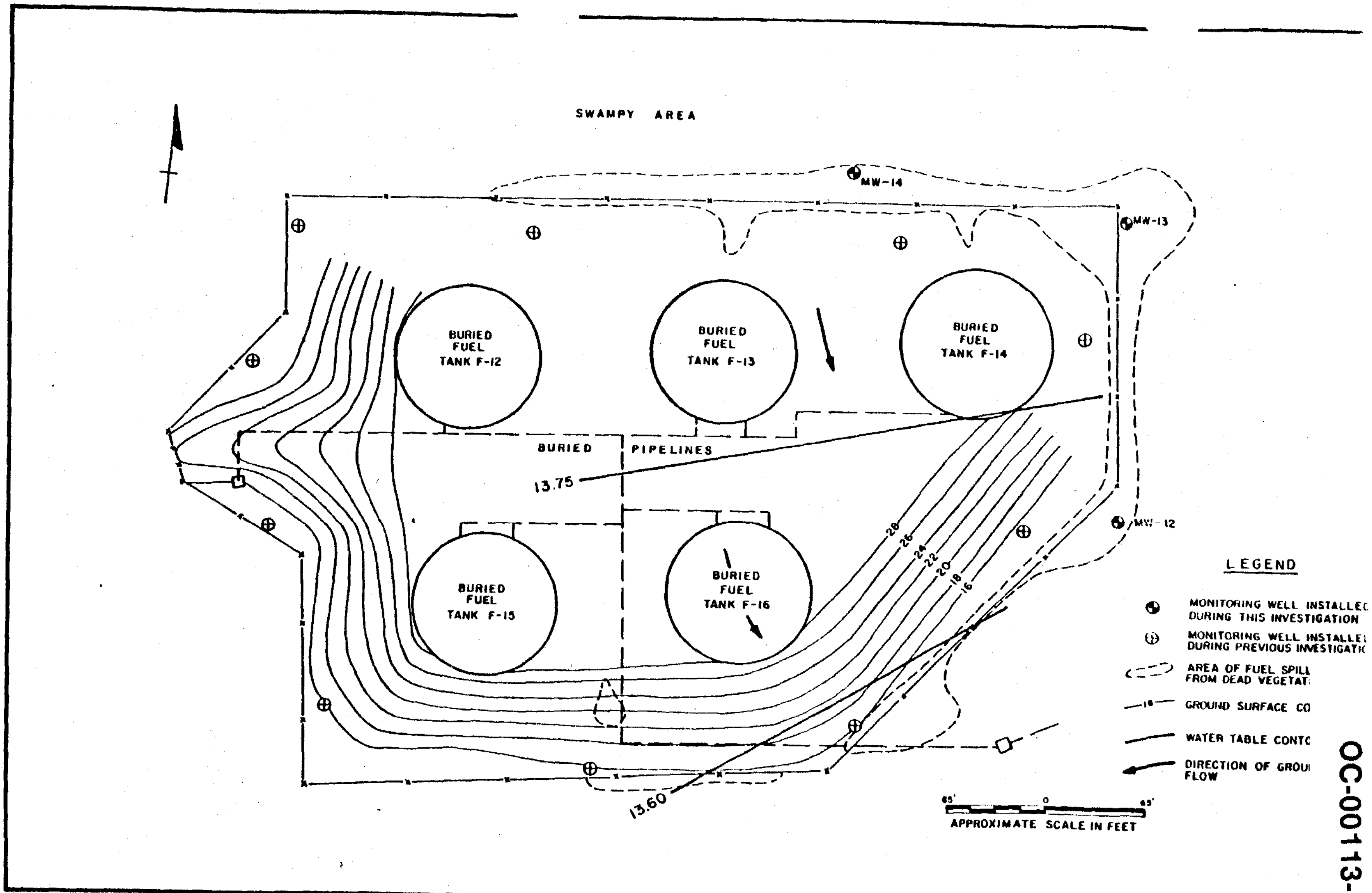

Figure 3: Tank Farm, showing locations of monitoring wells and water-table elevations (measured December 7, 1982). Arrows show direction of flow in shallow groundwater system.

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OC-00113-01.02-02/01/83

wells are pumped, thereby rapidly lowering the water table, floating fuel tends to remain suspended by capillary action in the sediment above the pumping water level. (This is demonstrated and discussed further in the section of this report entitled "Remedial Measures.") Therefore, the observation wells used in the tank repair project are not suitable for measuring the thickness of fuel which has accumulated on the water table in the tank area. Because of this, three additional monitoring wells were installed at the eastern end of the Tank Farm in order to better define the subsurface occurrence of fuel there.

Subsurface Investigation

The locations of the three monitoring wells installed at the Tank Farm are shown in Figure 3. Geologic logs and well-construction specifications are provided in Appendix B. Backhoe pits were not excavated at the Tank Farm.

Monitoring Well MW-12 is located southeast of buried tank F-14, outside of the fence that surrounds the Tank Farm (Figure 3). Interlayered silt and clay were observed in the top 5 feet of the boring. These were underlain by silty sand and fine to medium sand to a depth of 8 feet. This was in turn underlain by more than 10 feet of medium grained, well-sorted sand.

Pure fuel was observed coming out of the MW-12 boring during drilling. Split-spoon samples from above the water table had a moderate fuel odor; those from below the water table had a moderate to strong fuel odor. Approximately 1 foot of pure fuel oil accumulated in the completed monitoring well. The fuel had a yellowish color, which suggests that it is fairly fresh. Fuel that has been in the ground for some time tends to acquire a dark color as a result of degradation and the suspension of colloidal material.

Monitoring Well MW-13 is located at the northeastern corner of the fence that surrounds the Tank Farm. Silt, clay and silty sand occurred to a depth of 6 feet. This was underlain by 12 feet of fine to medium sand. As in MW-12, pure fuel was observed coming out of the borehole during drilling. Split-spoon samples from near the water table had a slight fuel odor; those from below the water table had a moderate to strong fuel odor. Two split-spoon samples from MW-13 were analyzed for fuel concentration. The results of these analyses are presented in Appendix D and will be discussed in the Summary and Conclusions part of this section. More than a foot of pure fuel accumulated on the water table in the completed monitoring well. As in MW-12, the fuel had a fairly fresh appearance.

Monitoring Well MW-14 is located on the northern side of the Tank Farm near Tanks F-13 and F-14 (Figure 3). The boring was augered by hand due to the drilling rig's inability to reach the chosen location because of soft ground. As in the other borings, silt and clay occurred to a depth of approximately 5 feet and were underlain by silty sand and well-sorted sand. No fuel was observed in the sediments or on the water table in the completed well.

In addition to the fuel thickness measurements made in the three monitoring wells which were installed as a part of this investigation, measurements were also made in some abandoned well-point boreholes. In most cases the boring had collapsed a few feet down, and the bottom of the fuel slug could not be accurately measured. Therefore, fuel-thickness measurements from these boreholes are not truly representative, and are considered to represent minimum thicknesses.

Summary and Conclusions

Three test borings/monitoring wells were installed on the northeastern side of the Tank Farm in order to delineate the occurrence of subsurface fuel. Fuel was observed in two of these monitoring wells, and in some of the abandoned well-point boreholes along the northeastern perimeter. As shown in Figure 4, approximately 0.9 feet of floating fuel was observed in MW-12, and 1.2 feet was observed in MW-13.

Fuel leakage at the Tank Farm is known to have occurred both at the surface and underground. It is likely that fuel floating on the water table originated from both sources. Based on fuel thickness measurements made in the monitoring wells and abandoned boreholes, the floating fuel is larely concentrated in the Tank Farm proper (Figure 4). The thickness of fuel measured in MW-12 and MW-13 indicates that some has also migrated eastward from the embankment.

The extent of fuel floating on the water table could not be well defined, particularly in the central part of the Tank Farm. However, based on the observations discussed above and shown in Figure 4, and on typical porosities for sediments of this type, the volume almost certainly equals thousands of gallons.

In view of the measured distribution of fuel thickness (and correlatively on fuel head potential) it is apparent that a lens of fuel exists which is somewhat mobile, gradually spreading outward from the Tank Farm area. Assuming that the leakage has been shut off, the lens will thin out, dispersing laterally. Lateral flow of floating fuel will continue until capillary forces equal those defined by the potential gradient. This

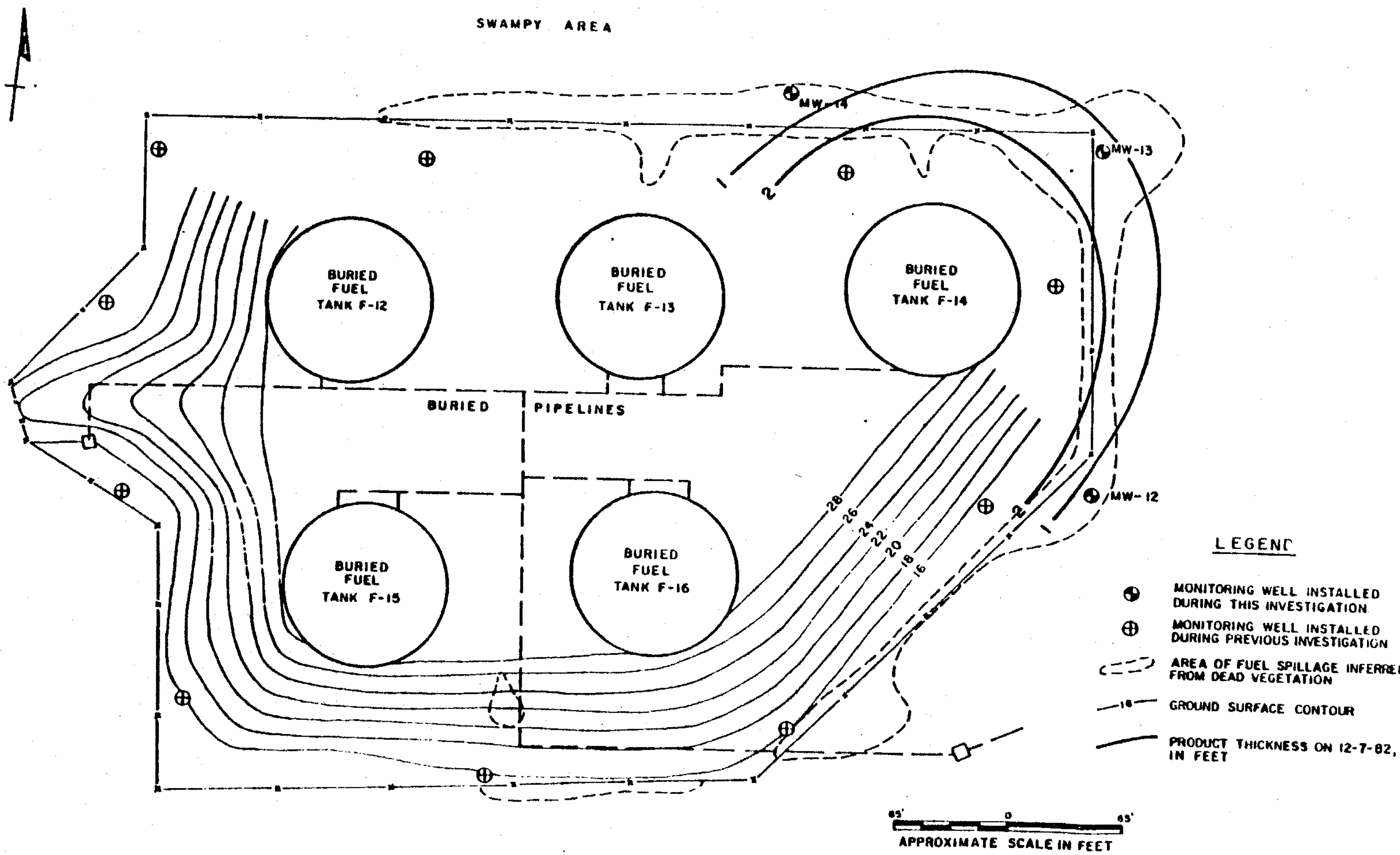

Figure 4: Tank Farm, showing measured thickness of subsurface fuel in monitoring wells on December 7, 1982.

OC-00113-01.02-02/01/83

equilibrium would be expected to occur within a few hundred feet of the perimeter fence under the observed conditions.

It is possible that some of the pure fuel will discharge to the surface at some point downgradient from the Tank Farm before it achieves this equilibrium condition. Such discharge may be into the drainage ditch just south of the site, or into the swampy area immediately to the east. There has not been any documented discharge of fuel up to this time, however.

As stated previously, two soil samples from MW-13 were analyzed in order to characterize typical degrees of fuel concentration just below the zone of free-floating fuel. As shown in Appendix D, a sample from a depth of 2 to 3 feet had a concentration of 0.04%. A sample from 6 to 7 feet had a concentration of 0.16%. These are typical residual concentrations for fuel which has been immobilized in the soil by capillary action. The dispersal of fuel occurs below the mean water-table level as a result of continuous water-table fluctuations in response to natural hydrogeologic events, such as precipitation.

If it is not removed, the fuel in the ground at the Tank Farm will remain there for many years, gradually decomposing as a result of natural volatilization, biodegradation, and dissolution. For the volume that apparently exists at the site, complete natural decomposition would probably take tens of years. During that period, the pure fuel will continue to be a source of dissolved fuel which will contaminate groundwater in the area.

In order to demonstrate the effects of fuel dissolution on groundwater quality near the Tank Farm, a groundwater sample from MW-13 was analyzed for dissolved fuel. The well was pumped with the pump intake at the bottom of the screen, or about 11 feet below ground surface. The water table in the well was drawndown 5 feet to a depth of about 8 feet. The sample was taken after 3 hours of pumping.

As indicated in Appendix D, the concentration of fuel in the groundwater was 90 ppm. The potential impact of this is discussed further in the section of this report entitled "Significance of Dissolved Fuel."

Measurements made at the Tank Farm indicate that the water table there is relatively flat, with a slight gradient toward the southeast (Figure 3). This indicates that groundwater flow in the shallow aquifer is also to the southeast. Shallow groundwater probably discharges into large drainage ditches - which occur about 500 feet from the site.

DAY TANK AREA

History of Fuel Leakage

Fuel facility personnel have indicated that fuel leakage is known to have occurred in the Day Tank area in recent years. Subsurface contamination by fuels apparently resulted from the accidental loss of fuel onto the ground surface near the Day Tank. Substantial losses of this type reportedly occurred in 1979 and 1981, when the tank overflowed. The extent of above-ground spills is evident from dead vegetation around the tank, as illustrated in Figure 5. It is virtually certain that a substantial amount of this fuel seeped into the ground and penetrated to the water table. The volumes of fuel lost during these events is unknown.

Shortly after the field portion of this investigation had been completed (December 1982), subsurface leakage was discovered from a 4-inch buried pipeline near the Day Tank (Figure 5). The period of leakage and volume of fuel lost is unknown, but it is likely that leakage occurred at a relatively small rate for a period of at least months.

Subsurface Investigation

Three backhoe pits and four test borings/monitoring wells were used to determine subsurface conditions in the Day Tank area. The locations of these are shown in Figure 5. Backhoe pit logs are shown in Appendix A.

Backhoe Pit BP-11 was excavated approximately 100 feet north of the buried Day Tank. Silt was observed in it to a depth of approximately 4 feet, and was underlain by fine sand. Sediment from the excavation had a moderate fuel odor. Groundwater was

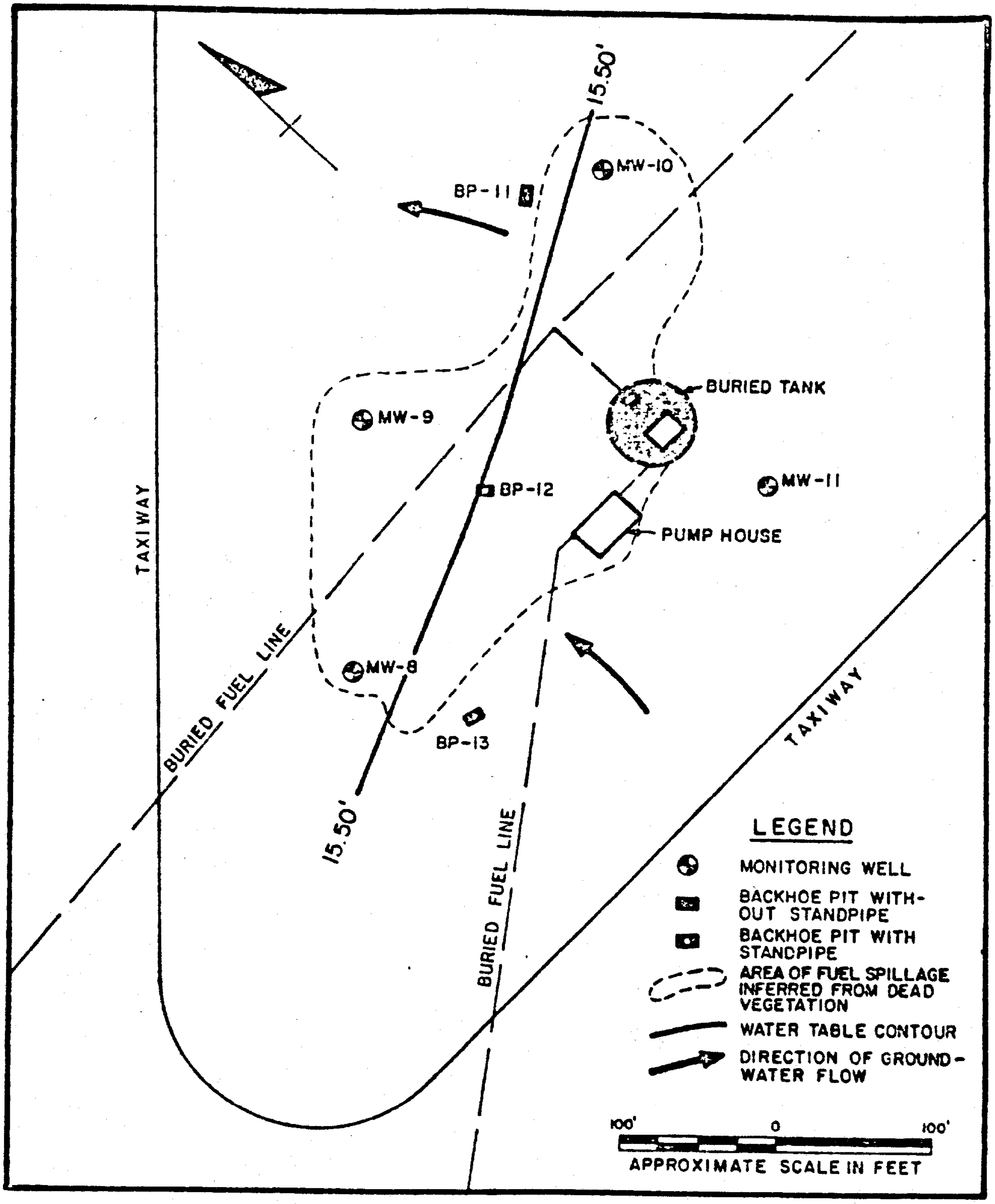

Figure 5: Day Tank area, showing locations of monitoring points and water-table elevation on December 7, 1982. Arrows show direction of flow in shallow groundwater system.

observed seeping into the pit from below 3 feet, and fuel emulsion occurred on the surface of groundwater which accumulated in the pit. Severe caving prohibited the installation of a standpipe in BP-11.

Backhoe Pit BP-12 was located approximately 50 feet northwest of the Day Tank. The soil profile was almost identical to that observed in BP-11. Unsaturated soil had a slight fuel odor, while saturated soil had a very distinct fuel odor. A fluid, believed to have been mostly fuel, was observed entering the pit from discrete points below 2 feet. A standpipe was installed in BP-12 to a depth of about 9 feet. Subsequent observations showed that 3.4 feet of free-floating fuel had accumulated on the groundwater surface in the standpipe.

Backhoe Pit BP-13 was located approximately 100 feet southwest of the pump house. In it, silt was observed to depth of 4 feet, and was underlain by fine sand with pockets of silt. Groundwater entered below 3 feet and had a slight to moderate fuel odor. Fuel emulsion was noticed on the surface of groundwater which accumulated in the pit. The fuel odor in BP-13 was less than that of BP-12. A standpipe was installed to a depth of 8 feet; subsequent monitoring did not indicate any free-floating fuel in the standpipe, although there was a slight fuel odor in the groundwater.

The location of the monitoring wells installed near the Day Tank are also shown in Figure 5. Geologic logs and construction details are shown in Appendix B.

Monitoring Well MW-8 is located approximately 125 feet west of the pump house, near backhoe pit BP-13. It was located at the edge of a known fuel spill area as indicated by dead vegetation. Sediment in the upper 5 feet consisted of silt and clay. As observed in the backhoe pits, the lower 15 feet consisted of fine to medium grain sand. Pure fuel was observed coming out of the boring during split-spoon sampling, and all soil samples had a moderate to very strong fuel odor. The groundwater surface in the completed monitoring well was found to have both fuel emulsion and free-floating fuel.

Monitoring Well MW-9 is located approximately 150 feet northwest of the pump house. The stratigraphy in MW-9 was essentially the same as that in MW-8. A moderate amount of fuel odor was observed in most of the sediment samples from below the water table. A strong fuel odor was observed in silty sand which occurred just below the shallow silt and clay unit, at a depth of about 5 feet (Appendix B).

Monitoring Well MW-10 is located approximately 150 feet northeast of the buried tank (Figure 5). Sediment observed in it consisted of clayey silt to a depth of 4 feet; this was underlain by silty fine to medium sand to 8 feet, and medium sand from there to 20 feet. A moderate amount of fuel odor was observed in all split-spoon samples from this well. No fuel was observed on the groundwater surface in the completed well.

Monitoring Well MW-11 is located just south of the buried tank, near the entrance road to the pump house. The upper 8 feet consisted of silt with varying amounts of clay and sand. These fine-grained sediments were underlain by 2 feet of loose fine to medium sand, which was in turn, underlain by medium sand. Some split-spoon samples had a moderate to strong fuel odor. No fuel was observed in the completed monitoring well.

Summary and Conclusions

Three backhoe pits and four monitoring wells were installed near the Day Tank to determine the extent of subsurface fuel there. Fuel was observed in sediments and groundwater from all test pits and borings. More than 3 feet of pure fuel accumulated in a standpipe in Backhoe Pit BP-12, located about 50 feet northwest of the buried Day Tank. Approximately 0.05 foot of pure fuel was observed on the water table in Monitoring Well MW-8, located about 200 feet west of the Day Tank.

In recent years there have been substantial accidental losses near the Day Tank. The loss of fuel onto the ground surface around the tank probably resulted in the seepage of significant amounts of fuel into the ground. This is probably the source of low to moderate levels of fuel which were observed in the soil and groundwater from most of the backhoe pits, borings and monitoring wells.

There is no evidence which indicates that fuel from this source has accumulated in large enough quantities to enable it to be mobile in pure form. Rather, it has probably dispersed to such an extent that it is largely retained in the soil by capillary action.

Two soil samples from Monitoring Well MW-8 were analyzed for fuel concentration, and demonstrate the extent of fuel dispersal throughout most of the area. As shown in Appendix D, a sample from a depth of 2 to 3 feet had a fuel concentration of 0.29%; a sample from 5 to 6 feet had a concentration of 0.21%. These are typical concentrations for a residual fuel which has been immobilized by capillary action.

The recent leakage of fuel from a buried pipeline near the Day Tank has resulted in the accumulation of a large amount of pure fuel on the water table. Some of this probably remained in the pipeline bed, tending to flow away from the point of leakage. That which leaked into the surrounding soil is probably spreading slowly in the form of a gradually thinning lens. It will continue to do so until it is entirely suspended in the soil by capillary action.

Although the fuel from this leak is locally mobile, there is little potential for it to spread in the natural soil any farther than a hundred feet or so from the point of origin. The silt and clay in which the lens is situated are relatively impermeable, and capillary pressures are relatively high. Also, the water table is fairly flat in the area, as indicated in Figure 5.

Two monitoring points near the buried pipeline showed the presence of pure fuel floating on the water table. In Monitoring Well MW-8 pure fuel occurred in combination with a few inches of fuel/water emulsion. The emulsion generally occurs as a result of long periods of water-table fluctuations, and suggests that pure fuel has existed in that area for some time. The combination of emulsion and pure fuel in MW-8 suggests an accumulation of fuel from at least two different leakage events.

Despite the observation of floating fuel in some monitoring points and not in others there remains considerable uncertainty about the volume of fuel in the ground near the Day Tank. In particular, the areal extent of pure fuel is still not well defined and the effective porosity of the fuel-saturated silts and clays can only be estimated to within about an order of magnitude. Based on what is known, it is estimated that a few thousand gallons of fuel is floating on the water table in the vicinity of the formerly leaking pipeline.

As at the Tank Farm, subsurface fuel at the Day Tank will slowly disintegrate as a result of natural volatilization, biodegradation and dissolution. There appears to be little potential for the migration of pure fuel away from the site. The greatest environmental risk resulting from the continuing presence of subsurface fuel at the Day Tank is expected to be the on-going contamination of groundwater by dissolved fuel.

Water-level measurements and the general topography in the area indicate that groundwater flows northward from the Day Tank area (Figure 5). Based on the local topographic setting, the distance from the Day Tank to a point of potential groundwater discharge is probably at least a mile. Beacuse of this, dissolved fuel contained in the shallow groundwater system would probably be reduced to insignificant concentrations before reaching any downgradient points of discharge. The potential environmental impact of dissolved fuel is discussed further in the section of this report entitled "Significance of Dissolved Fuel."

TEST CELLS

History of Fuel Leakage

As indicated by Mr. Troxler, there was a significant loss of fuel from one or two of the buried storage tanks at the Test Cells in the autumn of 1981. The volume of lost fuel is unknown, but leakage probably occurred at a low rate over an extended period. Small holes were discovered in the tanks and were subsequently repaired. The leakage resulted in the discharge of fuel into a nearby water-filled drainage ditch, as a consequence of lateral subsurface flow.

During the course of this investigation, fuel was observed emanating from cracks in the pavement just north of the Test Cells. This is probably caused by a leak in a subsurface fuel transfer pipe.

Subsurface Investigation

Three backhoe pits were excavated and three monitoring wells installed at the Test Cells. The locations of these are shown in Figure 6. Backhoe pit logs are shown in Appendix A.

Backhoe Pit BP-1 was located just east of the parking area on the northeast side of the Test Cells. The excavation showed a 5-foot layer of silty fine to medium sand near the surface, which was underlain by sandy silt. Sediment from the pit did not show any indication of fuel, but groundwater which accumulated in the bottom of the pit had a slight oily sheen on its surface. A 10-foot standpipe was installed in BP-1, but was rendered useless by vandalism before any monitoring could be done.

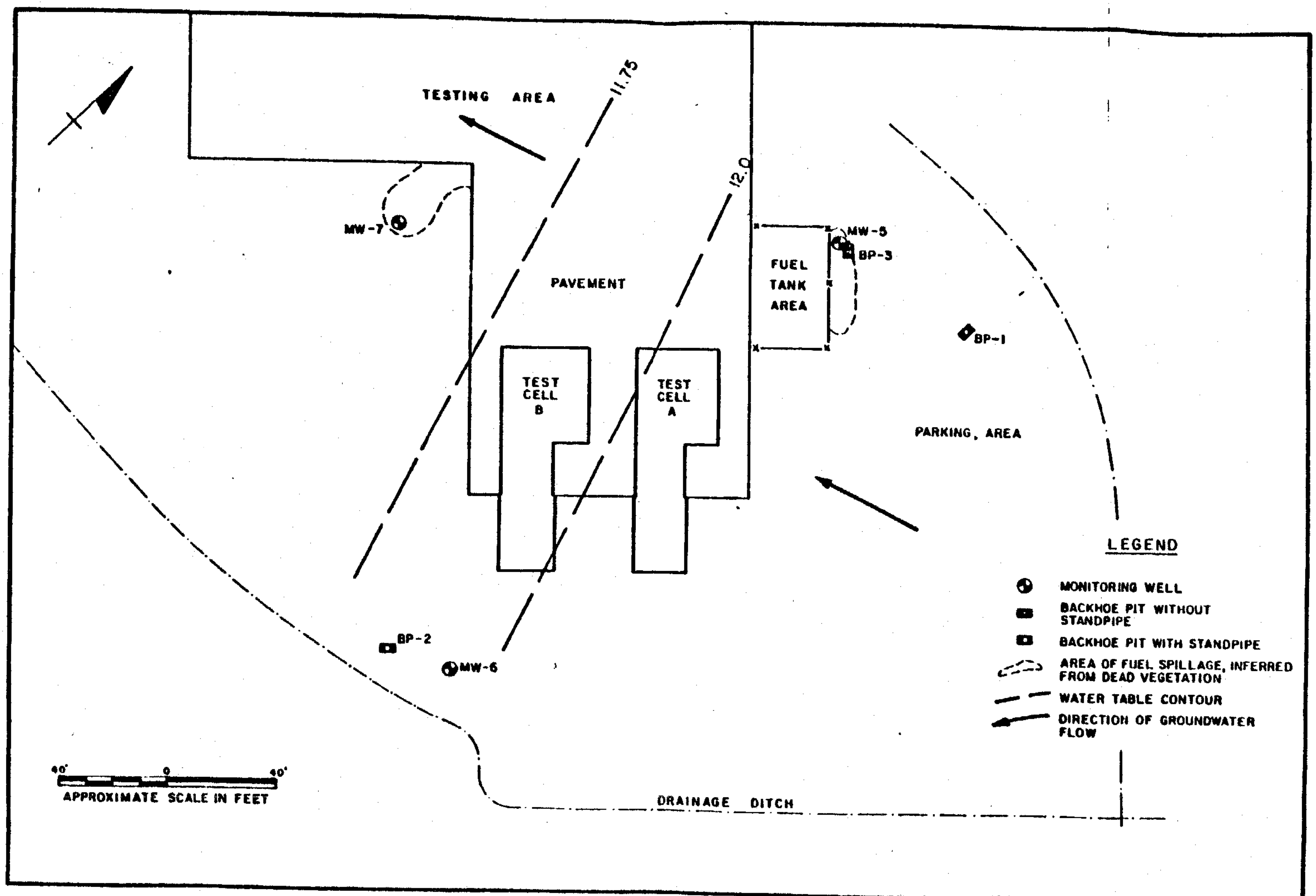

Figure 6: Test Cell area, showing locations of monitoring points and water-table elevations on December 7, 1982. Arrows show direction of flow in shallow groundwater system.

Backhoe Pit BP-2 was excavated approximately 50 feet southwest of the southwestern corner of Test Cell B. Silty fine sand was observed in the upper 3 feet of the profile. This was underlain by a 1-foot layer of silt, which was in turn underlain by well-sorted medium to coarse sand. No fuel was observed in any of the sediments, but groundwater in the bottom of the pit had a trace of oil sheen on its surface.

A standpipe was installed in BP-2 to a depth of about 8 feet. Subsequent observations indicated that a slight oily sheen occurred on the water surface in this standpipe. A slight fuel odor was also apparent in the standpipe. However, there was not a measurable thickness of free-floating fuel on the water table.

Backhoe Pit BP-3 was excavated a few feet east-northeast of the fence that surrounds the buried fuel tanks. In this pit sand fill was observed to the total depth of about 11 feet. A distinct fuel odor was observed during excavation, and increased with depth. A standpipe was not installed in BP-3 due to the apparently unsaturated condition of the sediments.

Based on the results of the backhoe pit investigation, three test borings and monitoring wells were also installed near the Test Cells (Figure 6). Geologic logs and construction specifications for each well are shown in Appendix B.

Monitoring Well MW-5 is located a few feet east of the fence which surrounds the buried fuel tanks (Figure 6). In the boring, the upper 10 feet of sediment consisted of silty fine to medium sand with a few thin clay seams occurring below 2 feet. Loose fine to medium sand occurred from 10 to 18 feet, and was underlain by clayey silt to the boring's total depth of 20 feet. A very strong fuel odor was observed in split-spoon samples from 2 to 8 feet, while moderate fuel odors were noted from 1 to 2 feet and 8 to 12 feet. A small amount of dark brown fuel was observed on the water surface after the installation of the monitoring well. Subsequent monitoring of MW-5 showed a slight increase in the quantity of fuel present.

Monitoring Well MW-6 is located just off the southern corner of Test Cell B (Figure 6). Silt and sand were observed to a depth of 6 feet, and were underlain by fine to medium sand to a depth of 18 feet. Silty sand occurred from 18 to 20 feet. No fuel was observed in any split-spoon samples from MW-6, or in the completed monitoring well.

Monitoring Well MW-7 is located approximately 50 feet from the western corner of Test Cell B. At that location, the upper 10 feet of sediment consisted of silt and sand. Small clay seams also occurred in the upper 4 feet. Fine to medium sand was found from 10 feet to the boring's total depth of 20 feet. A slight fuel odor was observed in split-spoon samples from 0 to 8 feet; however, no fuel was observed in the completed monitoring well.

Summary and Conclusions

Three backhoe pits were excavated, and three monitoring wells were installed at the Test Cells in order to determine whether significant amounts of fuel occur in the subsurface there. Fuel was observed in sediments from two backhoe pits located east of the buried fuel tanks which are at the northeastern corner of Test Cell A (Figure 6).

Fuel was also observed in sediments from a test boring located near the buried tanks, and in sediments from a test boring located approximately 150 feet northwest of the Test Cells. Fuel odors were observed in the completed monitoring wells, and the well near the buried tanks had a small amount of free-floating fuel on the water table.

As stated previously, fuel is known to have leaked from the buried storage tanks near Test Cell A, and subsequently discharged into a nearby drainage ditch. It is apparent that some of this fuel still remains in the soil between the tanks and the ditch. A soil sample from Monitoring Well MW-5 was measured for fuel concentration (Appendix D). Taken from just below the water table, the sample had a fuel concentration of 0.16%. This is consistent with the residual concentrations in soils from other sites, as discussed previously.

The thin amount of free-floating product observed in Monitoring Well MW-5 suggests that a small volume of somewhat mobile fuel occurs in the immediate vicinity of the tanks. However, this probably constitutes no more than a few hundred gallons, and there is not enough evidence of mobility to warrant remedial action.

There appears to be a slight sheen on the standing water in the drainage ditch just east of the Test Cells. This could be derived from the slow but continuing discharge of fuel from the ground into the ditch. However, since Monitoring Well MW-5 and Backhoe Pit BP-1 showed little evidence of mobile fuel, this seems unlikely. It is possible that the sheen was derived from the decomposition of other organic material in the stagnant water. There was no fuel odor observed near the ditch. Chemical analyses of the ditch water will probably be necessary to resolve this uncertainty.

As indicated previously, fuel is also known to have leaked from a buried pipeline beneath the pavement just north of the Test Cells. Some of this may have reached the water table beneath the point of leakage. Some has also emerged from cracks in the pavement, and discharged to the ground as surface run-off about 75 feet northwest of Test Cell B (Figure 6).

Although a small amount of this fuel was observed in sediments near the point of run-off, no fuel was observed in the completed monitoring well (MW-7) which was located there. This indicates that there are not large volumes of fuel in the subsurface northwest of the Test Cells, and probably not significant volumes of mobile fuel beneath the point of this leakage.

As Figure 6 indicates, groundwater in the Test Cell area generally flows to the northwest. It is expected that a plume of dissolved fuel exists in the groundwater downgradient from the points of leakage, as discussed for the Tank Farm and Day-Tank areas. Shallow groundwater from this source probably normally discharges into drainage ditches which exist at the southwestern end of Runway 5R. It probably also discharges into the ditches near the Test Cells during periods of high water table.

In view of the relatively low volumes of fuel that seem to exist in the subsurface near the Test Cells, the discharge rate of dissolved fuel into surface waters is probably very low. Once in surface waters, subsequent dilution and evaporation would make it unlikely that any detectable trace of dissolved fuel would remain in surface waters far downstream from the Test Cells.

A 4-inch water supply well is located near the two water tanks on the southern side of the Test Cells. The groundwater is used primarily for cooling, and may also be used for drinking and sanitation. Drilling records indicate that the well draws water from a sandy layer which occurs between the depths of 135 and

165 feet. Logs of other nearby wells indicate that this interval is overlain by relatively impermeable silt layers. One of these layers was observed at a depth of about 20 feet in the three monitoring wells. Because of these silty layers, any dissolved fuels which may occur in the shallow groundwater system probably have little potential to enter the water supply well at the Test Cells.

ABANDONED TANK FARM (NORTH STATION)

History of Fuel Leakage

The Abandoned Tank Farm is located approximately 300 yards east of the old CPO Club on the northern side of the base (Figure 1).

As shown in Figure 7, at least two buried lines exist at the Abandoned Tank Farm by which wash fluids from tanks and pipes were drained to waste. Although there has been no knowledge of any significant fuel discharge from these drains, they may have been a source of periodic fuel leakage during the time when the facility was in use. They may also have been a means for small volumes of fuel to discharge since the facility was abandoned.

Mr. Troxler of the Watch Office has indicated that when the tanks were abandoned, they were emptied of fuel and then filled with water. Tank G-5, a 50,000 gallon concrete tank located in the central part of the facility (Figure 7) was then used to store waste oil for some period. It is no longer used for this purpose, but the tank is thought to still contain a foot of oil, or about 5,000 gallons.

Subsurface Investigation

In order to determine subsurface conditions in the vicinity of the remaining fuel tanks at the Abandoned Tank Farm, three backhoe pits were dug and four monitoring wells were installed. Locations are shown in Figure 7. Backhoe pit logs are shown in Appendix A.

Backhoe Pit BP-8 was located between the southernmost buried tank and the middle buried tank. Alternating layers of silt and sand occurred in the pit to a depth of approximately 5 feet.

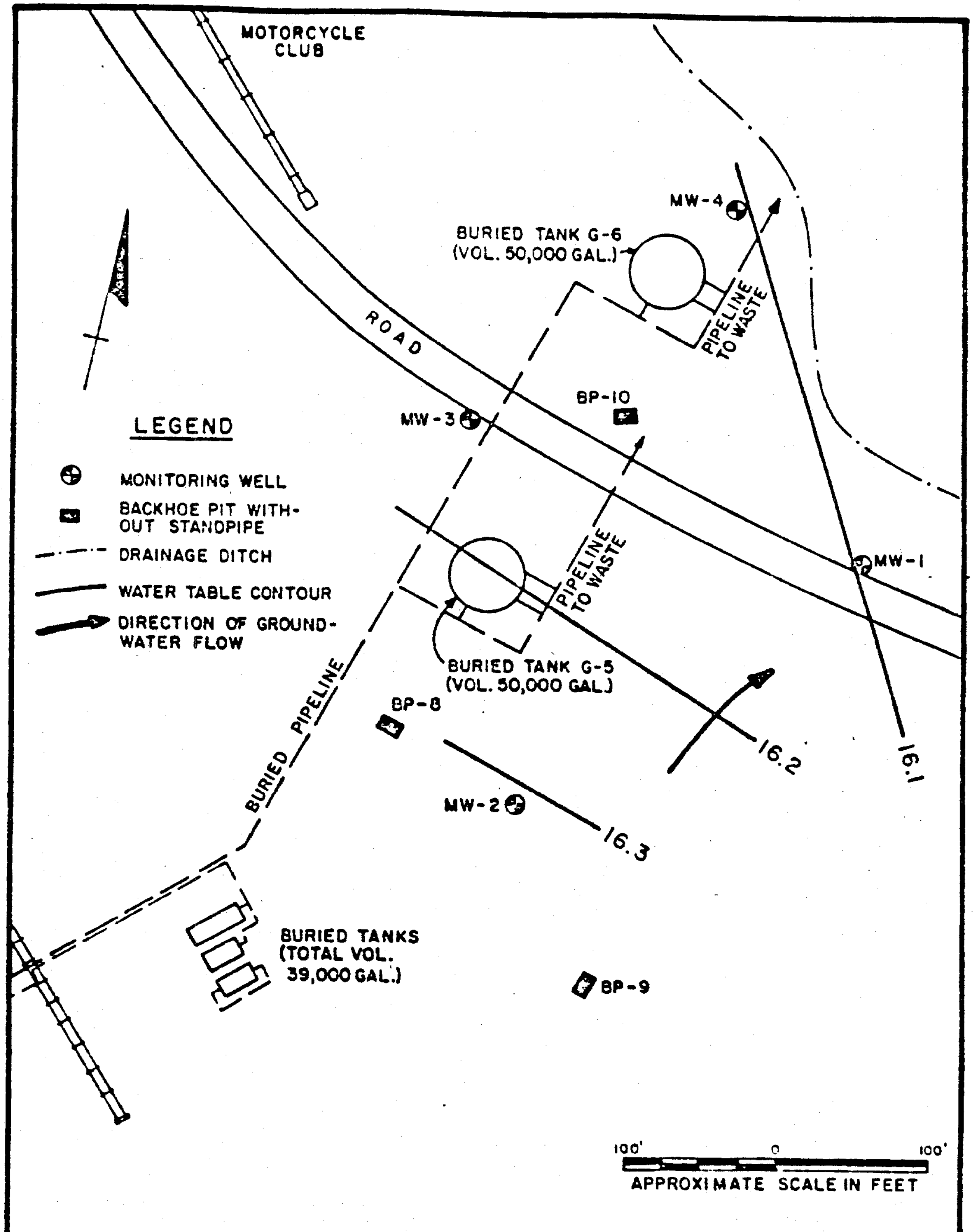

Figure 7: Abandoned (North Station) Tank Farm, showing locations of monitoring points and water-table elevations on December 7, 1982. Arrows show direction of flow in shallow groundwater system.

These were underlain by a 1-foot layer of clayey silt, which was in turn underlain by sand. Groundwater was observed coming into the pit below a depth of 2 feet. A slight odor of degraded fuel was observed in both the sediments from the pit and groundwater which accumulated in it. A slight oil sheen was observed on the groundwater surface.

Backhoe Pit BP-9 was located east-northeast of the southernmost buried tanks (Figure 7). Silt occurred to a depth of slightly more than 5 feet, and was underlain by sand. A rapid influx of groundwater occurred between 3 and 6 feet. A distinct oil sheen was observed on the accumulated water, but there was no fuel odor. Similarly, no fuel was observed in the sediments excavated from BP-9.

Backhoe Pit BP-10 was located roughly halfway between the middle buried fuel tank (G-5) and the northernmost buried fuel tank (Figure 7.) As in the other two backhoe pits, sediments consisted of alternating layers of silt and sand. An influx of groundwater occurred within the uppermost 2 feet, and slight fuel emulsions were observed in the accumulated water. A more rapid influx of groundwater occurred below 2 feet; it was accompanied by some fuel emulsion and sheen. A moderate odor of degraded fuel was also observed in both the sediments and groundwater of BP-10. No standpipe was installed due to severe caving of the excavation walls.

The locations of the four monitoring wells installed at the Abandoned Tank Farm are also shown in Figure 7. Geologic logs and construction details are shown in Appendix B.

Monitoring Well MW-1 is located approximately 150 feet northwest of Tank G-5, just north of the road. Split-spoon sampling indicated that naturally occurring clayey silt was present to a depth of about 6 feet. This was underlain by a thin layer of silty fine sand, which was in turn underlain by well-sorted medium to coarse sand to the total depth of 16 feet. No fuel was observed in split-spoon samples, or in the completed monitoring well.

Monitoring Well MW-2 was installed approximately 100 feet northeast of the southernmost buried tanks (Figure 7). Clayey silt occurred to a depth of 5 feet, and was underlain by a thin layer of silty fine sand. As in MW-1, these layers were underlain by relatively well-sorted medium sand to the boring's total depth of 20 feet. A slight to moderate fuel odor was observed in some split-spoon samples; however, there was no fuel observed in the completed monitoring well.

Monitoring Well MW-3 is located just north of Tank G-5, directly adjacent to and south of the road (Figure 7). Split-spoon sampling indicated that layers of sandy silt and silty sand occurred to a depth of 7 feet. These were underlain by fine to medium sand to the boring's total depth of 20 feet. Variable degrees of fuel odor were noticed in almost all of the split-spoon samples from MW-3. A trace of fuel emulsion on the groundwater surface was observed before and shortly after the installation of the monitoring well. The emulsion was not observed in subsequent monitoring of the well.

Monitoring Well MW-4 is located approximately 15 feet north of the northernmost buried tank. In the test boring, silt occurred to a depth of 4 feet. This was underlain by a thin layer of silty sand, which was in turn underlain by medium sand to the boring's total depth of 18 feet. A trace to moderate fuel odor was observed in some split-spoon samples. No fuel was observed in the completed monitoring well.

Summary and Conclusions

Three backhoe pits were excavated and four monitoring wells were installed at the Abandoned Tank Farm in an attempt to determine whether fuel occurs in the subsurface. Traces of freely occurring degraded fuel were observed in two backhoe pits. A distinct odor of degraded fuel was observed in a third backhoe pit which was located north of Tank G-5. However, no freely occurring fuel was observed in the third pit.

Similarly, an odor of degraded fuel was observed in split-spoon samples from three out of four test borings. Emulsified fuel was observed on the groundwater surface in a monitoring well installed north of Tank G-5; however, no free-floating product was observed in any well.

It is apparent that small amounts of fuel which probably leaked from the tanks or buried pipelines persist in the subsurface at the Abandoned Tank Farm. The distinct odor of degraded fuel in backhoe pit BP-10, which was located near an old waste drain, suggests that the drain outlet may have been a source of some leakage. This, in addition to the observation of emulsified fuel in Monitoring Well MW-3, suggests that Tank G-5 may have been the source. Trace amounts of fuel observed in the other monitoring points could have originated from the spillage of small amounts of fuel at the surface during the time when the facility was active.

There is no evidence of any free product mobility. The relatively small amount of fuel which occurs in the subsurface appears to be bound in the soil by capillary action. Fuel was observed both above and below the water table, and was probably dispersed in that manner by water table fluctuations.

As shown in Figure 7, groundwater at the site generally flows north to northeast, and may discharge into nearby shallow drainage ditches that flow north toward Potters Road. It is likely that groundwater downgradient (north) from the site contains low levels of dissolved fuel. However, in view of the small volume of subsurface fuel that was observed at the site, the dissolved fraction in the groundwater is expected to be so low that it is probably insignificant. This is discussed further in the section of this report entitled "Significance of Dissolved Fuel."

FIRE TRAINING AREA

History of Fuel Leakage

Discussions were held with Mr. Morton and Mr. Pipkin of the Public Works Department. These individuals indicated that runoff from fire fighting exercises usually has included some fuel. Normally, the runoff is collected by a drain system which channels it into a buried oil/water separator (Figure 8). However, occasionally fuel and water overflow the berm and flow onto the ground nearby. Vegetation damage occurs just north of the burning circles and reflects the occurrence of such runoff.

There exists some potential for fuel in this surface runoff to seep into the ground, thereby contaminating shallow groundwater. Such seepage had not been previously known, however. Similarly, it had been thought that some potential existed for leakage to occur from the drain system and oil/water separator. This had not been previously documented either, however.

It was also reported that an area near the fire training circles was at some time used for the disposal of waste fuels and lubricants by the "fuel farming" method. With this method, the hydrocarbon products would have been spread on the soil over a large area, then tilled regularly. As a result, the products would be removed from the soil by natural volatilization and biodegradation. If the disposal and farming had at some time been performed incorrectly, products may have seeped beyond the tilled zone and entered the local groundwater system. Due to this potential, a backhoe pit was excavated in the former fuel farming area to check soil and groundwater conditions.

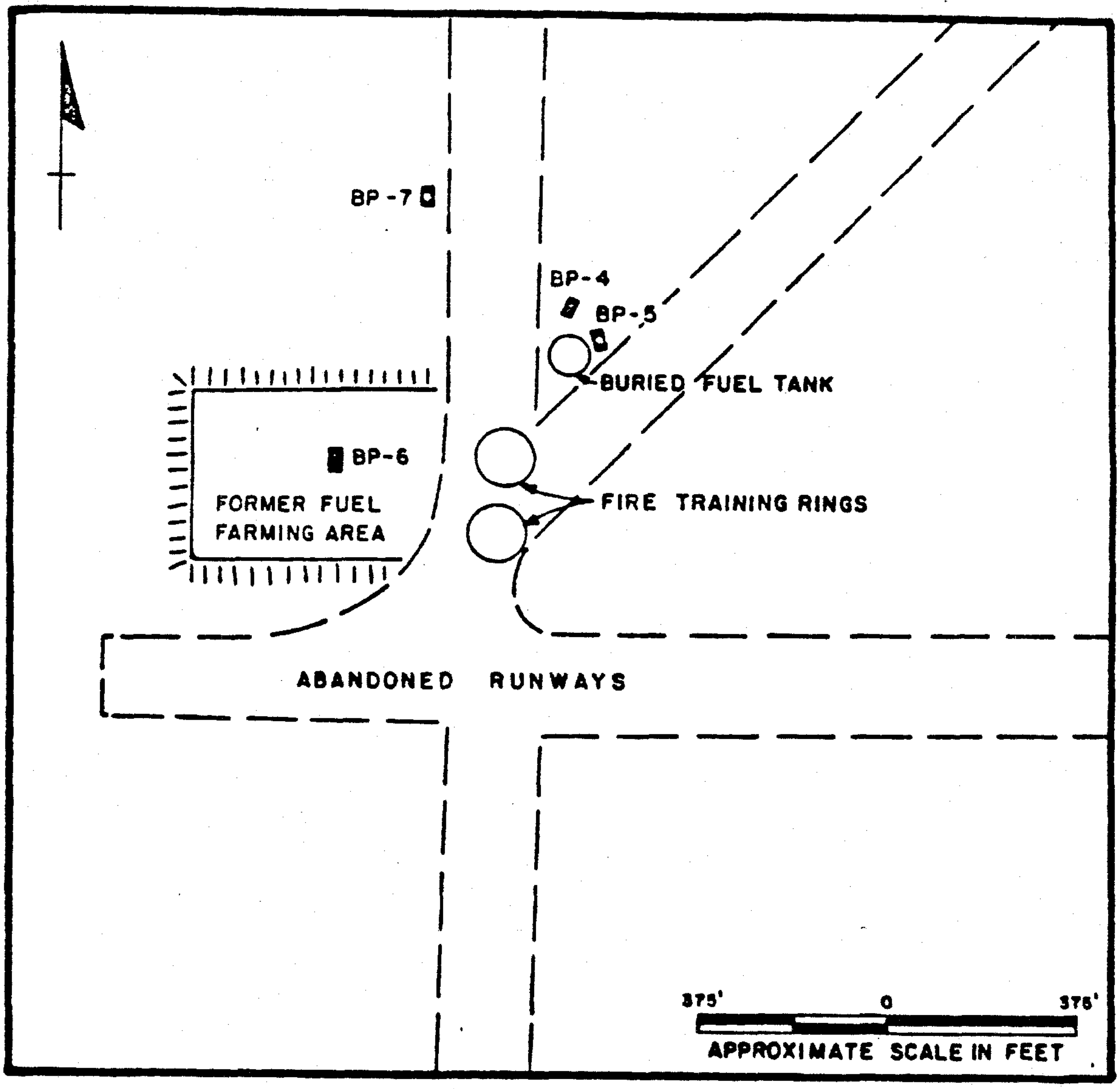

Figure 8: Fire-Training area, showing locations of monitoring points.

Subsurface Investigation

Four backhoe pits were excavated at the Fire Training Area as shown in Figure 8. Descriptive logs from the pits are presented in Appendix A.

Backhoe Pit BP-4 was located north of the buried oil/water separator on the eastern side of the old runway (Figure 8). Alternating layers of silt and sand were observed in the upper 7 feet of the excavation. These were underlain by well-sorted coarse sand. No standpipe was installed in the excavation due to severe wall collapsing both above and below the water table. No fuel was observed in sediments from BP-4. However, a trace of hydrocarbon sheen was observed on groundwater which acccumulated in the excavation.

Backhoe Pit BP-5 was located just east of the buried oil/water separator on the eastern side of the old runway. It exhibited approximately 3.5 feet of silt near the surface, which was underlain by sand. No fuel was observed in sediments from BP-5 or on the surface of groundwater which accumulated in the pit. A standpipe was installed in BP-5 to a depth of about 9 feet. In subsequent monitoring, no fuel was observed.

Backhoe Pit BP-7 was located north of the buried oil/water separator approximately 1 foot west of the old runway (Figure 8). It exhibited silt in the upper 6 feet which was underlain by well-sorted medium to coarse sand. No fuel was observed in the excavation. A standpipe was installed to a depth of about 9 feet. Subsequent monitoring of the standpipe has shown no indication of fuel.

Backhoe Pit BP-6 was located in the old fuel farming field approximately 150 feet west of the old runway (Figure 8). BP-6 indicated the occurrence of a 6-foot layer of silt near the surface, which was underlain by silty, medium grained sand. No fuel was observed in the sediments or on groundwater which accumulated in the pit. A standpipe was not installed in the excavation due to collapsing conditions, the isolated location of the pit, and the apparent small probability of any free-floating fuel being found.

Summary and Recommendations

Four backhoe pits were excavated at the Fire Training Area in an attempt to determine whether spilled or leaked fuel occurred in the subsurface. One of these was located in the former fuel farming area. A trace of fuel was observed in one backhoe pit (BP-4) located near the buried oil/water separator. However, this was not a clear indication and did not appear to reflect a significant amount of fuel occurring in the subsurface. No sign of fuel was observed in any other pit or in the standpipes that were installed in two of them.

On this basis, it is concluded that significant amounts of fuel do not occur in the subsurface at the Fire Training Area. Therefore, no further action is warranted at this time.

THE SIGNIFICANCE OF DISSOLVED FUEL

Fuel products are commonly assumed to be immiscible in water. Their solubilities are indeed low, but in the context of drinking water quality can be quite significant. Plumes of dissolved fuel commonly occur in groundwater downgradient from any subsurface occurrence of pure fuel, as shown schematically in Figure 9.

Ineson and Packham (1967) have indicated that the solubility of gasoline in water is typically in the range of 20 to 80 ppm (parts per million). This is generally consistent with the individual solubilities of the various constituents of light fuels, such as heptane, toluene, and benzene (Verschueren, 1977). The solubility of JP-5 can be expected to be at least as high as that of gasoline.

Water quality standards are not usually specific about acceptable concentrations of fuels. According to the Virginia State Health Department, fuels as a whole are not permitted to exceed taste and odor threshold concentrations in municipal water supplies. These thresholds are usually about the same as those of the constituent compounds, or around 0.01 to 1 ppm for light fuels.

As indicated in a previous section, a groundwater sample from the Tank Farm was tested for dissolved JP-5, and had a concentration of 90 ppm (Appendix D). This suggests that groundwater in the immediate vicinity of freely occurring subsurface fuel is essentially saturated with fuel.

Dissolved fuel concentrations will usually be attenuated as groundwater transports them from their points of origin. This is primarily due to dispersion and the adsorption (absorption) of dissolved compounds by sediments. Adsorption occurs more readily in clay-rich sediments. Based on the observation of

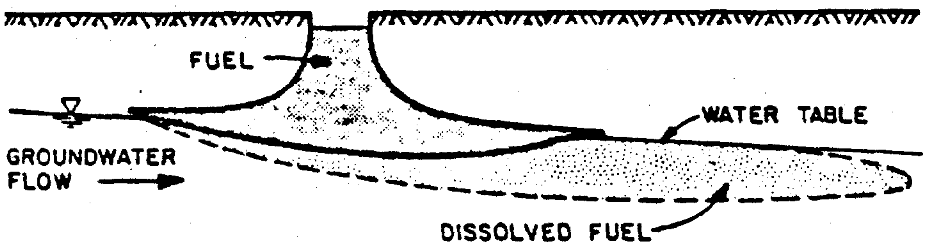

Figure 9: Schematic illustration of the migration of dissolved fuel away from a zone of subsurface fuel leakage.

observation of split-spoon samples, most shallow groundwater flow at the sites occurs in sand which has little clay in it. Nevertheless, some adsorption probably does occur. Fine-grained strata which separate the shallow aquifer from deeper ones probably have a high capacity for the retention of dissolved fuels by adsorption.

Based on the observed occurrence of subsurface fuel, there appears to be some potential for dissolved fuel to contaminate shallow groundwater at four of the five sites studied. The concentration of contaminants in a plume downgradient from each site depends largely on the amount of free fuel occurring in the ground at the source. To a lesser extent, it also depends on characteristics of nearby sediments (as described above) and characteristics of the local groundwater flow system. The environmental significance of such a plume depends on the proximity of streams and other points of groundwater discharge, including nearby wells.

Using existing information, concentrations of dissolved fuel in groundwater cannot be accurately predicted downgradient from the sources. This can only be determined with additional sampling. However, based on a qualitative evaluation of the factors described above, there does not appear to be an imminent hazard resulting from the occurrence of dissolved fuel at these four sites.

In each case, it appears that dissolved contaminants would discharge from the shallow groundwater system before leaving the Base. In the cases of the Tank Farm, Test Cells, and Abandoned Tank Farm, such discharge probably occurs to drainage ditches within 1000 feet of the sites. When dissolved fuel from the shallow groundwater system discharges into surface waters, any significant concentrations of fuel are probably rapidly removed by volatilization. The Day Tank appears to be so isolated that significant levels of dissolved fuel are probably attenuated before reaching any points of discharge.

Generally, it would appear that the only significant environmental threat posed by dissolved fuel at these sites would be to deeper groundwater systems. However, based on what is known of local stratigraphy and groundwater use, it would seem that there is little potential for dissolved fuel to enter deeper aquifers. Available well logs indicate the presence of numerous fine grained units which would prevent any significant downward flow; however, this should be further investigated.

REMEDIAL MEASURES

As described in the preceding sections of this report, various amounts of fuel occur in the subsurface at the Tank Farm, Day Tank, Test Cells, and Abandoned (North Station) Test Farm. Existing subsurface fuel generally has a low degree of mobility as pure fuel. Because of this and the distances between spill sites and zones of potential discharge, the occurrence of pure subsurface fuel poses little direct environmental threat.

However, some degree of indirect threat results from the continuing dissolution of fuel into the groundwater. Dissolved fuel will continue to enter the shallow groundwater system for as long as any pure fuel remains suspended in soil near the water table.

Therefore, if the decision is made to abate groundwater contamination resulting from subsurface fuel occurrence, it will probably be necessary to deal with two related but somewhat different problems: the presence of dissolved fuel in the groundwater, and the continuing presence of a source of the dissolved fuel. In the following sections these problems will be discussed separately.

Dissolved Fuel

As stated previously, lighter fuel products such as JP-5 and gasoline reportedly have water solubilities in the neighborhood of 20 to 80 ppm. Groundwater sampled at the Tank Farm had a JP-5 concentration of 90 ppm. Despite the effects of dilution and natural adsorption, it is possible that dissolved fuel could be transported by groundwater into nearby drainage ditches, or be induced into deeper groundwater systems.

The flow of dissolved contaminants can be contained by reversing the existing directions of groundwater flow. This is normally done by pumping the groundwater with one or more withdrawal wells located in the plume of contaminated groundwater. Contaminated effluent from the collection wells would have to be treated and then either returned to the aquifer or discharged to surface waters.

A comprehensive solution to the problem of dissolved fuel would require aquifer restoration by pumping and treating virtually all of the affected groundwater. Due to the retention of fuel by adsorption to sediments, it would probably be necessary to pump more than one affected pore volume. In a typical case, millions of gallons of groundwater would have to be pumped and treated before satisfactory aquifer restoration is achieved.

At each of the fuel facilities, the effective withdrawal of contaminated groundwater could probably be accomplished with one high-capacity shallow well located just downgradient from the source (spill) area.

Two methods of treatment are often used for low levels of organic contaminants, such as fuels. Both methods take advantage of the hydrophobic nature of light petroleum products, and the relative ease with which such compounds transfer to another phase.

Adsorption is widely used for the treatment of organics in surface-water supplies, and is most often achieved by passing contaminated water through columns or beds of activated carbon. In this case, contaminated groundwater would be passed through such columns directly from the wellhead, and then either discharged to surface waters or injected back into the aquifer. It would be necessary to install columns or beds semi-permanently at each spill site, and to periodically regenerate the carbon.

For these reasons, the use of activated carbon for a temporary, long-term groundwater withdrawal and treatment system is not generally economical.

Low levels of fuel products may also be effectively removed by aeration or air stripping. At relatively isolated locations, such as those investigated here, air stripping can be accomplished simply by spraying the effluent into the air from raised, exposed nozzles. The atomization of groundwater in this manner is much more efficient than the aeration columns or beds traditionally used for water treatment. Moreover, it is extremely economical since it requires only an array of small-diameter pipe outlets, nozzles, and simple runoff control. As in the case of an adsorption system, runoff could either be discharged to surface waters or allowed to drain back into the aquifer.

Effective treatment by this method can be accomplished at any time except during frozen periods. Based on our experience with the use of such systems, the effects on air quality can be expected to be minimal within 100 yards of the system, and negligible beyond that.

Pure Fuel

Pure, or undissolved, fuel has been found in the subsurface in varying amounts at the Tank Farm, Day Tank, Test Cells, and Abandoned Tank Farm. At the Tank Farm and Day Tank some sediments near the water table are completely saturated with fuel. At the Test Cells and Abandoned Tank Farm, only residual saturation seems to be present.

There appears to be little potential for any of this fuel to flow laterally to such an extent that it could discharge directly into surface waters. However, at each site pure fuel in the subsurface is a source of dissolved fuel which almost certainly occurs in the groundwater downgradient from the point of leakage. Unless it is removed from the soil, pure fuel will most likely continue to be a source of dissolved fuel in the groundwater for many years. On this basis, the remedial option discussed below would be intended to remove pure fuel from the subsurface, thereby eliminating the source of dissolved fuel.

Collection Trenches

In those places where subsurface fuel occurs in large enough quantities to be mobile, collection trenches can sometimes be used to recover the fuel. The method is frequently advantageous where the water table is shallow and where there are no limitations on extensive digging. These criteria fit the Tank Farm and Day Tank areas.

The trenches should be excavated to well below the water table, which at the above two sites would be a depth of 5 to 10 feet. Digging and trench maintenance would be facilitated by the silty competent soils which extend below the water table at both sites. In order to collect fuel with the trenches it would be necessary to pump groundwater from them, thereby creating a small water-table gradient toward the trench. A second skimmer-type pump should be used to remove accumulated fuel from the trench.

Fuel collection will be most effective if the trenches are excavated in the area of thickest fuel accumulation. In the case of highly mobile fuel, it might be advantageous to put the trench on the downgradient side of the subsurface fuel lens, between the lens and any point of potential discharge into surface waters.

It should be borne in mind that this method cannot remove all of the pure fuel that occurs in any given zone. Depending on sediment and fuel characteristics, as much as half of the fuel may remain in the soil, immobilized by capillary action. This portion would have to be dealt with in another manner, as is discussed in a following section.

Collection trenches are probably the least expensive means by which mobile subsurface fuel can be recovered.

Recovery Wells

When groundwater is pumped from recovery wells, a cone of drawdown is created which also induces the flow of floating fuel into or toward the recovery well. Fuel will collect on the water's surface in the well, and can be recovered with a second pump or with a bailer. Like collection trenches, recovery wells will only be effective in places where there is a sufficient quantity of fuel for it to be mobile.

The use of wells to collect floating fuel is advantageous because their use is flexible and effective. They can be installed easily, and sequentially if necessary, in response to new information about fuel occurrence and mobility. They are also far less disruptive and obtrusive than collection trenches.

Monitoring Wells MW-8 and MW-13 were tested in an effort to determine the viability of using recovery wells at the Tank Farm and the Day Tank. In each case, floating fuel was removed from the well with a bailer. Groundwater in the well was not pumped, however. The rate of fuel influx into each well was recorded and is shown in Figure 10.

The results of these tests (Figure 10) indicate that fuel re-entered each well soon after it was bailed. Some of this probably originated in the sand pack installed around the well screen. Complete recovery of the slug thickness took approximately one day in each case.

An inflow test was also conducted by pumping MW-13 for a relatively brief period. While groundwater was pumped from the bottom of the well, the thickness of the fuel slug on the water surface was periodically measured. Fuel was not bailed from the well at any time during the test. The water level in the well was drawn down about 5 feet. Sustained pumping was hampered by the monitoring well's low yield and by mechanical problems with the pump.

As shown in Figure 11, pumping commenced with 0.9 foot of fuel floating in the well. Much of this fuel disappeared as the water table was drawndown. Figure 11 shows that about 0.2 foot of fuel was measured in the well after about 10 minutes of pumping. A slow influx of fuel then occurred at about the same rate as was observed when the fuel was simply bailed (Figure 11). Pump surging after about 100 minutes caused the fuel thickness to diminish again, just prior to the end of the test.

It is likely that when the water table was drawn down in the sediment around the well, fuel was left suspended above the new pumping level by capillary action, and thereby immobilized. The tendency for this to happen depends on the original fuel in the formation, the amount of drawdown, and the textural

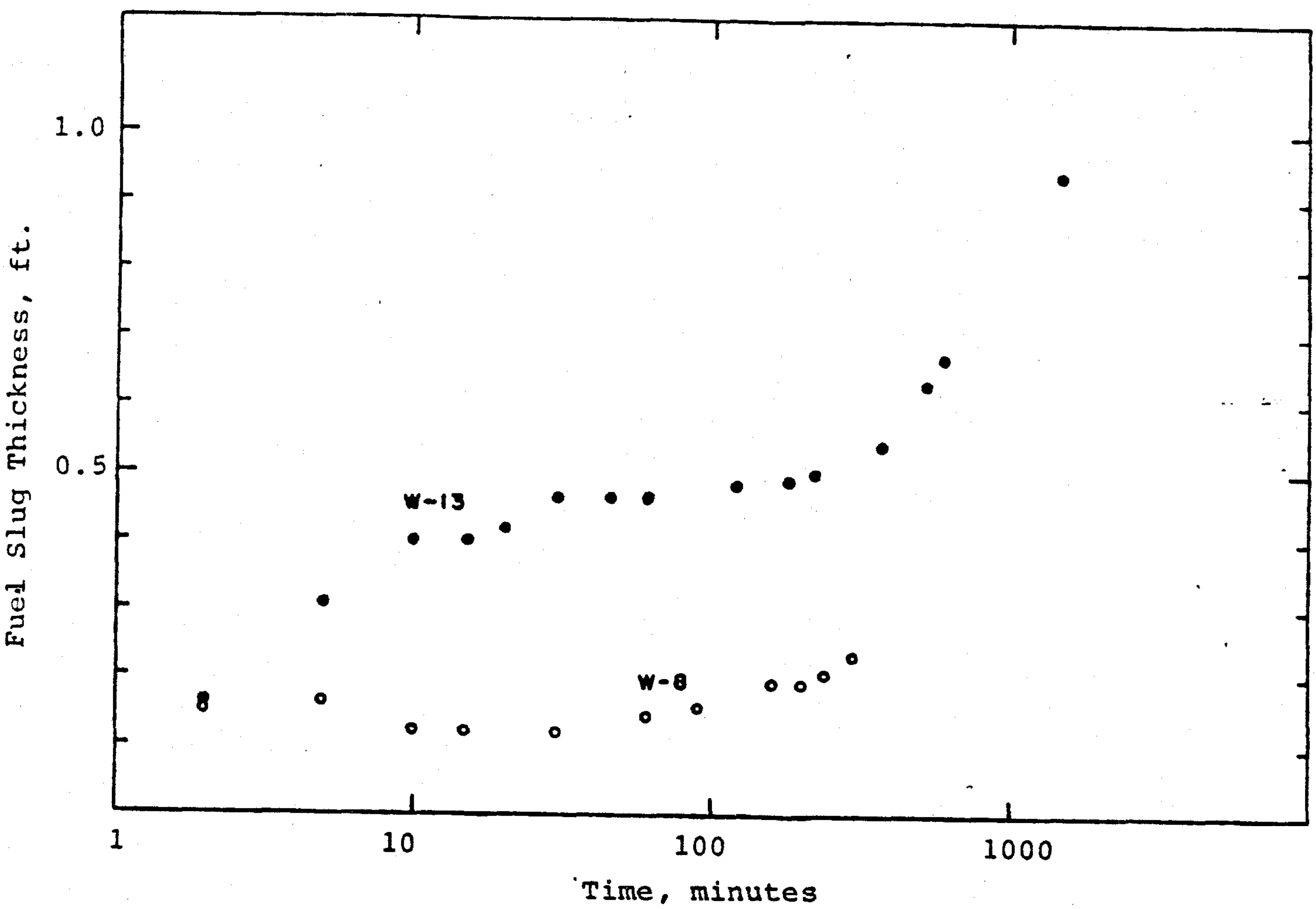

Figure 10: Influx of fuel into monitoring wells from which fuel had been bailed. Initial fuel thickness in MW-13: 1.23 feet; initial thickness in MW-8: 0.29 feet.

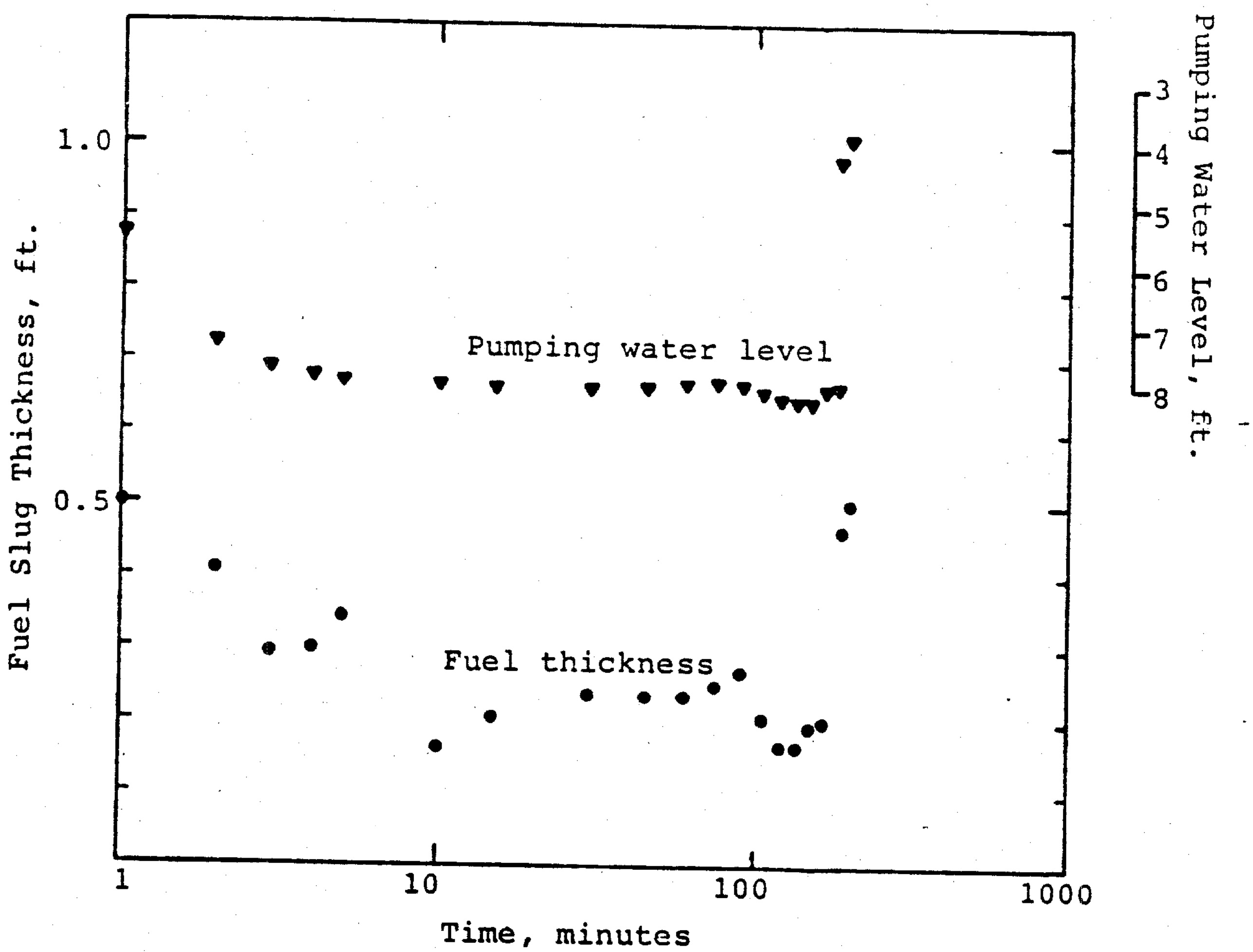

Figure 11: Change of fuel-slug thickness in MW-13 when groundwater was pumped from well. Initial slug thickness 0.94 feet.

characteristics and stratification of the sediment. Soon after pumping ceased, a slight influx was observed.

Due to limitations in the hydraulic efficiency of small diameter monitoring wells, and resulting short duration of this pumping test, it is difficult to generalize about the effects of well pumping on fuel influx rates. However, based on the results of this test it seems that fuel can be effectively induced into recovery wells at these sites. It appears that recovery would best be accomplished by continuously bailing free-floating fuel from the water surface in the well, with minimal lowering of the water table.

Fuel recovery rates would be expected to be fairly low, on the order of tens of gallons per day per well. To speed up the rate would probably require the installation of more than one recovery well, but this should be determined only after testing an actual recovery well. A properly designed and constructed recovery well would be essential for effective recovery. It should be at least 6 inches in diameter and have a gravel pack at least 2 inches thick.

Flushing System

The effectiveness of either trenches or wells can be increased by actively flushing fuel from the soil. This should be done by causing substantially greater-than-normal rates of vertical water infiltration over those areas hydraulically influenced by trenches or wells. At the Tank Farm and Day Tank this could be easily accomplished with heavy duty lawn sprinklers such as those used on golf courses.

The increased rates of infiltration will re-mobilize some of the fuel which is suspended above the water table by capillary action. The water will also help to mobilize pure fuel which is floating on the water table, both by raising the water table and by causing increased lateral flow toward the recovery trench or well.

Biodegradation

Subsurface fuel sustains naturally occurring bacteria, which consumes it at a very low rate. It is estimated that the complete removal of subsurface fuel by naturally occurring biodegradation, volatilization, and dissolution would take at least 10 years at the Tank Farm and Day Tank. With the addition and nurturing of commercially available mutant bacteria, fuel can be eliminated from the subsurface in a matter of months.

The mutant bacteria used for enhanced biodegradation require moisture, but are almost exclusively aerobic. Rates of biodegradation are therefore proportional to the degree to which a fluid medium is oxygenated. In the case of free-floating fuel, most bacterial activity occurs at the fuel/groundwater interface. Since the area of this interface is relatively small compared to exposed areas in the unsaturated zone, and since groundwater generally has little dissolved oxygen in it, rates of biodegradation in the saturated zone are normally low.

The rate of biodegradation can be significantly increased by hydraulically manipulating the local groundwater system with some of the methods discussed previously. For example, the thickness of completely saturated fuel can be reduced or eliminated by sharply lowering the water table with the pumping wells. This would facilitate the collection of mobile fuel, and at the same time cause much of the fuel to be suspended in the unsaturated zone where biodegradation is more effective.

It has been found that rates of biodegradation are optimized if bacteria-laden water is continually flushed through the affected area. An efficient system, therefore, consists of a closed loop by which groundwater is pumped from recovery wells, bacteria growth is enhanced in a reactor tank, and bacteria and nutrient-laden water is caused to infiltrate back into the aquifer.

A distinct advantage of biodegradation is that it is highly effective in areas where the fuel saturation is low and hydraulic means of recovery (such as trenches and wells) are therefore ineffective. Because of this, enhanced biodegradation is the only practical means by which fuel can be removed from the subsurface at the Abandoned Tank Farm (North Station) and the Test Cells. It would also be the only practical method by which to remove immobile fuel at the Tank Farm and the Day Tank, after the mobile fraction has been recovered with trenches or wells.

GENERAL SUMMARY AND CONCLUSIONS

A hydrogeological investigation was performed to delineate the extent of fuel in the subsurface at the Oceana Naval Air Station. The investigation was performed at the Tank Farm, Day Tank, Test Cells, Abandoned Tank Farm (North Station), and Fire Training Area (Figure 1).

Field work was planned on the basis of existing information concerning subsurface fuel, and on hypotheses regarding possible fuel occurrence and mobility. In the initial phase of field work, 13 backhoe pits were dug as part of a preliminary effort to find subsurface fuel, and to describe soil and groundwater conditions.

Six standpipes were installed in those backhoe pits where there seem to be some potential for fuel accumulation, and where soil conditions were favorable. They were subsequently used to measure fuel occurrence and water table elevations.

Thirteen test borings were drilled and monitoring wells were installed to facilitate the quantification of soil, groundwater, and subsurface fuel information. Continuous split-spoon samples were obtained to delineate fuel occurrence and stratigraphy. Measurements of floating fuel occurrence and water table elevations were measured in the monitoring wells.

At the Tank Farm, three test borings/monitoring wells were installed on the northeastern side of the fenced-in area (Figure 3). Fuel thickness measurements were made in these and in some previously installed well-point borings. Floating fuel was observed in two monitoring wells and eight old well point borings, as shown in Figure 4.

Fuel leakage has been well-documented at the Tank Farm, and a program is presently underway to repair each of the five buried tanks. Measurements made during this investigation have shown that substantial amounts of fuel remain in the ground in the northeastern part of the Tank Farm. Based on observed head potentials, a lens of subsurface fuel is gradually dispersing or spreading beyond the immediate boundaries of the Tank Farm. This lens will not flow far, and probably does not pose any direct environmental threat beyond the Tank Farm area. However, the lens of fuel will continue to be an indirect threat, inasmuch as it is a source of dissolved fuel in nearby groundwater.

Near the Day Tank, three backhoe pits were excavated and four monitoring wells were installed (Figure 5). Fuel was observed in all of them. The loss of fuel onto the ground surface and its subsequent infiltration appears to have been a source of widely occurring low levels of subsurface fuel. Recent leakage from a buried pipe appears to have been the source of a large accumulation of pure fuel in the ground just west of the Day Tank.

As at the Tank Farm, there is little potential for pure subsurface fuel at the Day Tank to flow far from its present location. However, any pure fuel remaining in the ground will continue to be a source of dissolved fuel in nearby groundwater.

At the Test Cells, three backhoe pits were excavated and three monitoring wells were installed (Figure 6). Subsurface fuel was observed near the buried fuel tanks near the northeastern corner of Test Cell A. Fuel is known to have leaked from these tanks in recent years, and discharged into a nearby drainage ditch. Only residual amounts were observed in the soil; there now appears to be no significant accumulation or flow of pure fuel.

Dissolved fuel probably occurs in groundwater just downgradient from the buried tank area. Since much less pure fuel exists there than at the Tank Farm or Day Tank, the amount of dissolved fuel would correspondingly be expected to be significantly less. Most of this probably discharges from the shallow groundwater system into the drainage ditches which occur near the Test Cells.

Three backhoe pits were excavated and four monitoring wells were installed at the Abandoned Tank Farm (North Station)(Figure 7). Traces of degraded fuel were observed in two of the backhoe pits and three of the monitoring wells. No free-floating fuel was observed. It seems likely that the observed fuel is the remnant of a larger volume that occurred in the subsurface during the period when the North Station Tank Farm was used. It may have originated from leaking pipes and tanks and periodic surface spills. The remaining freely occurring fuel is probably a source of dissolved fuel in the local shallow groundwater system.

Four backhoe pits were excavated in the Fire Training Area (Figure 8). A trace of fuel was observed in one pit located near the buried oil/water separator. This may have originated from the infiltration of fuel which flowed onto the ground from the burning circle. However, the amount of fuel observed was very small, and did not reflect a significant amount of fuel occurring in the subsurface. No sign of fuel was observed in any of the other pits. On this basis, no environmental threat exists in the Fire Training Area.

At each site, except the Fire Training Area, the occurrence of a plume of dissolved fuel appears to be the greatest environmental threat related to subsurface fuel occurrence. The solubility of light fuels in groundwater is many times the allowable limits for drinking water. Groundwater immediately beneath freely occurring subsurface fuel may be expected to have fuel concentrations near saturation level.

Concentrations of dissolved fuel will be attenuated with distance from the source, according to the characteristics of sediments and the groundwater flow system. This cannot be quantified with existing information, however. Most of the dissolved fuel from these sites will probably be transported in the shallow groundwater system to a point where it is discharged into a nearby drainage ditch. Because of this, it is not anticipated that any dissolved fuel will be transported off of the Base in the shallow groundwater system. It is possible that some dissolved fuel may enter deeper aquifers as a result of the pumping of nearby wells. Intervening low permeability units will probably prevent this from happening to any significant degree. However, this should be proven.

Possible remedial measures have been discussed for dissolved fuel and freely occurring fuel. Plumes of dissolved fuel can be contained with groundwater withdrawal wells. The groundwater can then be treated on-site by such means as adsorption (activated carbon) and aeration, prior to being discharged.

A simple and inexpensive air-stripping system can be constructed on-site for the treatment of contaminated groundwater. It would consist of discharge pipes and nozzles which would atomize the groundwater into the open air. Effluent could be discharged to drainage ditches or recirculated to the groundwater system.

The mobile portion of freely occurring subsurface fuel can be collected with trenches or wells. Shallow water table levels and cohesive soils make the use of trenches practical. It has been shown that properly designed wells would also be efficient.

Wells would probably be more expensive than trenches, but would be less disruptive.

Neither collection wells nor trenches would be able to remove that portion of the free fuel which is retained in the soil by capillary action. This portion would continue to be a source of dissolved fuel, however. The most effective way to remove it would be with a recirculating system which combines pumping, enhanced biodegradation, and flushing.

RECOMMENDATIONS

1. This investigation has shown that varying amounts of fuel occur in the subsurface at the Tank Farm, Day Tank, Test Cells, and Abandoned (North Station) Tank Farm. The greatest threat posed by this fuel appears to be that it is a source of dissolved fuel in nearby groundwater. Potential environmental problems resulting from dissolved fuel in the groundwater need to be investigated further. This should include the following steps:

   a. An inventory should be made of all wells on the Station and those within half a mile of the perimeter of the Station. This can be compiled fairly easily by NAS personnel, using NAS records and those from the State and County. The inventory should include the following information for each well:

      * Exact location
      * Surface elevation
      * Depth of screened interval
      * Other well construction specifications
      * Nature of groundwater use
      * Typical short-term and long-term pumping rates
      * Static (non-pumping) water table elevation
      * Typical water table drawdown during pumping

* Any existing water quality data

* Geologic log

b. Selected nearby water-supply wells should be analyzed to determine their areas of hydraulic influence. This may be estimated for some wells based on estimated quantitative aquifer characteristics and the data listed above. Aquifer tests have probably been run on any large water-supply wells, and data from these tests can frequently be used for this purpose. For questionable wells, it may be necessary to conduct aquifer tests specifically for this purpose.

In every case an attempt must be made to determine the hydraulic effects of pumping on groundwater in the shallow aquifer. It must then be determined if any potential exists for dissolved fuel to enter nearby wells or deeper aquifers, either as a result of natural groundwater flow or well pumping.

This phase of work must be done by a qualified hydrogeologist or a hydrologist. The estimated costs for this phase are indicated on Form 1391, which follows this narrative.

c. If, based on the above analysis, there appears to be some potential for dissolved fuel to at some time enter wells or deeper aquifers, the plume(s) must be defined more specifically.

To do this, additional monitoring wells should be installed downgradient from the spill sites(s). Deep borings (50 to 150 feet) may be necessary to better define the relationship between the shallow groundwater system and deeper ones. Water quality samples and head measurements should be taken from the monitoring wells.

As in this investigation, 2-inch PVC monitoring wells will be adequate. However, since dissolved fuel will be the primary concern, the wells should be screened well below the water table, so that floating fuel is not induced by pumping.

2. If the above investigation shows a significant potential for dissolved fuel to enter nearby wells or a deeper aquifer, that potential should be removed using the measures discussed in the section of this report entitled "Remedial Measures."

The scope of this work cannot be anticipated prior to the completion of Phases A and B; therefore estimated costs are not given.

The plume(s) of dissolved fuel should be removed with a withdrawal and treatment system. Air stripping will probably be most effective for the long-term treatment of low levels of dissolved fuel.

Mobile fuel at the source should be removed using collection trenches and or/wells, as described previously.

The immobile fraction of free fuel remaining in the subsurface should be removed with a combination system of groundwater withdrawal trenches and wells, enhanced biodegradation, and reinjection (flushing) with bacterial-laden water.

3. Existing and potential occurrences of subsurface fuel should be monitored regularly using the monitoring wells and standpipes installed during this investigation. This should be done by sniffing the well casings and standpipes, and by using a transparent interface sampler such as one produced by Oil Recovery Systems, Inc., (approximately $75.00) or equivalent. Wells and standpipes at the Tank Farm and Day Tank should be checked monthly. Those at the Test Cells should be checked quarterly. Those at the Abandoned (North Station) Tank Farm should be checked annually.

4. The Virginia State Water Control Board requires notification in the event that any fuel is found underground. The Tidewater Regional Office should be contacted. This report should provide any documentation they require, prior to the implementation of any additional work.

1. COMPONENT	FY 19___ MILITARY CONSTRUCTION PROJECT DATA	2. DATE
Navy		Feb. 1983

3. INSTALLATION AND LOCATION	4. PROJECT TITLE
NAS Oceana, Virginia Beach, VA	Subsurface Dissolved Fuel Investigation

5. PROGRAM ELEMENT	6. CATEGORY CODE	7. PROJECT NUMBER	8. PROJECT COST ($000)
---	---	---	$26.0

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
1a. Well Inventory	hr.	80	35	2.8
1b. Aquifer Testing and Analysis	hr.	160	35	5.6
1c. Monitoring Well Installation and Testing	ea.	8	1200	9.6
1d. Data Analysis and Report	hr.	160	35	5.6
Subtotal	hr.			23.6
Contingency (10%)				2.4
TOTAL				26.0

10. DESCRIPTION OF PROPOSED CONSTRUCTION

Work items are described in detail in accompanying report. Costs of remedial fuel removal cannot be reliably anticipated prior to the results of these work items.

1a. Well inventory performed primarily by Oceana personnel; indicated costs are for guidance and evaluation by professional hydrogeologist.

1b. Quantification of local aquifer characteristics to better define the threat to local water supplies resulting from subsurface fuel occurrence.

1c. Installation and testing of additional monitoring wells to define plumes of dissolved fuel at two sites on Base. Includes planning and supervision by hydrogeologist, and water-chemistry analysis.

1d. Analysis of all information obtained in steps 1a, 1b, and 1c, and more specific evaluation of the environmental threat posed by dissolved fuel in groundwater.

APPENDIX A

BACKHOE PIT LOGS

BACKHOE PIT LOGS

BP-1

Location: Test cell area, 10' east of parking area in east side.

Depth	Unified Classification	Description
0-0.3'	Pt	Sandy Topsoil, not well developed, with decomposed leaves and roots.
0.3-1.9'	SM	Sand, light gray; very fine to fine sand, little silt, moist, friable, mottled especially near roots; no fuel observed.
1.9-3.1'	SM	Sand, light brown; as above, patches of gray sand, friable to stiff, distinct mottling, no fuel observed.
3.1-5.3'	SM	Sand, medium gray; medium sand, trace to little silt, moist, friable, distinct mottling, becoming increasingly orange toward bottom, all orange at bottom; no fuel observed.
5.3-11+'	MH	Silt, dark gray; some sand, little clay (sticky), homogenous, influx of groundwater near top; trace fuel sheen on groundwater in pit, no odor.

BP-2

Location: Test cell area; 50' southwest of southwest corner of western cell.

Depth	Unified Classification	Description
0-3.0'	SM	Sand, medium gray; fine sand, some silt, moist, stiff, orange mottling which increases towards bottom; no fuel observed.
3.0-3.6'	SM	Sand, as above; moist to wet, soft, sticky (capillary zone); no fuel observed.
3.6-4.7'	ML	Silt, dark gray; little fine sand, little clay, wet, sticky, no mottling, rapid influx of groundwater, trace of a fuel sheen; no fuel odor.
4.7-8+'	SP	Sand, medium to dark gray; medium to coarse sand, trace silt, beach sand, saturated; no fuel observed.

BP-3

Location: Test cell area; 3' from east fence around buried fuel tanks.

Depth	Unified Classification	Description
0-1.6'	SM	Sand fill, medium brown; fine to medium sand, little silt, trace clay, slightly moist, very stiff, friable; no fuel observed.

Depth	Unified Classification	Description
1.6-11.0'	SM	Sand, dark bluish gray; fine to medium sand, little silt, increasingly moist with depth (not saturated), stiff, slightly cohesive; little to moderate odor of JP-5 increasing with depth

BP-4

Depth	Unified Classification	Description
0.-0.6'	Pt	Topsoil, sandy.
0.6-0.9'	SM	Sand, medium brown.
0.9-1.4'	MH	Silt, dark gray, little very fine sand, dry, friable, very stiff, no fuel observed.
1.4-2.8'	SM	Sand, medium dark gray, very fine sand, some silt, slightly moist, plastic, very stiff, slightly mottled; no fuel observed.
2.8-4.0'	ML	Silt, dark gray, little fine sand, little doy, moist, plastic, medium stiff; no fuel observed.
4.0-4.8'	ML	Silt, as above; highly mottled and moist; no fuel observed.
4.8-7.0'	SP	Sand, medium greenish gray; fine to medium sand, moist, mottled, well sorted, friable, soft; no fuel observed.

Depth	Unified Classification	Description
7.0-8.5'	SP	Sand, orangish brown; coarse sand, trace silt, well sorted, wet, friable; no fuel observed.
8.5-11+'	SP	Sand, dark gray; as above, saturated; trace sheen on groundwater.

BP-5

Location: Fire-Training area; 20' east of buried oil/water separator, just east of old runway.

Depth	Unified Classification	Description
0-0.9'	Pt	Topsoil, sandy, overlying old macadam.
0.9-1.4'	MH	Silt, dark gray; little very fine sand, dry, friable, very stiff; no fuel observed.
1.4-2.6'	MH	Silt, as above; slightly mottled and moist; no fuel observed.
2.6-3.7'	MH	Silt, dark gray; little fine sand, little clay, moist, moderately stiff, sticky, increasingly mottled with depth; no fuel observed.
3.7-10+'	SM	Sand, light gray mottled with orange; fine sand, little silt, saturated about 6" down, groundwater influx at 4.5'; no fuel observed.

BP-7

Location: Fire-training area; 1' west of old runway, 75' north of buried oil/water separator.

Depth	Unified Classification	Description
0-0.3'	Pt	Topsoil, sandy.
0.3-0.6'	SM	Sand, light brown; fine sand, - little silt, dry, friable; no fuel observed
0.6-1.9'	MH	Silt, medium to dark gray; little fine sand, trace clay, moist, medium stiff, some mottling; no fuel observed.
1.9-4.3'	ML	Silt, dark gray, little fine sand, little clay, moist, cohesive, slightly mottled; no fuel observed.
4.3-6.3'	SM	Sand, light greenish gray; fine sand, little silt, moist, friable, slightly mottled; no fuel observed.
6.3-7+'	SP	Sand, light brown; medium to coarse sand, trace silt, well sorted, saturated, friable; no fuel observed.

BP-7

Location: Fire-training area; 1' west of old runway, 75' north of buried oil/water separator.

Depth	Unified Classification	Description
0-0.3'	Pt	Topsoil, sandy.
0.3-0.6'	SM	Sand, light brown; fine sand, little silt, dry, friable; no fuel observed
0.6-1.9'	MH	Silt, medium to dark gray; little fine sand, trace clay, moist, medium stiff, some mottling; no fuel observed.
1.9-4.3'	ML	Silt, dark gray, little fine sand, little clay, moist, cohesive, slightly mottled; no fuel observed.
4.3-6.3'	SM	Sand, light greenish gray; fine sand, little silt, moist, friable, slightly mottled; no fuel observed.
6.3-7+'	SP	Sand, light brown; medium to coarse sand, trace silt, well sorted, saturated, friable; no fuel observed.

BP-8

Location: Old fuel farm; between southern and middle buried fuel tanks at old fuel farm.

Depth	Unified Classification	Description
0-0.4'	Pt	Topsoil, sandy.
0.4-0.9'	MH	Silt, medium to dark gray; little sand, trace clay, slightly moist, friable, medium stiff; no fuel observed.
0.9-1.3'	SM	Sand, light gray mottled with dark orange; fine sand, little silt, slightly moist, friable, stiff; no fuel observed.
1.3-4.9'	MH	Silt, dark brown; little very fine sand, trace clay, moist, friable, stiff, small amount of groundwater coming in below 2'; trace of oil sheen on groundwater, also possible slight odor of degraded gasoline in water.
4.9-6.0'	ML	Clayey silt, light gray mottled with orange; little very fine sand, saturated, sticky, medium stiff, fairly rapid influx of groundwater.
6.0-8.0+'	SM	Sand, bluish gray with some orange mottling; fine sand, little silt, trace clay, saturated, soft, mottles disappear below 7.0', texture is coarser below 7.0'; no discernable fuel odor.

BP-9

Location: Old fuel farm; 60' northeast of southern-most buried tank, approximately 125' from BP-8.

Depth	Unified Classification	Description
0-0.9'	Pt	Topsoil, light brown, stiff.
0.9-3.2'	MH	Silt, dark gray; little sand, trace clay, slightly moist, friable, medium stiff, rapid influx of water below 3'; no fuel observed.
3.2-5.5'	MH	Silt, light gray with orange mottling; little very fine sand, saturated, friable, stiff; rapid influx of water with a distinct oil sheen, no certain odor.
5.5-7.0+'	SM	Sand, light gray with some orange mottling; fine sand, little silt, saturated, friable; no fuel observed.

BP-10

Location: Old fuel farm; half-way between northern most buried tanks and the middle buried tanks.

Depth	Unified Classification	Description
0-0.4'	Pt	Topsoil, sandy.
0.4-0.8'	SW	Sand, light brown; fine to coarse sand, trace gravel, trace silt, moist, friable, soft; no fuel observed.

Depth	Unified Classification	Description
0.8-1.6'	MH	Silt, dark brownish gray; little very fine sand, moist, friable, stiff; no fuel observed.
1.6-3.7'	MH	Silt, dark bluish gray with pockets of medium gray; little very fine sand, trace clay, moist, friable, medium stiff, increasingly moist with depth, little perched groundwater coming in at top; slight emulsions on collected water but no sheen; slight fuel odor.
3.7-6.0+'	SM	Sand, grayish green; very fine sand and silt, moist, medium stiff, somewhat cohesive, silt decreasing with depth; moderate odor of degraded fuel, rapid influx of groundwater with fuel emulsion, slight sheen.

BP-11

Location: Day tank area; 75' north of buried tank.

Depth	Unified Classification	Description
0-0.9'	Pt	Topsoil, organic, not sandy.

Depth	Unified Classification	Description
0.9-2.5'	MH-ML	Silt, light gray; little very fine sand, little clay, moist, stiff, moderately cohesive; moderate fuel odor.
2.5-4.3'	MH-ML	Silt, grayish brown, as above, groundwater seeps in below 3', moderately rapid; fuel emulsions noticed on accumulated water.
4.3-11.0+'	SM	Sand, light bluish gray; fine sand, well sorted, little silt, trace clay, has pockets of sandy silt and clay, saturated, friable, fuel emulsion on accumulated water.

BP-12

Location: Day tank area; 40' southwest of buried tank.

Depth	Unified Classification	Description
0-0.6'	ML	Silty topsoil.
0.6-4.2'	MH-ML	Silt, dark gray; little fine sand, trace clay, slightly moist, friable, very stiff, fluid enters pit below 2' in discrete points; fluid probably mostly fuel, slight fuel odor.

Depth	Unified Classification	Description
4.2-10.5+'	SM	Sand, bluish gray; pockets of silt, saturated; distinct fuel odor.

BP-13

Location: Day tank area; 100' south of buried tank.

Depth	Unified Classification	Description
0-0.4'	SM	Sandy Topsoil.
0.4-4.1'	MH-ML	Silt, dark brownish gray; little fine sand, trace clay, slightly moist, friable, slightly stiff, somewhat mottled below 3.5'; groundwater enters below 3' with a fuel odor.
4.1-10.0+'	MH-SM	Sand and silt, light bluish gray; moderately mottled, saturated; slow influx of groundwater with moderate fuel odor, fuel emulsions on accumulated water, less fuel odor in this pit than in BP-12.

APPENDIX B

TEST BORING/MONITORING WELL LOGS

SOIL/ROCK CLASSIFIC

Project Oceana Job No. 8280 Boring No. MW-1

Location Old Fuel Farm Classified by RCB Sheet 1 of 2

ontractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 18.4'

thod of Advancing Boring Split-Spoon Augering Static Water Level 2.3'

Date Started 11/22/82 Date Completed 11/24/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
1	S1 S2	2 4 4 5		ML	0.0'-1.0' Topsoil, sandy; dark brown, fine to coarse sand, moist, friable. 1.0'-2.0' Silt; Dark gray; fine sand, moist, stiff.			No fuel odor No fuel odor	18 17
2 3	S3 S4	4 5 5 3		ML	2.0'-3.0' As above. 3.0'-4.0' Silt; Medium brownish-gray; fine sand, very moist, soft.			No fuel odor No fuel odor	16 15
4 5	S5 S6	2 2 2 3		ML	4.0'-5.0' As above, saturated, medium stiff. 5.0'-6.0' As above.			No fuel odor No fuel odor	14 13
6 7	S7 S8	6 7 4 9		SM	6.0'-7.0' Sand; Medium brownish-gray; fine sand, little silt, moderately well sorted, very moist, medium stiff. 7.0'-8.0' As above, little to some silt in pockets.			No fuel odor No fuel odor	12 11
8 9 10	S9 S10	4 3 7 10		SW	8.0'-9.0' Sand; Light brownish-gray; medium to coarse sand, well sorted, some silt, medium stiff and cohesive. 9.0'-10.0' As above, trace silt.			No fuel odor No fuel odor	10 9

OC-00113-01.02-02/01/83

Project: Oceana | Job No. 8280 | Boring No. MW-1

Location: Old Fuel Farm | Classified by: RCB | Sheet 2 of 2

Contractor: Herbert Assoc. | Driller: R. Seage | Ground Surf. Elev. 18.4'

Method of Advancing Boring: Split-Spoon Augering | Static Water Level: 2.3'

Date Started: 11/22/82 | Date Completed: 11/24/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S11	13			10.0'-11.0' As above.			No fuel odor	8
11		13		SW	11.0'-12.0' As above.			No fuel odor	
	S12	10							7
12		9							
	S13	7			12.0'-13.0' As above.			No fuel odor	6
13		11		SW					
	S14	9			13.0'-14.0' As above			No fuel odor	5
14		13							
	S15	20			14.0'-15.0' As above.			No fuel odor	4
15		18		SW					
	S16	20			15.0'-16.0' As above.			No fuel odor	3
16		22							

Project: Oceana Job No.: 8280 Boring No.: MW-2

Location: Old Fuel Farm Classified by: RCB Sheet 1 of 2

Contractor: Herbert Assoc. Driller: R. Seage Ground Surf. Elev. 17.6'

Method of Advancing Boring: Split-Spoon Augering Static Water Level: 1.3'

Date Started: 11/22/82 Date Completed: 11/30/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
0–1	S1	1, 1		ML	0.0'-1.0' Topsoil and Silt; Dark gray; little fine sand, slightly moist, friable, medium stiff.			No fuel odor	17
1–2	S2	3, 2		ML	1.0'-2.0' Silt as above.			No fuel odor (water level ▽)	16
2–3	S3	2, 3		ML	2.0'-3.0' Silt; Dark grayish-brown; little very fine sand, trace clay, slightly moist, friable, medium stiff.			No fuel odor	15
3–4	S4	2, 3		ML	3.0'-4.0' Silt as above.			No fuel odor	14
4–5	S5	3, 3		ML	4.0'-5.0' Silt as above; with parts of light gray very fine silty sand, mottled, very moist, medium stiff.			No fuel odor	13
5–6	S6	10, 13		SM	5.0'-6.0' Silty Sand; Light gray; very fine to fine sand, some silt, mottled, moist, slightly friable, medium stiff.			No fuel odor	12
6–7	S7	6, 7		SP	6.0'-7.0' Sand; Light gray; medium sand, well-sorted, trace silt, not mottled, moist, soft.			No fuel odor	11
7–8	S8	4, 5		SW	7.0'-8.0' Sand; Medium gray; very fine to medium sand, very moist, friable soft.			No fuel odor	10
8–9	S9	4, 6		SP	8.0'-9.0' Sand as above.			No fuel odor	9
9–10	S10	8, 7		SP	9.0'-10.0' Sand; Medium gray; medium sand, moderately well-sorted, moist, friable, soft.			Trace fuel odor	8

SOIL ROCK CLASSIFIC OC-00113-01.02-02/01/83

Project Oceana Job No. 8280 Boring No. MW-2

Location Old Fuel Farm Classified by RCB Sheet 2 of 2

Contractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 17.6

Method of Advancing Boring Split-Spoon Augering Static Water Level 1.3'

Date Started 11/22/82 Date Completed 11/30/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S11	10 8		SP	10.0'-11.0' Sand as above.			No fuel odor	7
11	S12	5 6			11.0'-12.0' Sand as above.			No fuel odor	6
12	S13	18 7		SP	12.0'-13.0' Sand as above.			Trace fuel odor	5
13	S14	18 14			13.0'-14.0' Sand as above.			Little fuel odor	4
14	S15	24 25		SP	14.0'-15.0' Sand as above.			Trace fuel odor	3
15	S16	25 29			15.0'-16.0' Sand as above.			Moderate fuel odor	2
16	S17	25 20		SP	16.0'-17.0' Sand as above.			Moderate to strong fuel odor	1
17	S18	21 20			17.0'-18.0' Sand as above.			Moderate to strong fuel odor	0
18	S19	10 17		SP	18.0'-19.0' Sand as above.			No fuel odor	-1
19	S20	25 31			19.0'-20.0' Sand as above.			No fuel odor	-2
20									

SOIL/ROCK CLASSIFICATION

OC-00113-01.02-02/01/83

Project Oceana Job No. 8280 Boring No. MW-3

Location Old Fuel Farm Classified by JST Sheet 1 of 2

Contractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 18.8

Method of Advancing Boring Split-Spoon Augering Static Water Level 2.7'

Date Started 11/23/82 Date Completed 11/23/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S1	3 10	22		0.0'-1.0' Topsoil; Dark brown; sandy, fine to coarse sand, moist, friable.			Trace fuel odor	
1	S2	10 20		ML	1.0'-2.0' Silt; Dark grayish-brown; some very fine sand, moist, stiff, cohesive.			Trace fuel odor	18
2	S3	10 14	16	ML	2.0'-3.0' Silt as above.			Strong fuel odor; also a septic odor	17
3	S4	14 11		SM	3.0'-4.0' Silty Sand; Medium greenish-gray; fine sand, little silt, trace medium sand, moist, friable, soft.			Strong fuel odor	16
4	S5	6 4	16		4.0'-5.0' Silt; Dark grayish-brown; some very fine to fine sand, saturated, slightly cohesive, medium stiff.			Strong fuel odor (Driller says strong fuel odor is coming from well.)	15
5	S6	6 6		MH	5.0'-6.0' Sandy Silt; Grayish-green; some very fine to fine sand, little clay; very moist; cohesive.			Strong fuel odor	14
6	S7	6 11	13	MH	6.0'-7.0' Sandy Silt as above.			Strong fuel odor	13
7	S8	13 6		SW	7.0'-8.0' Sand; Light greenish-gray; fine to medium sand, trace silt, saturated, friable, soft.			Strong fuel odor	12
8	S9	3 3	16	SW	8.0'-9.0' Sand as above.			Weak fuel odor	11
9	S10	6 13		SP	9.0'-10.0' Sand; Medium gray; medium sand, well-sorted, saturated, friable, soft.			Trace of fuel odor	10
10									9

IL/ROCK CLASSIFI

Project Oceana   Job No. 8280   Boring No. MW-3

Location Old Fuel Farm   Classified by JST   Sheet 2 of 2

ontractor Herbert Assoc.   Driller R. Seage   Ground Surf. Elev. 18.8

ethod of Advancing Boring Split-Spoon Augering   Static Water Level 2.7'

Date Started 11/23/82   Date Completed 11/23/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
11	S11	10 10	24	SP	10.0'-11.0' Sand as above, trace of silt.			Trace fuel odor	8
12	S12	9 7			11.0'-12.0' Sand as above.			No fuel odor	7
13	S13	9 13	22	SP	12.0'-13.0' Sand as above.			Moderate fuel odor (smells like septic but may be weathered fuel)	6
14	S14	20 25			13.0'-14.0' Sand as above.			Weak odor (smells like septic but may be weathered fuel).	5
15	S15	12 17	16	SP	14.0'-15.0' Sand as above, trace of fine sand, medium stiff, cohesive. Sand heaving.			Moderate fuel odor	4
16	S16	27 35			15.0'-16.0' Sand as above, trace of silt. Cohesive.			Weak fuel odor	3
17	S17	14 20	11	SW	16.0'-17.0' Sand; Light greenish-gray; fine to medium sand, trace silt, saturated, medium stiff, slightly cohesive, tighter, mod. sorted.			Strong fuel odor	2
18	S18	27 38			17.0'-18.0' Sand as above, light to medium gray.			Strong odor (smells like septic, but may be weathered fuel).	1
19	S19	0 7	10	SP	18.0'-19.0' Sand; Greenish-gray; medium to coarse sand, trace of silt and fine sand, saturated, friable, soft (loose).			Moderate fuel odor	0
20	S20	24 32			19.0'-20.0' Sand as above.			Moderate fuel odor	-1

APPENDIX C

WELL ELEVATION DATA

GALLUP SURVEYORS & ENGINEERS, LTD.

BRUCE B. GALLUP, C.L.S.
BRUCE W. GALLUP, P.E.

325 FIRST COLONIAL ROAD
VIRGINIA BEACH, VIRGINIA 23454
(804) 428-8132

December 14, 1982

Mr. Robert Brod
R.E. Wright Associates, Inc.
3240 Schoolhouse Road
Middletown, Pa. 17057

Dear Mr. Brod:

At your direction our firm recently obtained vertical control datum on the respective "monitor well sites" located on the Oceana Naval Facility. This involved getting the elevation of the top of well pipes and the respective ground elevation at each site.

The well site areas (listed by priority), designations and elevations (N.O.S. Datum - M.S.L. 0.00') are as follows:

First Priority - "Fuel Farm Area"

W - 12	Top of P.V.C.	= 17.43
	Ground	= 15.5
W - 13	Top of P.V.C.	= 16.70
	Ground	= 14.8
W - 14	Top of P.V.C.	= 19.40
	Ground	= 14.7

"Old" Well Sites (Galvanized Pipes)

MW - 1	Top of Pipe	= 16.19
	Ground	= 15.1
MW - 2	Top of Pipe	= 16.78
	Ground	= 15.3
MW - 3	Top of Pipe	= 16.45
	Ground	= 15.2
MW - 4	Top of Pipe	= 16.19
	Ground	= 15.1
MW - 5	Top of Pipe	= 17.70
	Ground	= 16.4
MW - 6	Top of Pipe	= 16.96
	Ground	= 15.8

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VIRGINIA BEACH, VIRGINIA 23454
(804) 428-8132

MW - 7	Top of Pipe	= 18.04
	Ground	= 16.6
MW - 8	Top of Pipe	= 17.67
	Ground	= 16.7
MW - 9	Top of Pipe	= 16.45
	Ground	= 15.1
MW - 10	Top of Pipe	= 16.31
	Ground	= 14.8

Second Priority - "Day Tank/Farm Area"

W - 8	Top of P.V.C.	= 19.52
	Ground	= 17.6
W - 9	Top of P.V.C.	= 18.74
	Ground	= 16.8
W - 10	Top of P.V.C.	= 19.27
	Ground	= 17.4
W -11	Top of P.V.C.	= 19.81
	Ground	= 18.3
DFSP - 1	Top of P.V.C.	= 18.65
	Ground	= 17.5
DFSP - 2	Top of P.V.C.	= 18.15
	Ground	= 17.4

Third Priority - "Test Cell Area" (Note: These wells are locked)

W - 5	Top of P.V.C.	= 16.75
	Concrete	= 15.74
W - 6	Top of P.V.C.	= 14.17
	Concrete	= 13.24
W - 7	Top of P.V.C.	= 15.59
	Concrete	= 14.70

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TCSP - 1	Top of P.V.C. = 13.43 Ground = 12.6

Fourth Priority - "C.P.O & Acey Deucey Club Area"

W - 1	Top of P.V.C. = 19.63 Ground = 18.4
W - 2	Top of P.V.C. = 19.04 Ground = 17.6
W - 3	Top of P.V.C. = 19.48 Ground = 18.8
W - 4	Top of P.V.C. = 19.09 Ground = 17.8

Noting that we completed all sites requested, I trust this information fulfils your requirements. If there are any questions or if we can be of any additional service, now or in the future, please don't hesitate to call.

Yours truly,

GALLUP SURVEYORS & ENGINEERS, LTD.

Terry W. Branch

Terry W. Branch

TWB:gb

APPENDIX D

FUEL CONCENTRATION DATA

JENNINGS LABORA
ANALYTICAL AND CONSULTI

OC-00113-01.02-02/01/83

1118 CYPRESS AVENUE • P. O. BOX 851 • VIRGINIA BEACH, VA. 23451 • PHONE (804) 425-1498

VA (EPA) CERTIFIED LABORATORY for
‑inking Water Analysis - Microbiological,
Inorganic and Organic

ASBESTOS ANALYSIS – NIOSH 582

Official Referee Chemists for:
AMERICAN OIL CHEMISTS SOCIETY
NATIONAL SOYBEAN
PROCESSORS ASSOCIATION

Laboratory Approved by VA. STATE WATER
CONTROL BOARD for Analysis of
Effluents for NPDES PERMITS
CERTIFIED OFFICIAL U.S.D.A. LABORATORY
FOR MEAT ANALYSIS

CERTIFICATE OF ANALYSIS

): R. E. WRIGHT ASSOCIATES, INC.
3240 Schoolhouse Road
Middletown, Pennsylvania 17057
ATTN: Mr. Robert C. Brod

DATE: December 17, 1982

AMPLE OF SOIL SAMPLES (5) and WATER SAMPLE (1)

MARKED

Samples delivered to laboratory 12/9/82 @ 12:00 Noon

FFICIAL SAMPLE BY:

SAMPLE AS MARKED	FUEL CONTENT(As Is Basis)
SOIL SAMPLES	
#1 - W-5 (S-5) (4-5') (1-1)	0.1616 %
#2 - W-8 (S-3) (2-3') (3-3)	0.2908 %
#3 - W-8 (S-6) (5-6') (1-3)	0.2068 %
#4 - W-13 (S-3 (2-3') (5-5)	0.0444 %
#5 - W-13 (S-7) (6-7') (4-6)	0.1616 %
WATER SAMPLE	
W-13 3 Hrs.	90.4 PPM

Respectfully submitted,
JENNINGS LABORATORIES, INC.

[signature]
CHEMIST

Laboratory Analysis No. 34004

OFFICIAL METHODS OF A.O.A.C., A.O.C.S., A.S.T.M., A.P.H.A., E.P.A. AND N.S.P.A. USED IN ALL ANALYSIS UNLESS OTHERWISE STATED

SOIL/ROCK CLASSIFICATION

Project Oceana Job No. 8280 Boring No. MW-4

Location Old Fuel Farm Classified by JST Sheet 1 of 2

Contractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 17.8

Method of Advancing Boring Split-Spoon Augering Static Water Level 1.7'

Date Started 11/23/82 Date Completed 11/24/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Construction Details and Remarks	Elevation, Ft.
0–1	S1	3, 4	18	ML	0.0'-1.0' Topsoil and Silt; Dark grayish-brown; little fine sand, trace clay, damp, medium stiff, cohesive.	No fuel odor	17
1–2	S2	5, 9			1.0'-2.0' Silt as above, moist.	No fuel odor	16
2–3	S3	5, 4	20	ML	2.0'-3.0' Silt as above.	No fuel odor	15
3–4	S4	4, 5			3.0'-4.0' Silt as above.	No fuel odor	14
4–5	S5	2, 4	18	ML	4.0'-5.0' Sandy Silt; Light brownish-gray; very fine to fine sand, trace clay, saturated, slightly cohesive.	No fuel odor	13
5–6	S6	4, 4		SM	5.0'-6.0' Silty Sand; Light greenish-gray; very fine to fine sand, some silt, saturated, friable, slightly stiff.	No fuel odor	12
6–7	S7	5, 3	18	SM	6.0'-7.0' Silty sand as above, slightly cohesive.	No fuel odor	11
7–8	S8	16, 17		SW	7.0'-8.0' Sand; Light greenish-gray; fine to medium sand, trace silt, poorly sorted, saturated, friable, loose.	Possible slight fuel odor	10
8–9	S9	5, 9	6	SP	8.0'-9.0' Sand; Light greenish-gray; medium sand, trace coarse sand, trace silt, well-sorted, saturated, friable loose.	Moderate fuel odor	9
9–10	S10	15, 14			9.0'-10.0' Sand as above.	Moderate fuel odor	8

SOIL/ROCK CLASSIFI...

Project Oceana Job No. 8280 Boring No. MW-4
Location Old Fuel Farm Classified by JST Sheet 2 of 2
Contractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 17.
Method of Advancing Boring Split-Spoon Augering Static Water Level 1.7'
Date Started 11/23/82 Date Completed 11/24/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S11	8			10.0'-11.0' Sand as above, sand is heaving.			Weak fuel odor	
11		7	16	SP					7
	S12	12			11.0'-12.0' Sand as above.			Weak fuel odor	
12		20							6
	S13	13			12.0'-13.0' Sand as above.			Trace of fuel odor	
13		22	16	SP					5
	S14	25			13.0'-14.0' Sand; Light greenish-gray; medium to coarse sand, trace of gravel, saturated, friable, loose.			Trace of fuel odor	
14		27							4
	S15	8			14.0'-15.0' Sand as above, light brownish-gray.			Trace of fuel odor	
15		18	16	SP					3
	S16	32			15.0'-16.0' Sand as above, medium sand, trace coarse sand.			Trace of fuel odor	
16		50							2
	S17	0			16.0'-17.0' Sand as above.			Trace of fuel odor	
17		16	3	SP					1
	S18	41			17.0'-18.0' Sand as above.			Trace of fuel odor	
18		49							0

OC-00113-01.02-02/01/83

SOIL/ROCK CLASSIFIC

Project Oceana — Job No. 8280 — Boring No. MW-5

Location Test Cells — Classified by JST — Sheet 1 of 2

Contractor Herbert Assoc. — Driller R. Seage — Ground Surf. Elev. 15.7

Method of Advancing Boring Split-Spoon Augering — Static Water Level 3.7'

Date Started 11/30/82 — Date Completed 11/30/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S1	1			0.0'-1.0' Silty Sand; Greenish-gray, fine to medium sand, some silt, poorly sorted, damp, friable, soft.			Moderate fuel odor	
1		5	18	SM					15
	S2	4			1.0'-2.0' Silty Sand as above, little silt. (May be fill.)			Moderate fuel odor	
2		3							14
	S3	2			2.0'-3.0' Silty Sand as above, little silt, moist.			Very strong fuel odor	
3		2	15	SM					13
	S4	3			3.0'-4.0' Silty Sand as above.			Very strong fuel odor	
4		2							12
	S5	1			4.0'-5.0' Silty Sand as above, saturated. Very soft.			Very strong fuel odor	
5		1	12	SM					11
	S6	0			5.0'-6.0' Silty Sand as above.			Very strong fuel odor	
6		1							10
	S7	1			6.0'-7.0' Silty Sand as above.			Very strong fuel odor	
7		1	17	SM					9
	S8	1			7.0'-8.0' Silty Sand as above.			Very strong fuel odor	
8		1							8
	S9	2			8.0'-9.0' Silty Sand as above, trace of clay in small lenses, slightly cohesive.			Moderate fuel odor	7
9		2	17	SM					
	S10	2			9.0'-10.0' Silty Sand as above.			Moderate fuel odor	
10		2							6

SOIL/ROCK CLASSIFI

Project: Oceana | Job No. 8280 | Boring No. MW-5

Location: Test Cells | Classified by: JST | Sheet 2 of 2

Contractor: Herbert Assoc. | Driller: R. Seage | Ground Surf. Elev. 15.

Method of Advancing Boring: Split-Spoon Augering | Static Water Level 3.7'

Date Started: 11/30/82 | Date Completed: 11/30/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Construction Details and Remarks	Elevation, Ft.
10–11	S11	2, 2	18	SP	10.0'-11.0' Sand; Greenish-gray; medium sand, trace fine sand, trace silt, saturated, friable, loose.	Moderate fuel odor	5
11–12	S12	3, 4			11.0'-12.0' Sand as above.	Moderate fuel odor	4
12–13	S13	3, 3	16	SW	12.0'-13.0' Sand; Greenish-gray; fine to medium sand, trace of silt, saturated, friable, loose.	Faint fuel odor	3
13–14	S14	4, 3			13.0'-14.0' Sand as above.	Faint fuel odor	2
14–15	S15	1, 6	24	SW	14.0'-15.0' Sand as above.	No fuel odor	1
15–16	S16	3, 9			15.0'-16.0' Sand as above, tighter in spots.	No fuel odor	0
16–17	S17	1, 2	22	SW	16.0'-17.0' Sand as above.	Faint fuel odor	-1
17–18	S18	5, 1			17.0'-18.0' Sand as above.	Faint fuel odor	-2
18–19	S19	1, 0	24	ML	18.0'-19.0' Clayey Silt; Greenish-gray; trace of fine sand little clay, moist, cohesive, soft.	No fuel odor	-3
19–20	S20	1, 0			19.0'-20.0' Clayey Silt as above.	No fuel odor	-4

OC-00113-01.02-02/01/83

SOIL/ROCK CLASSIFIC...

Project: Oceana   Job No. 8280   Boring No. MW-6

Location: Test Cells   Classified by: JST   Sheet 1 of 2

Contractor: Herbert Assoc.   Driller: R. Seage   Ground Surf. Elev. 13.2

Method of Advancing Boring: Split-Spoon Augering   Static Water Level 1.3'

Date Started: 11/30/82   Date Completed: 11/30/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery, In.	USCS	Sediment Description and Classification	Construction Details and Remarks	Elevation, Ft.
0–1	S1	1, 2	18	ML	0.0'-1.0' Sandy Silt; Medium brown; some fine to medium sand, many organics, mottled appearance (shades of gray and reddish-brown), damp, slightly cohesive, stiff.	Organic odor but no fuel odor	13
1–2	S2	5, 7			1.0'-2.0' Sandy Silt as above.	No fuel odor	12
2–3	S3	5, 6	17	ML	2.0'-3.0' Sandy Silt; Light grayish-brown; little fine to medium sand, trace clay, damp, cohesive, stiff, much of sample appears highly oxidized.	No fuel odor	11
3–4	S4	9, 9			3.0'-4.0' Sandy Silt as above.	No fuel odor	10
4–5	S5	5, 3	19	SM	4.0'-5.0' Silty Sand; Light orangish-brown; fine sand, little medium sand, little silt, trace clay in the form of small clay lenses, moist, friable to cohesive, medium stiff.	No fuel odor	9
5–6	S6	4, 8			5.0'-6.0' Silty Sand as above, becoming less silty with depth.	No fuel odor	8
6–7	S7	6, 7	20	SW	6.0'-7.0' Sand; Light grayish-brown; medium sand, little coarse sand, trace of fine sand and silt, saturated, friable, loose.	No fuel odor	7
7–8	S8	9, 8			7.0'-8.0' Sand as above.	No fuel odor	6
8–9	S9	8, 13	22	SW	8.0'-9.0' Sand; Greenish-gray; fine to medium sand, trace silt, saturated, friable, loose, some stiffness in spots.	No fuel odor	5
9–10	S10	15, 16			9.0'-10.0' Sand as above.	No fuel odor	4

OC-00113-01.02-02/01/83

SOIL/ROCK CLASSIFICATION SHEET

Project Oceana Job No. 8280 Boring No. MW-6

Location Test Cells Classified by JST Sheet 2 of 2

Contractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 13.2

Method of Advancing Boring Split-Spoon Augering Static Water Level 1.3'

Date Started 11/30/82 Date Completed 11/30/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S11	8			10.0'-11.0' Sand as above, sand is heaving.			Faint odor, not fuel odor	3
11		9	23	SW					
	S12	2			11.0'-12.0' Sand as above.			No fuel odor	2
12		5							
	S13	8			12.0'-13.0' Sand as above, light grayish-brown.			No fuel odor	1
13		10	21	SW					
	S14	10			13.0'-14.0' Sand as above.			No fuel odor	0
14		6							
	S15	6			14.0'-15.0' Sand as above.			No fuel odor	-1
15		2	21	SW					
	S16	1			15.0'-16.0' Sand as above.			No fuel odor	-2
16		2							
	S17	2			16.0'-17.0' Sand as above, greenish-gray, very loose, soft.			No fuel odor	-3
17		1	23	SW					
	S18	0			17.0'-18.0' Sand as above, becoming siltier with depth.			No fuel odor	-4
18		1							
	S19	5		SM	18.0'-19.0' Silty Sand; Greenish-gray; fine to medium sand, little silt, saturated, friable.			No fuel odor	-5
19		3	20	ML					
	S20	8			19.0'-19.5' Silt; Gray; trace very fine sand, saturated, medium stiff, slightly cohesive to friable.			No fuel odor	-6
20		10		SM	19.5'-20.0' Silty Sand as above.				

SOIL/ROCK CLASSIFICATION SHEET

Project: Oceana Job No. 8280 Boring No. MW-7
Location: Test Cells Classified by: JST Sheet 1 of 2
Contractor: Herbert Assoc. Driller: R. Seage Ground Surf. Elev. 14.
Method of Advancing Boring: Split-Spoon Augering Static Water Level: 3.3'
Date Started: 12/3/82 Date Completed: 12/3/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
0–1	S1	5, 7	18	ML	0.0'-1.0' Silt; Dark greenish-gray; trace fine sand and clay, many organics, moist, cohesive, tight.			Slight fuel odor	14
1–2	S2	9, 11			1.0'-2.0' Silt as above, light greenish-gray, little clay, tighter.			Slight fuel odor	13
2–3	S3	6, 7	17	ML	2.0'-3.0' Sandy Clayey Silt; Dark greenish-gray; little very fine to fine sand, little clay, moist, cohesive, stiff, very tight in areas of high clay content.			Slight fuel odor	12
3–4	S4	9, 13		MH	3.0'-4.0' Sandy Silt; Dark greenish-gray; some fine sand, trace medium sand, very moist, medium stiff, friable.			Slight fuel odor	11
4–5	S5	9, 16	19	SM	4.0'-5.0' Silty Sand; Grayish-green; very fine to medium sand, some silt, saturated, slightly cohesive, medium stiff.			Slight fuel odor	10
5–6	S6	17, 22			5.0'-6.0' Silty Sand as above.			Slight fuel odor	9
6–7	S7	3, 3	21	SM	6.0'-7.0' Silty Sand as above, dark greenish-gray, trace of clay in small layers.			Slight fuel odor	8
7–8	S8	7, 10			7.0'-8.0' Silty Sand as above.			Slight fuel odor	7
8–9	S9	8, 9	20	SM	8.0'-9.0' Silty Sand; Greenish-gray; fine to medium sand, trace coarse sand, little silt, saturated, friable, loose.			No fuel odor	6
9–10	S10	16, 8			9.0'-10.0' Silty Sand as above.			No fuel odor	5

SOIL/ROCK CLASSIFIC

Project Oceana Job No. 8280 Boring No. MW-7

Location Test Cells Classified by JST Sheet 2 of 2

Contractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 14.7

Method of Advancing Boring Split-Spoon Augering Static Water Level 3.3'

Date Started 12/3/82 Date Completed 12/3/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Construction Details and Remarks	Elevation, Ft.
	S11	3			10.0'-11.0' Sand; Greenish-gray; medium sand, little fine sand, saturated, friable, loose.	Slight fuel odor	
11		4	24	SP			4
	S12	4			11.0'-12.0' Sand as above.	Slight fuel odor	
12		3					3
	S13	8			12.0'-13.0' Sand as above.	No fuel odor	
13		8	23	SP			2
	S14	10			13.0'-14.0' Sand as above.	No fuel odor	
14		12					1
	S15	5			14.0'-15.0' Sand; Greenish-gray; fine to medium sand, trace silt, saturated, friable, very loose, soft.	No fuel odor	
15		9	12	SW			0
	S16	9			15.0'-16.0' Sand as above.	No fuel odor	
16		6					-1
	S17	3			16.0'-17.0' Sand as above.	No fuel odor	
17		3	0	SW			-2
	S18	5			17.0'-18.0' Sand as above.	No fuel odor	
18		4					-3

OC-00113-01.02-02/01/83

... L/ROCK CLASSIFI...

Project Oceana | Job No. 8280 | Boring No. MW-8

Location Test Cells | Classified by JST | Sheet 1 of 2

ontractor Herbert Assoc. | Driller R. Seage | Ground Surf. Elev. 17.

ethod of Advancing Boring Split-Spoon Augering | Static Water Level 2.0'

Date Started 12/1/82 | Date Completed 12/1/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
1	S1	2, 4	14	MH	0.0'-1.0' Silt; Dark brown; trace fine sand, trace clay, many organics, moist, cohesive, stiff.			Strong fuel odor	17
2	S2	5, 5			1.0'-2.0' Silt as above, clay content increasing with depth.			Strong fuel odor	16
3	S3	3, 3	16	CL	2.0'-3.0' Silty Clay; Grayish-brown; little silt, moist, cohesive, stiff, fairly tight, tough.			Strong fuel odor	15
4	S4	3, 2			3.0'-4.0' Silty Clay as above.			Strong fuel odor	14
5	S5	2, 3	15	CH	4.0'-5.0' Clay; Grayish-green; trace silt, damp, plastic, tight, highly cohesive.			Strong fuel odor	13
6	S6	1, 3		SW	5.0'-6.0' Sand; Greenish-gray; fine to medium sand, trace silt, saturated, friable, loose.			Strong fuel odor	12
7	S7	4, 7	20	SW	6.0'-7.0' Sand; Greenish-gray to brownish-gray; fine to medium sand, trace silt, trace coarse sand, saturated, friable, loose.			Strong fuel odor	11
8	S8	9, 11			7.0'-8.0' Sand as above.			Strong fuel odor	10
9	S9	8, 6	23	SP	8.0'-9.0' Sand as above, mostly medium sand.			Moderate fuel odor	9
10	S10	6, 5			9.0'-10.0' Sand as above.			Moderate fuel odor	8

OC-00113-01.02-02/01/83

...L. ROCK CLASSIFIC

Project Oceana | Job No. 8280 | Boring No. MW-8

Location Day Tank | Classified by JST | Sheet 2 of 2

Contractor Herbert Assoc. | Driller R. Seage | Ground Surf. Elev. 17.

Method of Advancing Boring Split-Spoon Augering | Static Water Level 2.0'

Date Started 12/1/82 | Date Completed 12/1/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S11	3			10.0'-11.0' Sand as above.			Moderate fuel odor	7
11		5	21	SP					
	S12	15			11.0'-12.0' Sand as above.			Moderate fuel odor	6
12		16							
	S13	5			12.0'-13.0' Sand as above, trace of coarse sand.			Moderate fuel odor	5
13		10	23	SP					
	S14	15			13.0'-14.0' Sand as above.			Moderate fuel odor	4
14		16							
	S15	3			14.0'-15.0' Sand as above.			Pure fuel coming from hole Very strong fuel odor	3
15		7	20	SP					
	S16	11			15.0'-16.0' Sand as above.			Very strong fuel odor	2
16		12							
	S17	9			16.0'-17.0' Sand as above, tighter			Strong fuel odor	1
17		13	22	SP					
	S18	32			17.0'-18.0' Sand as above, very tight, tough.			Strong fuel odor	0
18		40							
	S19	8			18.0'-19.0' Sand as above.			Strong fuel odor	-1
19		20	22	SP					
	S20	25			19.0'-20.0' Sand as above.			Strong fuel odor	-2
20		29							

OC-00113-01.02-02/01/83

SOIL/ROCK CLASSIFI[illegible]

Project: Oceana | Job No. 8280 | Boring No. MW-9
Location: Day Tank | Classified by JST | Sheet 1 of 2
Contractor: Herbert Assoc. | Driller: R. Seage | Ground Surf. Elev. 16.[illegible]
Method of Advancing Boring: Split-Spoon Augering | Static Water Level 1.4'
Date Started: 12/1/82 | Date Completed: 12/1/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Construction Details and Remarks	Elevation, Ft.
0–1	S1	2, 3	15	ML	0.0'-1.0' Silt; Tan to dark brown; trace clay, trace fine sand, some organics, damp, cohesive, stiff.	Organic odor but no fuel odor	16
1–2	S2	5, 5			1.0'-2.0' Silt as above, clay content increasing with depth.	No fuel odor	15
2–3	S3	3, 3	14	CL	2.0'-3.0' Silty Clay; Dark grayish-brown; little silt, damp, slightly plastic, cohesive, fairly tight.	Moderate fuel odor	14
3–4	S4	3, 4			3.0'-4.0' Silty Clay as above.	Moderate fuel odor	13
4–5	S5	3, 1	14	CL	4.0'-5.0' Clay; Dark grayish-green; trace silt; damp, plastic, tight, highly cohesive.	Moderate fuel odor	12
5–6	S6	2, 1		SM	5.0'-6.0' Silty Sand; Greenish-gray; very fine to medium sand, little silt, saturated, friable, loose.	Strong fuel odor	11
6–7	S7	4, 6	18	SW	6.0'-7.0' Silty Sand as above.	Moderate fuel odor	10
7–8	S8	6, 5			7.0'-8.0' Sand; Greenish-gray; fine to medium sand, trace silt, saturated, loose, friable.	Moderate fuel odor	9
8–9	S9	10, 16	20	SP	8.0'-9.0' Sand; Greenish-gray; medium sand, little fine sand, saturated, friable, soft.	Trace fuel odor	8
9–10	S10	28, 30			9.0'-10.0' Sand as above.	Trace fuel odor	7

..IL, ROCK CLASSIFI..

Project Oceana Job No. 8280 Boring No. MW-9

Location Day Tank Classified by JST Sheet 2 of 2

Contractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 16.8

Method of Advancing Boring Split-Spoon Augering Static Water Level 1.4'

Date Started 12/1/82 Date Completed 12/1/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S11	4			10.0'-11.0' Sand as above, sand starting to heave.			Moderate fuel odor	6
11		4	21	SP					
	S12	10			11.0'-12.0' Sand as above.			Moderate fuel odor	5
12		13							
	S13	9			12.0'-13.0' Sand as above.			Moderate fuel odor	4
13		9	22	SP					
	S14	10			13.0'-14.0' Sand as above.			Moderate fuel odor	3
14		12							
	S15	6			14.0'-15.0' Sand as above, trace fine sand.			Moderate fuel odor	2
15		10	20	SP					
	S16	12			15.0'-16.0' Sand as above.			Moderate fuel odor	1
16		22							
	S17	7			16.0'-17.0' Sand as above, heaving badly.			Moderate fuel odor	0
17		7	18	SP					
	S18	13			17.0'-18.0' Sand as above.			Moderate fuel odor	-1
18		15							
									-2

- -L/ROCK CLASSIF

Project Oceana Job No. 8280 Boring No. MW-10

Location Day Tank Classified by JST Sheet 1 of 2

Contractor Herbert Assoc. Driller R. Seage Ground Surf. Elev. 17

Method of Advancing Boring Split-Spoon Augering Static Water Level 1.8'

Date Started 12/2/82 Date Completed 12/2/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S1	1			0.0'-1.0' Clayey Silt to Silty Clay Dark brown to light brownish-gray; silt and clay, appears layered, organics, cohesive, damp, stiff, very tight in spots.			Moderate fuel odor	17
1		3	19	ML CL					
	S2	3			1.0'-2.0' Clayey Silt to Silty Clay as above.			Moderate fuel odor	16
2		4							
	S3	3			2.0'-3.0' Clayey Silt to Silty Clay as above.			Moderate fuel odor	15
3		3	18	ML CL					
	S4	4			3.0'-4.0' Clayey Silt to Silty Clay as above.			Moderate fuel odor	14
4		3							
	S5	5			4.0'-5.0' Silty Sand; Greenish-brown to greenish-gray; fine to medium sand, some silt, trace clay, moist, slightly cohesive, medium stiff.			Moderate fuel odor	13
5		3	15	SM					
	S6	6			5.0'-6.0' Silty Sand; Greenish-gray; fine to medium sand, some silt, saturated, friable.			Moderate fuel odor	12
6		4							
	S7	2			6.0'-7.0' Silty Sand; Greenish-brown; fine sand, little medium sand, little silt, trace clay, saturated, friable to slightly cohesive.			Moderate fuel odor	11
7		1	20	SM					
	S8	5			7.0'-8.0' Silty Sand as above.			Moderate fuel odor	10
8		3							
	S9	6			8.0'-9.0' Sand; Greenish-gray; medium sand, little fine sand, trace silt, trace coarse sand, saturated, friable, tighter in spots.			Moderate fuel odor	9
9		7	21	SW					
	S10	15			9.0'-10.0' Sand as above.			Moderate fuel odor	8
10		22							

Project: Oceana | Job No.: 8280 | Boring No.: MW-10

Location: Day Tank | Classified by: JST | Sheet 2 of 2

Contractor: Herbert Assoc. | Driller: R. Seage | Ground Surf. Elev.: 17.4

Method of Advancing Boring: Split Spoon - Augering | Static Water Level: 1.8'

Date Started: 12/2/82 | Date Completed: 12/2/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
10–11	S11	2, 7	20	SW	10.0'-11.0' Sand; Light brownish gray; medium sand, trace fine & coarse sand, friable loose.			Moderate Fuel Odor	7
11–12	S12	15, 16			11.0'-12.0' Sand as above.			Moderate Fuel Odor	6
12–13	S13	9, 11	23	SW	12.0'-13.0' Sand; Brownish gray; medium sand, saturated, friable, sand is heaving a little, little fine sand			Moderate Fuel Odor	5
13–14	S14	19, 22			13.0'-14.0' Sand as above.			Moderate Fuel Odor	4
14–15	S15	8, 8	22	SW	14.0'-15.0' Sand as above.			Moderate Fuel Odor	3
15–16	S16	9, 10			15.0'-16.0' Sand as above			Moderate Fuel Odor	2
16–17	S17	9, 11	14	SW	16.0'-17.0' Sand as above, brownish gray to greenish gray.			Moderate Fuel Odor	1
17–18	S18	23, 23			17.0'-18.0' Sand as above.			Moderate Fuel Odor	0
18–19	S19	13, 18	0	SW	18.0'-20.0' Sand as above.				-1
19–20	S20	25, 30							-2

..IL/ROCK CLASSIFI

OC-00113-01.02-02/01/83

Project: Oceana — Job No. 8280 — Boring No. MW-11

Location: Day Tank — Classified by: JST — Sheet 1 of 2

Contractor: Herbert Assoc. — Driller: R. Seage — Ground Surf. Elev. 18.3'

Method of Advancing Boring: Split Spoon - Augering — Static Water Level 2.5'

Date Started: 12/1/82 — Date Completed: 12/1/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Construction Details and Remarks	Elevation, Ft.
0–1	S1	2, 4	14	ML	0.0'-1.0' Silt; Dark brown; trace clay, organics, Moist, cohesive, medium stiff.	Organic Odor No Fuel Odor	18
1–2	S2	2, 3		SM	1.0'-2.0' Silty Sand; Medium brown; fine to medium sand, little silt, moist, friable, loose	Slight Fuel Odor	17
2–3	S3	2, 2	16	ML	2.0'-3.0' Clayey Silt; Dark brown; little clay, trace fine sand, saturated, cohesive, fairly tight in spots.	Moderate Fuel Odor ▽	16
3–4	S4	2, 2			3.0'-4.0' Clayey Silt as above.	Moderate Fuel odor	15
4–5	S5	2, 3	19	ML	4.0'-5.0' Sandy Silt; Medium to dark brown; little fine to medium sand, trace clay, saturated, moderately cohesive, stiff in spots.	Strong Fuel Odor	14
5–6	S6	4, 5			5.0-6.0' Sandy silt as above, becoming sandier with depth	Strong Fuel Odor	13
6–7	S7	6, 7	18	SM	6.0'-7.0' Silty Sand; Greenish gray; fine to medium sand, little silt, saturated, friable	Strong Fuel Odor	12
7–8	S8	8, 11			7.0'-8.0' Silty sand as above	Strong Fuel Odor	11
8–9	S9	10, 11	21	SW	8.0'-9.0' Sand; Light greenish gray; fine to medium sand, trace very fine sand and silt, saturated, friable.	Strong Fuel Odor	10
9–10	S10	12, 11			9.0'-10.0' Sand as above.	Strong Fuel Odor	9

SOIL/ROCK CLASSIFIC... **OC-00113-01.02-02/01/83**

Project: Oceana — Job No. 8280 — Boring No. MW-11

Location: Day Tank . — Classified by: JST — Sheet 2 of 2

Contractor: Herbert Assoc. — Driller: R. Seage — Ground Surf. Elev. 18.3'

Method of Advancing Boring: Split Spoon - Augering — Static Water Level: 2.5'

Date Started: 12/1/82 — Date Completed: 12/1/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S11	2			10.0'-11.0' Sand; Greenish gray; medium sand, little fine sand, saturated, friable, loose, sand beginning to heave			Moderate Fuel Odor	8
11		7	21	SW					
	S12	11			11.0'-12.0' Sand as above.			Moderate Fuel Odor	7
12		15							
	S13	4			12.0'-13.0' Sand as above.			Moderate Fuel Odor	6
13		7	21	SW	13.0'-14.0' Sand as above.			Moderate Fuel Odor	
	S14	11							5
14		14							
	S15	7			14.0'-15.0' Sand as above.			Moderate Fuel Odor	4
15		11	23	SW	15.0'-16.0' Sand as above, sand heaving badly			Moderate Fuel Odor	
	S16	23							3
16		NA							
									2

SOIL/ROCK CLASSIFIC

Project Oceana | Job No. 8280 | Boring No. MW-12

Location New Fuel Farm | Classified by JST | Sheet 1 of 2

Contractor Herbert Assoc. | Driller R. Seage | Ground Surf. Elev. 15.5'

Method of Advancing Boring Split Spoon - Augering | Static Water Level 2.4'

Date Started 12/2/82 | Date Completed 12/2/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Construction Details and Remarks	Elevation, Ft.
0	S1	1, 1	17	ML	0.0'-1.0' Clayey Silt; Medium brown; some clay, organics, damp, cohesive, medium stiff.	Moderate Fuel Odor	15
1	S2	3, 3		CL	1.0'-2.0' Silty Clay; Tan; little silt, damp, cohesive, stiff, very tight.	Moderate Fuel Odor	14
2	S3	3, 3	19	CL	2.0'-3.0' Silty Clay as above.	Moderate Fuel Odor	13
3	S4	4, 4			3.0'-4.0' Silty Clay as above.	Moderate Fuel Odor	12
4	S5	5, 6	18	ML	4.0'-5.0' Clayey Silt; Medium brown; little clay, very moist in spots, cohesive, medium stiff.	Strong Fuel Odor	11
5	S6	5, 4		SM	5.0'-6.0' Silty Sand; Brownish gray; very fine to fine sand, little silt, trace clay, saturated, slightly cohesive to friable.	Strong Fuel Odor	10
6	S7	6, 6	17	SW	6.0'-7.0' Sand; Brownish gray; fine to medium sand, trace silt, saturated, friable, soft.	Strong Fuel Odor	9
7	S8	7, 10			7.0'-8.0' Sand as above.	Strong Fuel Odor	8
8	S9	10, 15	20	SP	8.0'-9.0' Sand; Brownish gray to greenish gray; medium sand, trace fine sand, saturated, friable, fairly tight.	Strong Fuel Odor	7
9	S10	15, 17			9.0'-10.0' Sand as above.	Moderate Fuel Odor	6
10							

IL/ROCK CLASSIFIC

OC-00113-01.02-02/01/83

Project: Oceana — Job No. 8280 — Boring No. MW-12

Location: New Fuel Farm — Classified by: JST — Sheet 2 of 2

Contractor: Herbert Assoc. — Driller: R. Seage — Ground Surf. Elev. 15.5'

Method of Advancing Boring: Split Spoon - Augering — Static Water Level: 2.4'

Date Started: 12/2/82 — Date Completed: 12/2/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Construction Details and Remarks	Elevation, Ft.
	S11	2			10.0'-11.0' Sand as above.	Strong Fuel Odor, Fuel Coming Out of Hole.	5
11		2	19	SP	11.0'-12.0' Sand as above.	Strong Fuel Odor	
	S12	12					4
12		16					
	S13	5			12.0'-13.0' Sand as above, little fine sand, trace silt	Moderate Fuel Odor	3
13		13	20	SW	13.0'-14.0' Sand as above.	Moderate Fuel Odor	
	S14	18					2
14		20					
	S15	2			14.0'-15.0' Sand as above.	Moderate Fuel Odor	1
15		4	21	SW	15.0'-16.0' Sand as above	Moderate Fuel Odor	
	S16	7					0
16		10					
	S17	6			16.0'-17.0' Sand as above.	Strong Fuel Odor	-1
17		10	12	SW	17.0'-18.0' Sand as above, sand is heaving	Strong Fuel Odor	
	S18	10					-2
18		11					
							-3

SOIL/ROCK CLASSIFIC

Project Oceana
Job No. 8280
Boring No. MW-14
Location New Fuel Farm.
Classified by JST
Sheet 1 of 1
Contractor
Driller JST
Ground Surf. Elev. 14.7'
Method of Advancing Boring Hand Auger
Static Water Level 0.4'
Date Started 12/7/82
Date Completed 12/7/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	NO SAMPLES TAKEN	Hand Augered to 5.58'		ML	0.0'-1.0' Silt; Dark brown; little clay, many organics, damp, cohesive.			No Fuel Odor	
1									14
				ML	1.0'-2.0' Clayey Silt; Dark brown; some clay, moist to saturated, cohesive.			No Fuel Odor	
2									13
				CL	2.0'-3.0 Silty Clay; Tan to medium brown; some silt, saturated, cohesive, stiff.			No Fuel Odor	
3									12
				SM	3.0'-4.0' Silty Sand: Light grayish brown; very fine to medium sand, little silt, trace clay, saturated, friable to slightly cohesive.			No Fuel Odor	
4									11
				SM	4.0'-5.0' Silty Sand to Sand; Greenish gray; fine to medium sand little silt, saturated, friable, very loose toward 5.0'.				
5									10
									9

Project: Oceana   Job No. 8280   Boring No. MW-13
Location: New Fuel Farm.   Classified by: JST   Sheet 1 of 2
Contractor: Herbert Assoc.   Driller: R. Seage   Ground Surf. Elev. 14.8
Method of Advancing Boring: Split Spoon - Augering   Static Water Level: 2.3'
Date Started: 12/2/82   Date Completed: 12/2/82

Depth, Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
0–1	S1	1, 2	15	ML	0.0'-1.0' Clayey Silt; Light grayish brown to tan; some clay, organics, damp, cohesive, stiff.			Organic Odor, No Fuel Odor	14
1–2	S2	4, 5			1.0'-2.0' Clayey Silt as above.			Slight Fuel Odor	13
2–3	S3	5, 5	17	CL	2.0'-3.0' Clay; Grayish to brownish green; trace silt, damp, highly plastic, cohesive, fairly tight.			Slight Fuel Odor ▽	12
3–4	S4	7, 6			3.0'-4.0' Silty Clay; Greenish gray; little silt, moist, cohesive, stiff.			Slight Fuel Odor	11
4–5	S5	6, 6	12	MH	4.0'-5.0' Sandy Silt; Greenish gray, little fine sand, trace medium sand and clay, saturated, slightly cohesive, medium stiff.			Moderate Fuel Odor	10
5–6	S6	5, 6		SM	5.0-'6.0' Silty Sand; Greenish gray; fine to medium sand, some silt, saturated, slightly cohesive to friable.			Moderate Fuel Odor	9
6–7	S7	4, 6	16	SW	6.0'-7.0' Sand; Greenish gray; fine to medium sand, trace coarse sand and silt, saturated, friable, loose.			Very Strong Fuel Odor	8
7–8	S8	7, 12			7.0'-8.0' Sand as above.			Very Strong Fuel Odor	7
8–9	S9	8, 14	20	SP	8.0'-9.0' Sand; Greenish gray to light brownish gray, medium sand, trace fine sand and silt, saturated, friable			Strong Fuel Odor	6
9–10	S10	17, 20			9.0'-10.0' Sand as above.			Strong Fuel Odor	5

SOIL/ROCK CLASSIFI[illegible] OC-00113-01.02-02/01/83

Project: Oceana Job No. 8280 Boring No. MW-13

Location: New Fuel Farm Classified by JST Sheet 2 of 2

Contractor: Herbert Associates Driller: R. Seage Ground Surf. Elev. 14.8

Method of Advancing Boring: Split Spoon - Augering Static Water Level 2.3'

Date Started 12/2/82 Date Completed 12/2/82

Depth. Ft.	Sample Occurrence and Number	Blows per 6 In.	Recovery In.	USCS	Sediment Description and Classification	Graphical Log	Well Construction	Construction Details and Remarks	Elevation, Ft.
	S11	2			10.0'-11.0' Sand; Greenish gray; fine to medium sand, little silt, saturated, friable.			Strong Fuel Odor	
11		2	16	SW					4
	S12	5			11.0'-12.0' Sand as above.			Strong Fuel Odor	
12		8							3
	S13	5			12.0'-13.0' Sand as above, mostly medium sand.			Strong Fuel Odor, Fuel Coming From Hole (worse than W-12)	
13		8	17	SP					2
	S14	10			13.0'-14.0' Sand as above.			Strong Fuel Odor	
14		14							1
	S15	5			14.0'-15.0' Sand as above.			Moderate Fuel Odor	
15		9	18	SP					0
	S16	13			15.0-'16.0' Sand as above.			Moderate Fuel Odor	
16		13							-1
	S17	7			16.0'-17.0' Sand as above.			Moderate Fuel Odor	
17		11	20	SP					-2
	S18	15			17.0'-18.0' Sand as above.			Moderate Fuel Odor	
18		16							-3
									-4