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FINAL
REPORT FOR BIOSLURPER FEASIBILITY EVALUATION AT NAVAL FUEL DEPOT POINT MOLATE, CA

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ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
EPA	(United States) Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
gpm	gallons per minute
GW	groundwater
KOT	knockout tank
LNAPL	light, nonaqueous-phase liquid
LRP	liquid ring pump
MDL	method detection limit
NA	not applicable
NFD	Naval Fuel Depot
OG	off-gas
OWS	oil-water separator
ppbv	parts per billion by volume
ppmv	parts per million by volume
PVC	polyvinyl chloride
PW	process water
SW	seal-tank water
TPH	total petroleum hydrocarbons
TPH-E	total petroleum hydrocarbons quantified as diesel and oil
VOA	volatile organic analysis

EXECUTIVE SUMMARY

A bioslurper system was tested at three wells at Naval Fuel Depot (NFD) Point Molate in July 2000. The system was tested in an effort to determine the recoverability of the light, nonaqueous-phase liquid (LNAPL) with a vacuum-enhanced system and to evaluate the effectiveness of the dual drop tube system at reducing the total petroleum hydrocarbons (TPH) concentrations in the process water. The protocol used during the demonstration was similar to that approved by the Environmental Security Technology Certification Program (ESTCP) and has been used at five other sites containing LNAPL. The test of the knockout tank (KOT) was removed from the protocol for NFD Point Molate due to its limited effectiveness at several previous test sites. The protocol is effective at providing a side-by-side comparison of the dual drop tube system and conventional bioslurper operation. In addition, the data generated under the protocol may be used to evaluate conventional bioslurping and will provide full-scale design data, if full-scale operation is deemed necessary.

The system was operated for three days at MW11-27R and was unsuccessful at recovering LNAPL. Approximately 10,000 gallons of groundwater and no LNAPL were recovered during the operation at the well. The average TPH concentrations in the seal and process water were 3.0 and 16 mg/L, respectively. A radius of influence test was conducted during the operation at MW11-27R to estimate the zone of remediation from the extraction well. The radius of influence data indicate that the bioslurper system was affecting soils to a distance of approximately 37.5 ft from the well. The thickness of the LNAPL was measured in the well daily and only showed a sheen of LNAPL (less than 0.01 ft.).

Due to the low LNAPL recovery at MW11-27R, the bioslurper system was switched to well P86-13/14 in order to complete the testing protocol. The system was operated in the conventional and dual drop tube configurations, and a second test in the conventional configuration was conducted after the dual drop tube test was complete. This well initially displayed relatively good LNAPL recovery, but a very low groundwater recovery rate (<0.5 gallons per minute [gpm]). Potable water from a nearby hydrant had to be metered into the bioslurper system to prevent overheating of the vacuum pump. Approximately 12 hours after the initiation of the demonstration, the LNAPL-recovery rate decreased, and no LNAPL was recovered during the second conventional test. A total of approximately 15,000 gallons of groundwater and 1.5 gallons of LNAPL were recovered during the operation at this well. The dual drop tube system was successful at reducing the TPH concentrations in the seal water and process water by 96% and 98%, respectively, relative to the concentrations during conventional operation.

Finally, the bioslurper system was operated at MW11-36 (which contains bunker fuel) to evaluate the effectiveness of the system for recovering relatively high viscosity fuel. The system was operated for 24 hours at the well in the dual drop tube configuration. Approximately 1,100 gallons of groundwater and 1.4 gallons of LNAPL were recovered during this period. The TPH concentrations in the seal water and process water were 0.84 and 0.92 mg/L, respectively, and the TPH concentration in the groundwater from MW11-36 was 1.2 mg/L. The analytical data indicate that the bioslurping process did not increase the TPH concentration in the water.

Section 1.0: INTRODUCTION

1.1 Objective/Scope

The objective of this feasibility study is to quantify the effectiveness of pre-pump LNAPL separation methods in controlling emulsion formation and off-gas emissions. The bioslurper system also conducted a test to evaluate the effectiveness of the system for recovering relatively high viscosity fuel. The bioslurper system was tested at three wells. The first well, MW11-27R, did not show any recoverable LNAPL, so the test was switched to another well after three days. The system was operated at the second well, P86-13/14, in the conventional and dual drop tube configurations. A second test in the conventional configuration was performed at the end. The bioslurper system was operated at a third well that contained bunker fuel for 24 hours. The results from the feasibility study have been used to determine if the pre-pump separation methods were effective in reducing off-gas emissions and controlling emulsion formation. The results were also used to see if the bioslurper would be effective in recovering bunker fuel.

1.2 Technology Description

Bioslurping is a new technology application that teams vacuum-assisted free-product recovery with bioventing and soil vapor extraction to simultaneously recover free product and remediate the vadose zone. Bioslurping is a vacuum-enhanced free-phase petroleum recovery technology. Unlike other LNAPL recovery technologies, bioslurping systems treat two separate geologic media simultaneously. Bioslurping pumps are designed to extract free-phase fuel from the water table and to aerate vadose zone soils through soil gas extraction. The systems also can be designed to achieve hydraulic control as is done with conventional pump-and-treat technology. The bioslurper system withdraws groundwater, free product, and soil gas in the same process stream using a single aboveground pump. Groundwater is separated from the free product and treated (when required) and discharged. Free product is recovered and can be recycled. Soil gas vapor is treated (when required) and discharged.

The bioslurper technology is unique because it utilizes elements of three separate remedial technologies, **free-product recovery, bioventing** and **soil vapor extraction**, to address two separate contaminant media.

1. **Free-product recovery** is the process of removing free-phase petroleum from the capillary fringe in liquid form. LNAPL recovery generally is accomplished by (a) using a skimmer pump to pump out any fuel that passively enters a well or (b) using a dual-pump recovery system that uses one pump to lower the water table and increase the fuel flow into the well (due to the gravity-induced gradient), and a second pump to skim off the fuel.
2. **Bioventing** is the process of enhancing natural in situ bioremediation of petroleum contamination in the vadose zone through forced aeration. Bioventing is accomplished through either air injection or soil-gas extraction.
2. **Soil vapor extraction** is a process that removes the volatile fraction of the fuel from the vadose zone through soil gas extraction. This process is generally ineffective at removing heavier compounds from the soil matrix.

Bioslurping may improve free-product recovery efficiency without requiring the extraction of large quantities of groundwater. The bioslurper system pulls a vacuum of up to 20 inches of mercury on the recovery wells to create a pressure gradient to assist movement of fuel into the well. The system is operated to cause very little drawdown in the aquifer, thus reducing the chance of creating a smear zone.

Bioslurping treats the vadose zone by increasing the oxygen levels in the unsaturated soils through soil-gas extraction. The slurping action of the bioslurper system cycles between recovering liquid (free product and/or groundwater) and soil gas. The rate of soil-gas extraction is dependent on the recovery rate of liquid into the well. When free-product removal activities are complete, the bioslurper system is easily converted to a conventional bioventing system to complete the remediation of the vadose zone soils.

Bioslurping systems are designed to minimize environmental discharges of groundwater and soil gas. As done in bioventing, bioslurper systems can be designed and operated to extract soil gas at a low rate to reduce volatilization of contaminants. In some instances the volatile discharge from the bioslurper can be kept below treatment action levels without treatment.

A significant feature of the slurping process is induced air flow toward the well, which is believed to increase LNAPL flow to the well. The pressure gradient created in the air phase results in a driving force on the LNAPL that is equivalent to the hydraulic gradient created with the dual pump recovery system. The air flow created by the vacuum thus actually enhances the LNAPL content around the well. For this reason, bioslurping has the potential for removing more LNAPL and at greater rates than do other pumping technologies.

Nonaqueous-phase liquids that are less dense than water move downward through the vadose zone and accumulate at and above the water table. The vertical interval containing the accumulated LNAPL also generally contains some air and water. Near the top of the LNAPL zone, both water and LNAPL contents are low and most of the pore space is filled by air. LNAPL contents usually are greatest toward the center of the LNAPL layer and decline to zero at the bottom where the pore space is fully occupied by water.

Section 2.0: BIOSLURPER SYSTEM CONFIGURATIONS USED DURING THE DEMONSTRATION

Several pre-pump separation configurations have been developed and tested by Battelle. The most promising configurations include the use of dual drop tubes for in-well separation of LNAPL from water (i.e., extracting LNAPL and water in two separate streams), and the use of a pre-pump KOT to separate LNAPL from water prior to entering a liquid ring pump (LRP). The dual drop tube system is more effective than the KOT at reducing the petroleum hydrocarbon concentrations. Therefore, only the conventional and dual drop tube systems were used during the demonstration.

2.1 Conventional Standard Drop Tube Configuration

The conventional bioslurping process has been demonstrated to be the most effective technology at recovering LNAPL from the subsurface (Battelle, 1997). Conventional bioslurper systems use an aboveground vacuum pump to produce a vacuum gradient in the subsurface to promote the migration of LNAPL to the extraction well(s). Each well is equipped with a single drop tube that extends to the LNAPL/groundwater interface in order to extract (or slurp) LNAPL, groundwater, and soil gas simultaneously (Figure 1). During the extraction process, the LNAPL, groundwater, soil gas, and any sediment are incidentally blended together and form frothy emulsions and floating solids, which can result in high petroleum hydrocarbon concentrations in the aqueous discharge stream from the bioslurper system. Extreme mixing often occurs in the turbulent conditions in the extraction pump; however, frothy emulsions have been detected upstream of the extraction pump. The turbulent conditions in the pump and the vacuum in the extraction stream also volatilize the lower molecular weight hydrocarbons.

2.2 Dual Drop Tube Configuration

The use of a dual drop tube oil-water separation system in the extraction well(s) also can significantly reduce the formation of stable emulsions and floating solids. This method is used to extract the groundwater and soil gas from the well in a separate stream from LNAPL, thereby preventing the mixing of the separate phases and the production of floating solids and emulsions. Similar to the conventional drop tube configuration, the pressure gradient in the well (produced by the aboveground pump) draws LNAPL, groundwater, and soil gas to the extraction wells. However, LNAPL is removed from the wells via one drop tube while groundwater and soil gas are removed via the other tube (Figure 2). The drop tube that extracts groundwater and soil gas is guarded by a shield that extends about 1 ft above and 1 ft below the oil-water interface (and the tip of the drop tube). This arrangement allows groundwater to be drawn through the bottom of the shield and soil gas through the top, while the shield prevents the LNAPL from entering the extraction tube. The drop tube that extracts LNAPL is located outside the shield, with the tip of the tube placed approximately 0.25 in. above the oil-water interface. The recovered groundwater and soil gas enter the LRP and exit to an oil-water separator (OWS) and a stack, respectively. The recovered LNAPL is captured in a separate tank (under vacuum) for temporary storage.

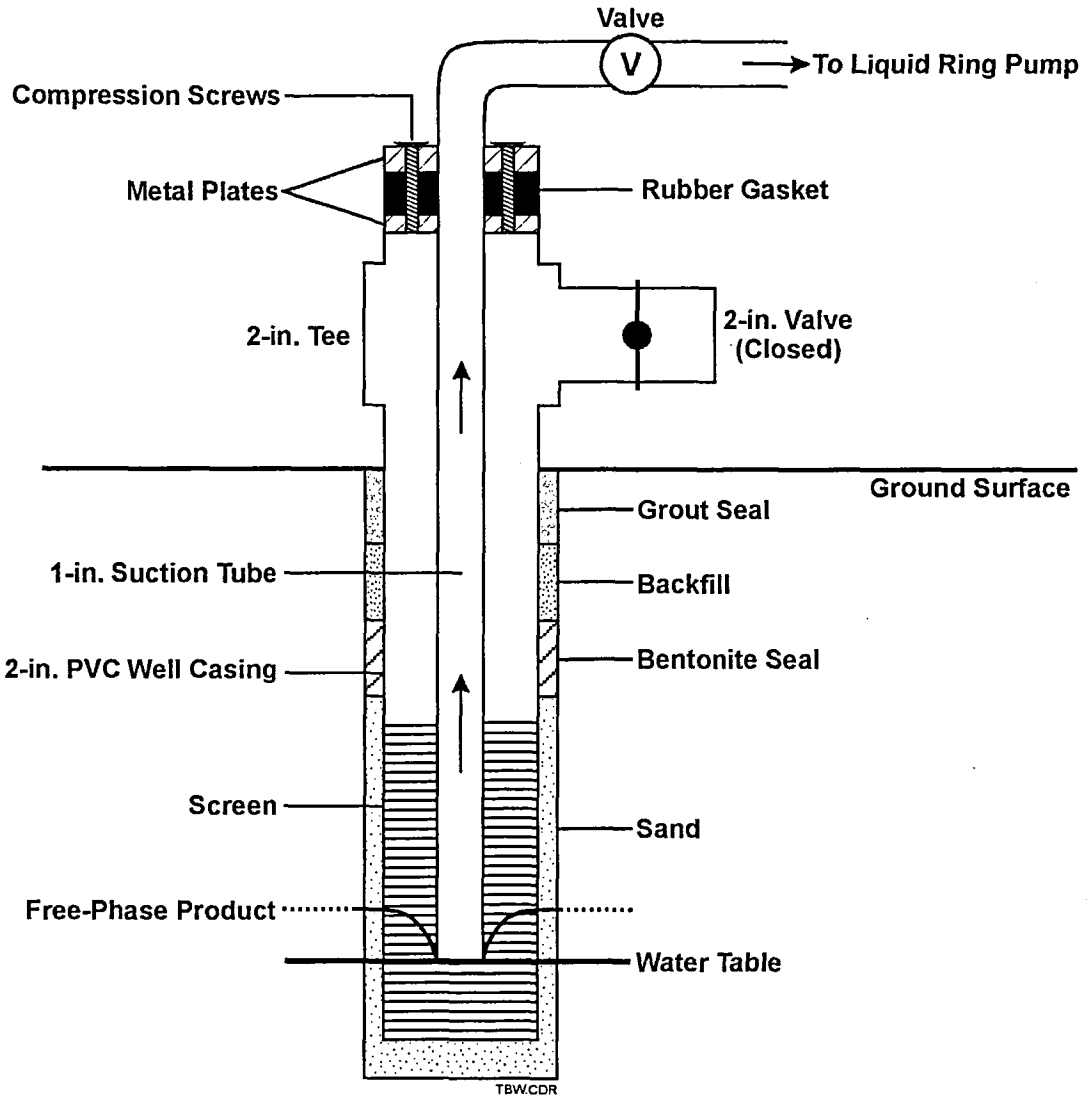

Figure 1. Conventional Standard (Single) Drop Tube Configuration

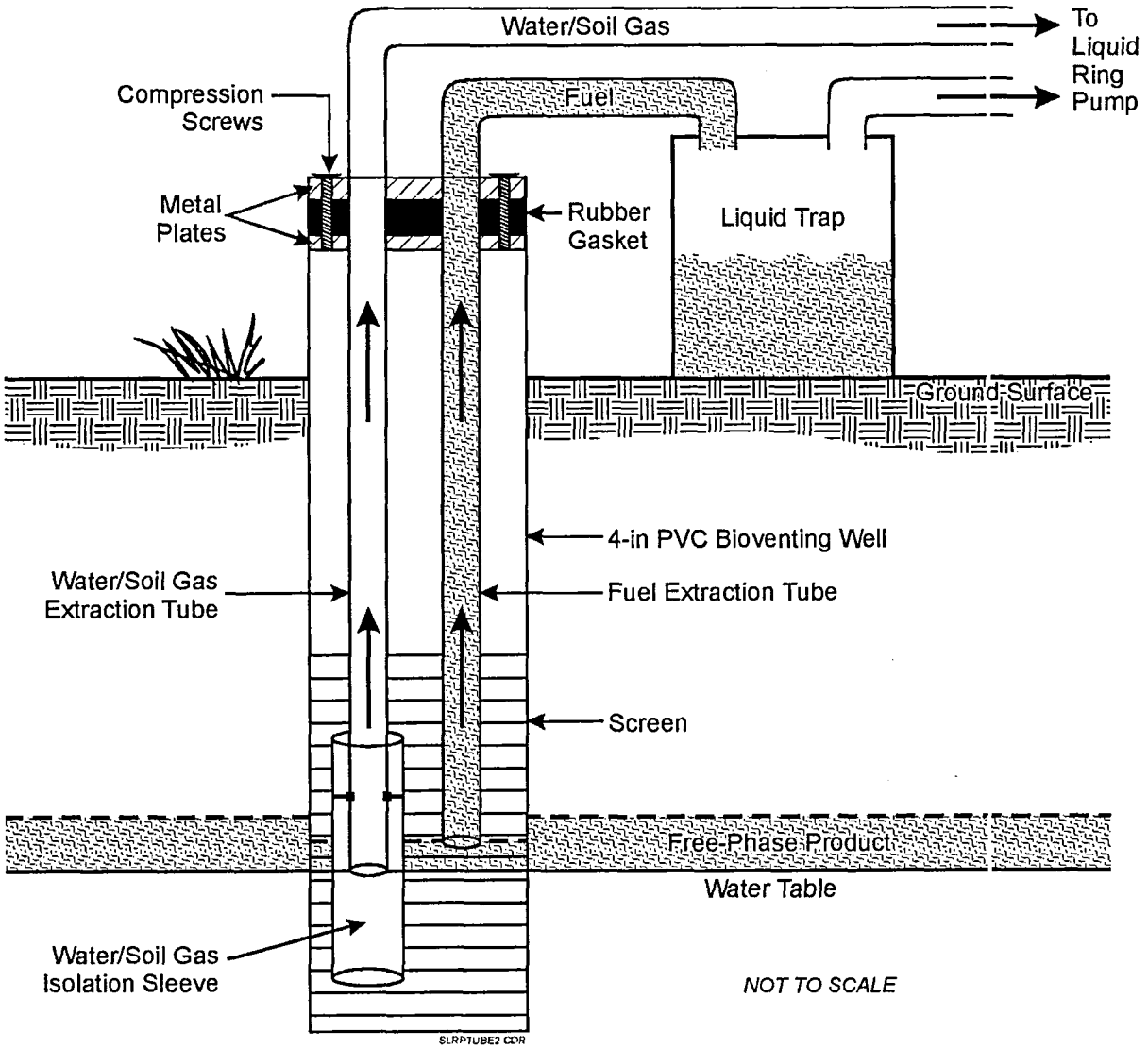

Figure 2. Dual Drop Tube Configuration

Section 3.0: DEMONSTRATION AT NFD POINT MOLATE

A short-term demonstration of the bioslurper in the conventional and dual drop tube configurations was conducted at three wells at NFD Point Molate, CA in July 2000. A map of Site 3 and the wells that were used during the demonstration is presented in Figure 3. Originally, it was planned to test the system at single well for 72 hours in each configuration throughout the demonstration. However, due to the minimal recoverable LNAPL in the extraction wells, the protocol required modification. The demonstration sequence included 59 hours of operation at well MW11-27R. When no LNAPL was recovered from MW11-27R, the system was reconfigured to operate at well P86-13/14. At P86-13/14, a series of three-day tests starting with the conventional drop tube configuration, followed by the dual drop tube configuration, and then back to the conventional drop tube configuration at the end of the demonstration. In addition, the system was operated in the dual drop tube configuration at well MW11-36 for 24 hours. The following sections of this report detail the sampling and analytical methods, and the results obtained during the demonstration. An evaluation of the effectiveness of pre-pump separation technologies tested and is presented in Section 4.0.

3.1 Methodology

The bioslurper system was tested at NFD Point Molate to determine the effectiveness of the system at recovering fuel at the site [bunker fuel (MW11-36), diesel (P86-13/14) and mixed bunker fuel and diesel (MW11-27R)], and to determine the effectiveness of the dual drop tube system. The primary capability of the pre-pump separation system being tested is the reduction of petroleum hydrocarbon concentrations in the effluent (vapor and water) streams from the bioslurper system. Therefore, water and off-gas samples were collected from their respective discharge streams during operation in each of the configurations to allow for direct comparison of the analytical results.

Two soil-gas monitoring points were installed at the same time MW11-27R was installed to monitoring pressure gradients produced by the bioslurper operation (for radius of influence determination) and to measure the composition of the soil gas near the extraction well. A detailed map of the are around MW11-27R including the monitoring points is presented in Figure 4. The monitoring points were placed at approximate distances of 10 and 20 ft from the extraction well, and discrete monitoring levels were placed at about 4, 7, and 10 ft below ground surface (bgs).

A vadose zone radius of influence test was conducted concurrently with the startup of the bioslurper pump at MW11-27R. Before a vacuum was established in the extraction well, the initial soil-gas pressures at the three adjacent monitoring points were recorded. The start of the bioslurper pump test created a steep pressure drop in the extraction well, which was the starting point for the radius of influence testing. Soil-gas pressures were measured at each of the three monitoring points at all depths to track the rate of outward propagation of the pressure drop in the extraction well. Soil-gas pressure data were recorded throughout the bioslurper pump test to determine the radius of influence.

Two groundwater samples were collected prior to initiating the demonstration in order to provide a reference for the degree of emulsification of the LNAPL in the process water during the bioslurper operation. In addition, two samples of the LNAPL were collected to determine the characteristics of the liquid.

Samples of the bioslurper water were routinely collected during each test from the seal water reservoir (seal water) and OWS effluent port (process water). Water samples were collected 24, 48, and 72 hours after the testing began in each configuration, and were analyzed for TPH-extractable (as oil and as diesel). Samples of the process water were collected in 40-mL volatile organic analysis (VOA) vials, labeled with sample identification numbers (SW for seal-tank water and PW for process water), placed on

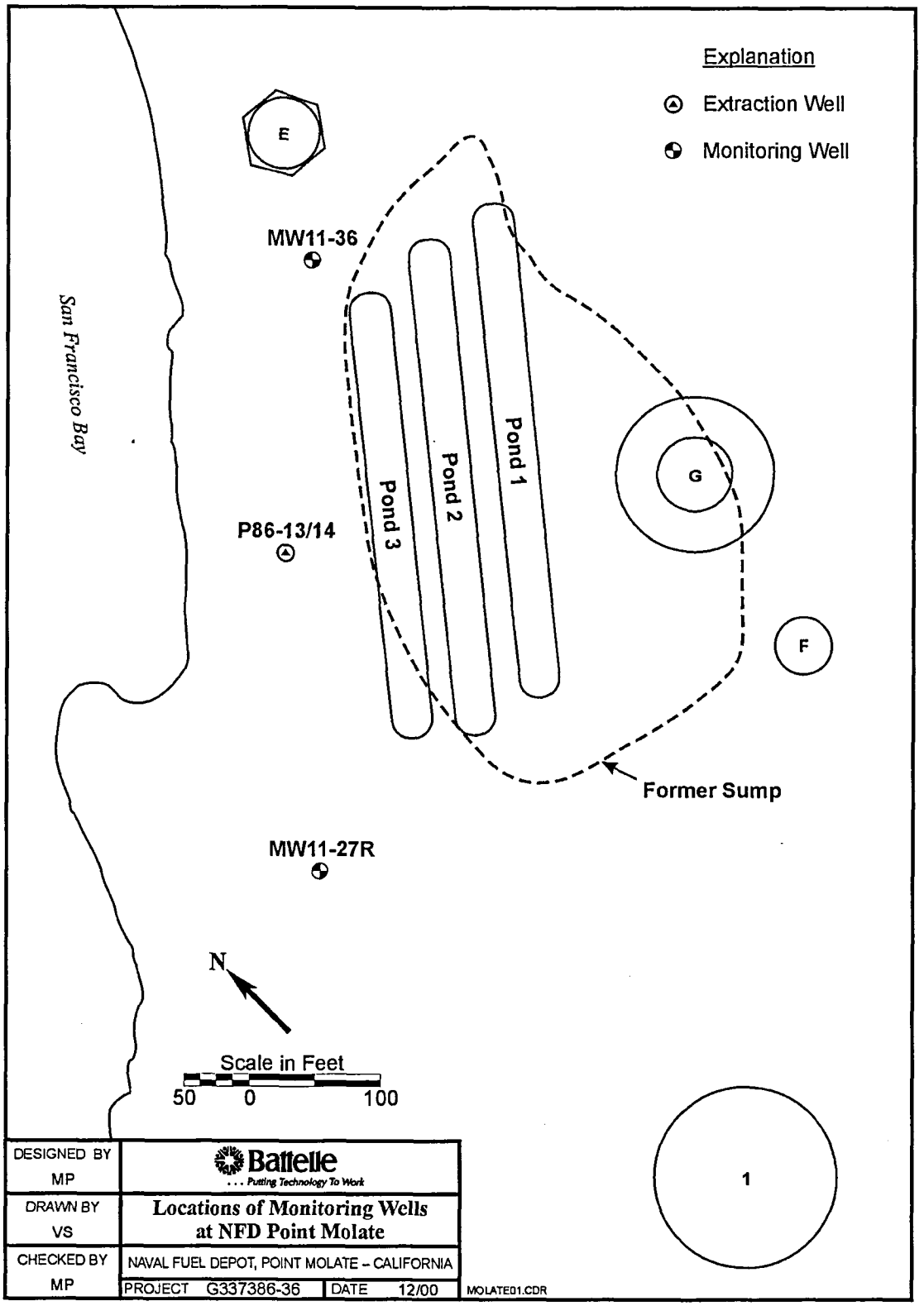

Figure 3. Locations of Monitoring Wells at NFD Point Molate Used During the In-Well Separation Demonstration

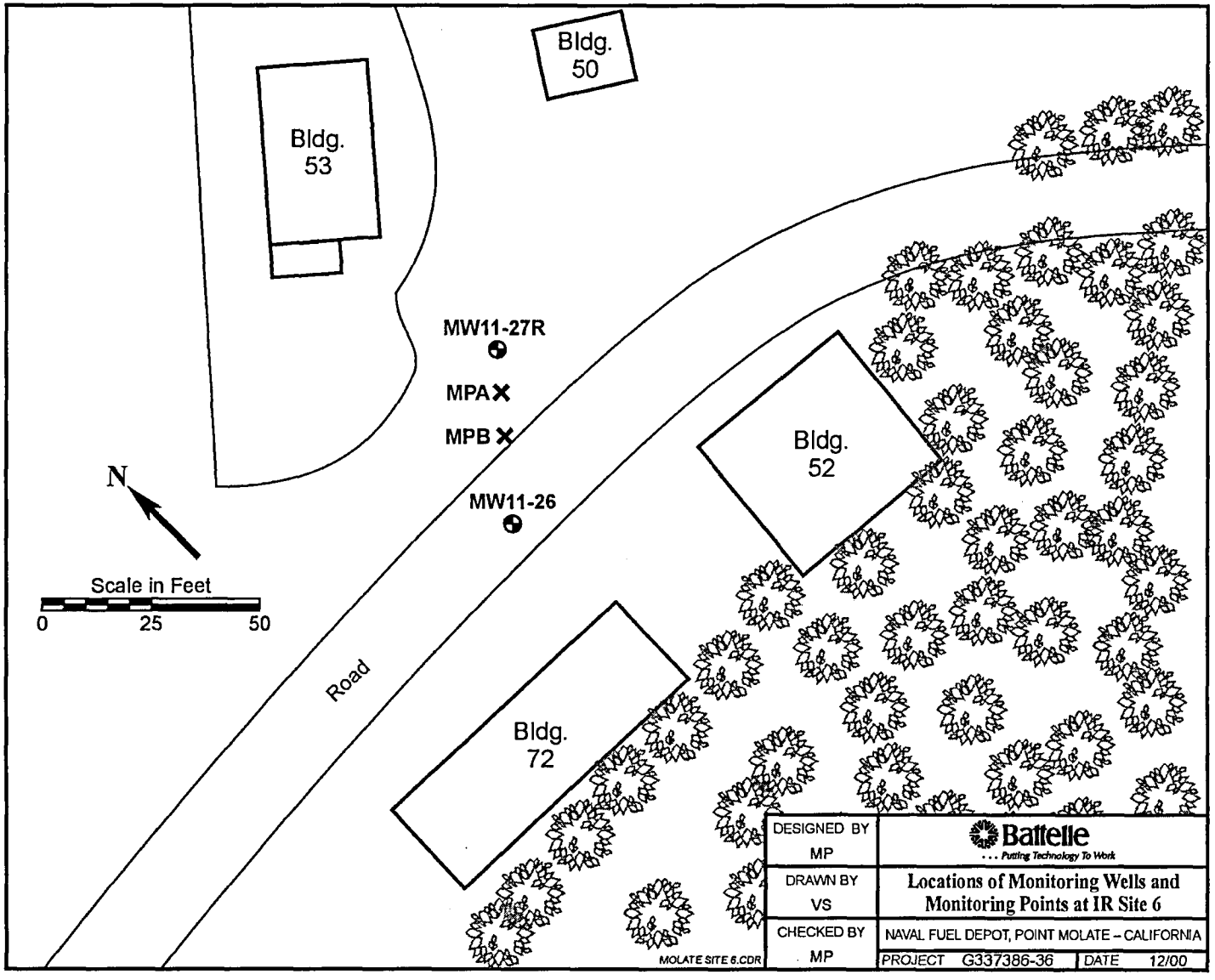

Figure 4. Locations of the Wells and Soil Gas Monitoring Points near Well MW11-27R.

ice, and shipped via express delivery to Alpha Analytical, Inc., of Sparks, NV, for analysis. The number of sample vials collected during each test depended on the analyses that were requested. Table 1 summarizes that analytical methods and sampling requirements followed for water samples.

Table 1. Sampling and Analytical Methods

Analyte	Analytical Method	MDL	Container	Sample Size	Preservation Technique	Holding Time
			Water			
TPH-E	SW-8015	0.5 mg/L	Amber glass bottle	1 to 2 L	Cool @ 4°C	14 days to extraction
			Stack Gas			
BTEX	EPA TO-3	1.0 ppbv	Summa canister	1 L	NA	30 days
TPH	EPA TO-3	10.0 ppbv	Summa canister	1 L	NA	30 days
	NA	NA	Handheld meter	NA	NA	NA

EPA = (United States) Environmental Protection Agency.
MDL = method detection limit.
NA = not applicable.
ppbv = parts per billion by volume.
TPH-E = total petroleum hydrocarbons quantified as diesel and oil.

TPH concentrations in the off-gas were quantified using a calibrated, handheld meter at 2, 4, 8, 12, and 24 hours after initiating each test. Thereafter, off-gas TPH concentrations were monitored at each 24-hour interval. The measurements were done by directly connecting the handheld meter to the stack until the TPH concentration stabilized to within ±10 ppmv. The handheld meter was calibrated using a 4,800-mg/L hexane standard prior to use.

To validate the off-gas measurements obtained from the handheld meter, vapor samples from the off-gas were collected on the first and third days using 1-L, evacuated, polished stainless steel, Summa air-sampling canisters. To collect a sample, the valve on the canister was opened, allowing the vacuum in the canister to be displaced with the vapor sample until equilibrium conditions with atmospheric pressure were reached. The inlet to the canisters was fitted with a restriction orifice so the sample could be collected continuously over a 24-hour period. The vacuum/pressure in each canister was recorded before and after each sampling event to ensure that the canister was received at the test site in an evacuated state and was completely filled during sampling.

System monitoring was performed on a routine basis to ensure proper operation of the bioslurper system. Performance monitoring included pump vacuum, wellhead vacuum, soil-gas vacuum, groundwater recovery rate, off-gas flowrate, off-gas composition, pump temperature, and ambient temperature. On the first day of operation in each testing phase, monitoring was performed at 2, 4, 8, 12, and 24 hours after system startup. Thereafter (days 2 and 3), performance monitoring was done in the morning and evening of each day.

At every system monitoring instance, the thicknesses of clean LNAPL and floating solids in the OWS were measured using a graduated cylinder. A qualitative assessment of the process water also was made to evaluate the degree of emulsification produced during the bioslurping process.

3.2 Performance Results for the Pre-Pump Separation Systems

Figures 5 and 6 present the cumulative LNAPL, and groundwater recovery, respectively, during each pre-pump separation test. The limited LNAPL recovery rate at MW11-27R necessitated the reconfiguration of the system to operate at P86-13/14. During the operation at P86-13/14, the LNAPL recovery rates were relatively high during the first 24 hours of the test in the conventional configuration (1 gallon was recovered). Throughout the remainder of the demonstration, the recovery rates were very low (< 0.3 gal/day). However, the LNAPL recovery rates during the dual drop tube test were on average higher than when the conventional configuration was being tested. During the entire demonstration (including operation at MW11-27R and MW11-36), approximately 9 gallons of LNAPL were extracted from the subsurface. These data include approximately 6 gallons of LNAPL that were removed from well P86-13/14 prior to initiating the test at that well.

The groundwater-recovery rates were varied depending on the well that was connected to the bioslurper. During operation at MW11-27R, the groundwater recovery rates were between 2.5 and 3.5 gallons per minute (gpm). Very low groundwater recovery rates (0.10 gpm) were recorded when the system was initially installed on P86-13/14. Recovery rates of less than 0.5 gpm can result in the liquid ring pump overheating and shutting down. To prevent the shutdown the system, tap water was metered into the seal water reservoir. For the first 24 hours of the test in the conventional configuration, the tap water was introduced at a rate of approximately 3 gpm. This flowrate was considered excessive, so the flowrate was reduced to approximately 1.5 gpm for the remainder of the first conventional test. The tap water was metered into the system at about 1 gpm for the dual drop tube and the second conventional configuration. The groundwater recovery rate during the operation at MW11-36 also was about 1 gpm.

Tables 2 and 3 display analytical results from groundwater, process water, and off-gas samples that were collected during the demonstration. The concentration of TPH in the groundwater at MW11-27R and MW11-36 were measured at 2.5 and 1.2 mg/L, respectively. The TPH concentration in the seal water during the first conventional test at P86-13/14 ranged from 10 to 54 mg/L, and the average concentration was 27.7 mg/L; whereas the TPH concentrations in the process water ranged from 6.1 to 34 mg/L, and the average was 21.0 mg/L during the same test. The TPH concentration in the seal water during the dual drop tube test were between 2.0 to 3.8 mg/L and the average concentration was 2.63 mg/L. The TPH concentrations in the process water ranged from 0.41 to 1.1 mg/L and the average was 0.74 mg/L. During the second conventional test, the TPH concentrations in the seal water ranged from 3.4 to 3.7 mg/L and the average concentration was 3.6 mg/L. The TPH concentrations in the process water were 2.7 and 3.0 mg/L and the average concentration was 3.0 mg/L.

Table 4 presents the results obtained from the LNAPL sample analysis. Two samples of LNAPL were collected, one from P86-13/14 and the other from MW11-36. The LNAPL sample was analyzed for viscosity only. The analytical results indicate that the viscosity of the samples from P86-13/14 and MW11-36 were 1.9 and 4.7 centistokes (cSt).

The stack gas discharge rate (which equals the soil gas extraction rate) was dependent on the well that being used. The off gas discharge rate during operation at well MW11-27 averaged 5 scfm. During operation at P86-13/14 at the average discharge rate was approximately 35 scfm. The flowrates were nearly the same when the standard and dual drop tube configurations were being operated. The discharge rate when operating at MW11-36 was approximately 28 scfm.

The vacuum levels in the vadose zone were monitored at the soil gas monitoring points and well MW11-26 during the first test in the standard configuration. After initiating the bioslurper system, the vacuum levels in the vadose zone reached equilibrium levels after approximately 24 hours. The average equilibrium vacuum levels were 0.035, 0.018, and 0.015 and distances of 10, 20 and 40 feet from well

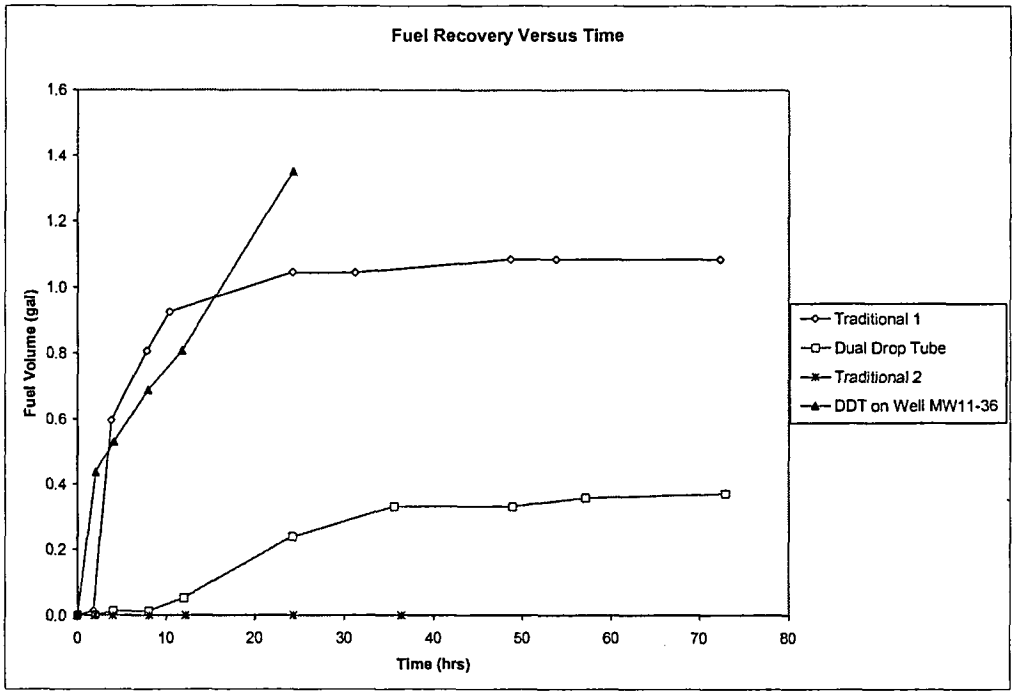

Figure 5. LNAPL Recovery During Pre-Pump Separation Demonstrations, NFD Point Molate

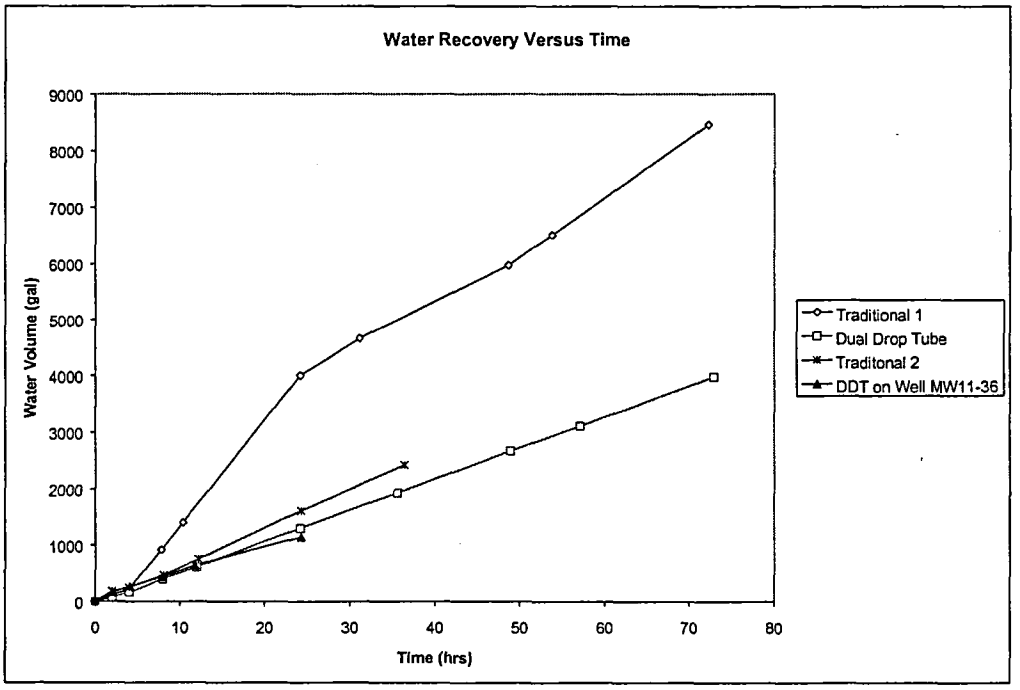

Figure 6. Groundwater Recovery During Pre-Pump Separation Demonstrations, NFD Point Molate

MW11-27, respectively. The vadose zone radius of influence was calculated by plotting the log of the average vacuum level at the monitoring points versus the distance from the extraction well. The radius of influence then was defined as the distance from the extraction well where 0.1 inch of H_2O can be measured. Based on this definition, the radius of influence during the bioslurper pump test at MW11-27R was approximately 37.5 ft (Figure 7).

Table 2. Groundwater and Process Water Analytical Results During Pre-Pump Separation Demonstrations, NFD Point Molate

Sample ID	TPH-E (as Diesel) (mg/L)	TPH-E (Oil) (mg/L)	Test Duration (hr)
Molate-GW-MW11-27R	2.5	ND	
Molate-GW-MW11-36	1.2	ND	
1st Conventional Bioslurper Test for Well MW11-27R			
Molate-SW-1	3.3	ND	24
Molate-PW-1	1.9	ND	24
Molate-SW-2	3.7	ND	48
Molate-PW-2	1.4	ND	48
Molate-SW-3	2.0	ND	72
Molate-PW-3	1.4	ND	72
PW Average	1.6	ND	
SW Average	3.0	ND	
1st Conventional Bioslurper Test for Well P86-13/14			
Molate-SW-4	54	2.3	24
Molate-PW-4	34	1.2	24
Molate-SW-5	19	1.5	48
Molate-PW-5	23	1.4	48
Molate-SW-6	10	1.2	72
Molate-PW-6	6.1	0.63	72
PW Average	21.0	1.1	
SW Average	27.7	1.7	
DDT Bioslurper Test for Well P86-13/14			
Molate-SW-7	2	ND	24
Molate-PW-7	1.1	ND	24
Molate-SW-8	2	ND	48
Molate-SW-8 DUP	2.2	ND	48
Molate-PW-8	0.43	ND	48
Molate-PW-8-DUP	0.41	ND	48
Molate-SW-9	3.8	0.54	72
Molate-PW-9	0.7	ND	72
PW Average	0.74	ND	
SW Average	2.63	0.18	
2nd Conventional Bioslurper Test for Well P86-13/14			
Molate-SW-10	3.7	0.5	24
Molate-PW-10	3.3	0.51	24
Molate-SW-11	3.4	0.73	36
Molate-PW-11	2.7	0.59	36
PW Average	3.0	0.6	
SW Average	3.6	0.6	
Bunker Fuel Testing - DDT Bioslurper Test for Well MW11-36			
Molate-PW-12	0.92	ND	12
Molate-SW-12	0.84	ND	12

GW = Groundwater.
PW = Process water.

(a) TPH-E quantified as diesel at site.
(b) TPH-P quantified as gasoline at site.

Table 3. Off-Gas Analytical Results During Pre-Pump Separation Demonstrations, NFD Point Molate

Sample ID	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Total Xylenes (ppmv)	TPH (C2-C4) (ppmv)	TPH (C5+) (ppmv)	Test Duration (hrs)
1st Conventional Bioslurper Test at P86-13/14							
Molate-OG-1	2.2	0.19	0.58	2.6	ND	180	24-48
Molate-OG-1 Dup	2.2	0.22	0.55	2.4	ND	170	24-48
Molate-OG-2	2.1	0.25	0.58	2.5	ND	86	48-72
Average	2.15	0.2275	0.5725	2.5	ND	130.5	NA
DDT Bioslurper Test at P86-13/14							
Molate-OG-3	1.6	0.14	0.38	1.7	ND	110	24-48
Molate-OG-4	1.4	0.087	0.22	0.95	ND	90	48-72
Average	1.5	0.1135	0.3	1.325	ND	100	NA
2nd Conventional Bioslurper Test at P86-13/14							
Molate-OG-5	1.3	0.12	0.27	1.3	ND	90	12-36
DDT Bioslurper Test at MW11-36 (Bunker Fuel)							
Molate-OG-6	0.11	0.11	0.26	1.1	ND	46	0-24

OG = Off-gas.
ppmv = parts per million by volume.
M = Reported value may be biased due to apparent matrix interferences.

Table 4. Viscosity Analytical Results During Pre-Pump Separation Demonstrations, NFD Point Molate

Sample ID	Viscosity (cSt) at 100°C
Molate-P86-13/14-FP (diesel)	1.9
Molate-MW11-36-FP (bunker fuel)	4.7

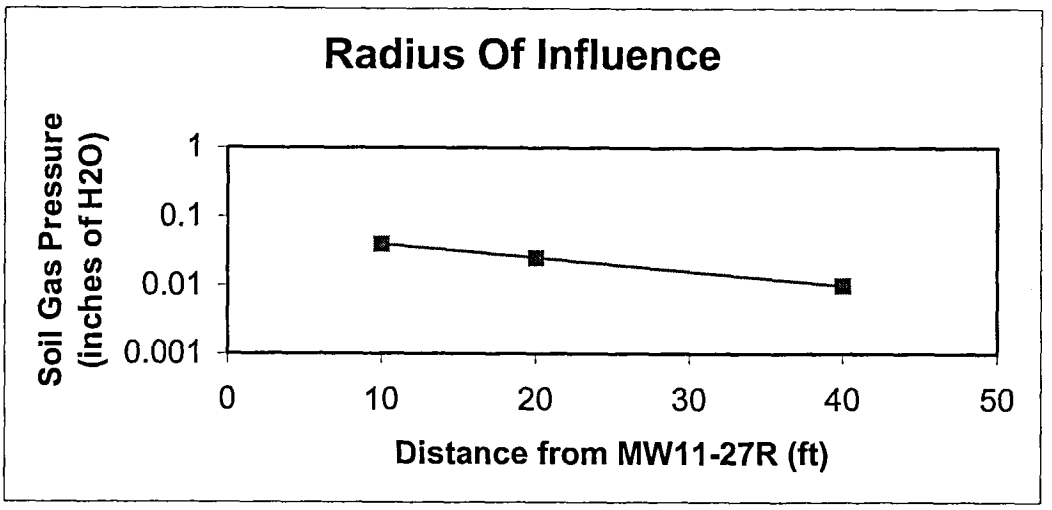

Figure 7. Vadose Zone Radius of Influence, NFD Point Molate

Section 4.0: CONCLUSIONS/RECOMMENDATIONS

The effectiveness of the bioslurper system at recovering bunker fuel was tested at NFD Point Molate in July 2000. In addition, the efficiency of the dual drop tube system for reducing the petroleum hydrocarbon in the aqueous and vapor streams and for reducing the production of floating solids was also tested. The site was selected primarily because of the unique type of fuel present at the site, and the interest in testing the bioslurper for LNAPL recovery.

A standard testing protocol was followed during the demonstration at NFD Point Molate. The testing protocol was designed to provide a side-by-side comparison of the dual drop tube technique with conventional bioslurper operation. To the extent possible, all testing was performed at the same single well throughout the demonstration. However, several wells were used during the demonstration at NFD Point Molate due to limited LNAPL recovery in the wells. The demonstration sequence included a series of three-day tests starting with the conventional drop tube configuration, followed by the dual drop tube configuration. Another test of the conventional drop tube configuration test was conducted at the end of the sequence to provide a second baseline for the conventional operation.

Only a limited amount of fuel was recovered during the testing at each of the wells during the demonstration. Because bioslurping has been shown to be the best demonstrated available technology for LNAPL recovery, these data suggest that the LNAPL present at the site is either only sparingly recoverable under any conventional method of recovery and/or is present in only limited quantities near the wells that were tested. The limited recoverability of the LNAPL is likely the result of a combination of the viscosity of the LNAPL, grain-size distribution of the soil, or LNAPL saturation in the soils near the test wells. Successful bioslurper operation has been achieved at sites with LNAPL having a viscosity of 823 cSt and very fine soils. Therefore, the low recovery is believed to be primarily the result of low LNAPL saturation levels in the soils near the wells tested. This conclusion is somewhat substantiated by the baildown test results that demonstrated very low passive recovery into the wells after the LNAPL had been bailed from the well. This conclusion, however, does not suggest that there are not wells at the site that contain recoverable LNAPL or that LNAPL is not recoverable during specific periods of the year (i.e., during spring rain events).

The test results did indicate that the dual drop tube system was successful at reducing the TPH concentrations in the seal and process water. During operation at P86-13/14, TPH concentrations in the seal water were reduced by at least 96%, and the TPH concentrations in the process water were reduced by more than 98%. These reductions were calculated using the analytical data from the phases of the test when LNAPL was being recovered (i.e., the first standard configuration and the dual drop tube tests). Because no LNAPL was being recovered during the second standard configuration, it was determined that it the analytical data from this phase of the test should not be compared to the data from the phases when LNAPL was being collected. In addition, the TPH concentrations measured were corrected for the dilution caused by the greater bleed rate of tap water during the first conventional test. This correction resulted in a doubling of the TPH concentrations measured during the first conventional test. The reduction in the TPH concentration caused by the operation of the dual drop tube system would likely be greater if the TPH concentration were also corrected for the LNAPL-recovery rates. In general, the greater the LNAPL-recovery rate, the greater the TPH concentrations in the seal and process water. However, the relationship between the LNAPL-recovery rate and the TPH concentrations is unknown, so the concentrations cannot be corrected.

Section 5.0: REFERENCE

Battelle. 1997. *Engineering Evaluation and Cost Analysis for Bioslurping Initiative.* Prepared for U.S. Air Force Center for Environmental Excellence, Technology Transfer Division, Brooks AFB, TX.