PACIFIC
ENVIRONMENTAL
GROUP, INC.

August 12, 1994
Project 310-058.3A

Ms. Tina Berry
Unocal Corporation
2000 Crow Canyon Place, Suite 400
San Ramon, California 94583

Re: Remedial Action Implementation Plan
Unocal Service Station 5760
376 Lewelling Boulevard
San Lorenzo, California

Dear Ms. Berry:

This letter, prepared by Pacific Environmental Group, Inc. (PACIFIC), presents an implementation plan for remediation activities to take place at the referenced site. The purpose of this plan is to outline the tasks required to execute the remediation approach described in a letter to your office (prepared by PACIFIC) dated June 20, 1994. Additionally, this implementation plan provides a tentative implementation schedule. For background information regarding site conditions, and remediation work completed to date, refer to the Remedial Action Plan presented by GeoStrategies, Inc. dated April 21, 1994.

REMEDIAL APPROACH IMPLEMENTATION PLAN

The proposed remedial approach consists of three primary components: (1) groundwater monitoring, (2) bulk hydrocarbon mass removal using soil vapor extraction (SVE), and (3) in-situ bioreclamation by oxygen and nutrient injection. Since groundwater monitoring is already underway, only Components 2 and 3 are discussed herein.

Task 1: Soil Vapor Extraction Field Test

As indicated in the PACIFIC letter previously referenced, a 5-day SVE field test will be conducted. The purpose of the field test is to collect data necessary for design and operation of an effective SVE system. The test will be conducted by applying a vacuum on Wells U-1 and U-3 (in sequence) and collecting data with respect to the following parameters.

- o Induced subsurface pressure gradient (i.e., subsurface pressure as a function of distance from the vacuum application point).
- o Soil vapor flow rate as a function of applied vacuum.
- o Subsurface vacuum at a fixed distance as a function of applied vacuum.
- o Time-series hydrocarbon concentration in extracted soil vapor.
- o Time-series oxygen and carbon dioxide concentrations in extracted soil vapor.

At the time this letter was being prepared the field test was underway. Preliminary results are described below.

1. The vacuum influence (subsurface pressure gradient) appears to be in excess of 45 feet. It is anticipated that this value will increase over time as the subsurface pressure gradient reaches steady-state, and soils dry. At the time the subsurface pressure data were collected, the applied vacuum was approximately 53 inches of water (gauge) and the soil vapor flow rate was approximately 66 cubic feet per minute (cfm).

2. The initial hydrocarbon concentration in soil vapor, as measured by a flame-ionization detector, was 1,000 parts per million by volume. This measurement was made approximately 1 hour into the field test. Assuming standard temperature and pressure (STP) conditions, and a molecular weight of 86.2 (hexane) to represent the hydrocarbon mixture molecular weight, the initial hydrocarbon mass removal rate was estimated to be 23 pounds per day.

3. A soil vapor sample was analyzed to ascertain oxygen and carbon dioxide concentrations. Comparison of these constituent concentrations in ambient air to concentrations in soil vapor are used to indicate biodegradation. Indicator compound concentrations in ambient air, in terms of volume percent, are 21 percent oxygen and 0.03 percent carbon dioxide. The sample contained 15 percent oxygen (probably elevated by SVE) and 6 percent carbon dioxide. Given that the typical background concentration of carbon dioxide in soil vapor not associated with an impacted area is around 3 percent, and the moderately low oxygen concentration as compared to ambient air, it appears biodegradation of hydrocarbons occurring beneath the site. Please elaborate

The preliminary SVE field test results suggest that SVE will effectively remove bulk hydrocarbon mass, and that bioreclamation will play a significant role in site remediation.

Task 2: Bioreclamation Assessment

Bioreclamation is based on the principal that indigenous bacteria and fungi within the saturated and vadose zones will adapt to the presence of hydrocarbons introduced into their environment, and then use the hydrocarbons as an energy source. In this process, the microorganisms degrade the hydrocarbons by transforming them to end products such as water, carbon dioxide, and biomass.

The goal of the bioreclamation at the referenced site is to enhance the rate and extent of hydrocarbon biodegradation in soil and groundwater. In order to facilitate effective bioreclamation, a bioreclamation assessment will be conducted. An initial baseline assessment will be performed before system start-up, and evaluation assessments will take place during system operation.

The baseline assessment will consists of measuring several parameters in the saturated and vadose zones. In the saturated zone, the groundwater will be analyzed for concentrations of dissolved oxygen, dissolved nutrients (nitrogen and phosphorous analysis), and dissolved hydrocarbons. Temperature and pH will also be measured. With regard to the vadose zone, the assessment will consist of analyzing the soil gas for concentrations of oxygen, carbon dioxide, and hydrocarbon vapors.

Using the data collected in the baseline assessment, the rate limiting factors of biodegradation will be analyzed. By comparing hydrocarbon, nutrient, and oxygen levels found in the saturated and vadose zone, bio-kinetic models will be formulated. For example, if the areas of higher dissolved hydrocarbons are found to coincide with the areas of sufficient nutrient levels and lower oxygen concentrations, it can be inferred that aerobic microorganisms are utilizing oxygen as the electron acceptor, and degrading the hydrocarbons. In this case, oxygen would be assumed to be the rate limiting factor. If, however, it is found that higher total petroleum hydrocarbons calculated as gasoline levels coincide with lower nutrient levels and higher oxygen levels, then it can be inferred that the rate limiting factor is the availability of nutrients to the microorganisms.

Task 3: Bioreclamation Design

Utilizing the information supplied by the baseline assessment, the bioreclamation design will be completed. For the purposes of this implementation plan, examples of the bioreclamation design process and possible outcomes follow.

Saturated Zone - Limiting Factor Oxygen: If, as a result of the baseline assessment, oxygen is found to be the rate limiting factor for biodegradation with the saturated zone, air injection into groundwater would be used to increase dissolved oxygen concentrations. This would be accomplished by introducing low volumes of atmospheric air into the groundwater using diffusers or sparging wells which are screened at the proper depth. As a side benefit to air injection into the saturated zone, oxygen would also be transported to the vadose zone.

Stoichiometric analysis of the aerobic biodegradation of hydrocarbons indicates that approximately 3.5 pounds of oxygen is needed to biodegrade 1 pound of hydrocarbon. An air injection system capable of injecting 3 cfm of air into the saturated zone would equate to a total injection mass of 75 pounds per day of oxygen (assuming air at STP contains 0.0174 pound of oxygen per cubic foot). If a 50 percent oxygen utilization rate is assumed for hydrocarbon degrading microorganisms in the saturated zone, a total of 10 pounds per day of hydrocarbons would be degraded. ok

Saturated Zone - Limiting Factor Nutrients: If the availability of nutrients to support biological activities is found to be the biodegradation rate limiting factor in the saturated zone, the addition of inorganic nutrients would be employed. A fertilizer solution containing nitrogen and phosphorous fertilizer would be injected into the monitoring wells, and would disperse passively out through the formation. Based on the areas identified in the assessment, and necessary nutrient levels, the injection locations and nutrient levels would be selected.

During system operation, the impact of nutrient addition on the groundwater would be analyzed to eliminate any surplus applications and minimize off-site migration. Nitrogen and phosphorous are of environmental concern when found in groundwater, and the addition of these chemicals would be closely monitored to avoid any adverse impacts.

Vadose Zone - Limiting Factor Oxygen: If it is determined that oxygen is the rate limiting factor in the vadose zone, bioventing (low flow vadose zone SVE/air injection) would be used to raise the soil gas oxygen concentration. For example, injecting 50 cfm of air into the vadose zone would provide 1,253 pounds of oxygen per day. Assuming an oxygen utilization rate of 10 percent, and a stoichiometric relationship of 3.5 pounds of oxygen per 1 pound of hydrocarbon degraded, a total of 36 pounds per day of hydrocarbons would be degraded. Biodegradation rates of between 2 and 20 milligrams per kilogram per day have been reported for bioventing systems at similar hydrocarbon-impacted sites.

ok Are these rates substantiated?

Task 4: Soil Vapor Extraction Design

SVE system design will be accomplished using the reduced data from the SVE field test. Primary design factors to be considered include radius of influence; subsurface hydrocarbon distribution; initial soil vapor hydrocarbon levels; the decay of hydrocarbon mass in extracted soil vapor; the maximum expected soil vapor flow rate per well; and the maximum effective applied vacuum. Based on an evaluation of the factors mentioned, the SVE well field will be specified, and effective operational parameters will be defined. Additionally, a concentration decay model for hydrocarbon mass in extracted soil vapor will be generated.

Task 5: General System Design

Given site and regulatory constraints, and the design specifications resulting from Tasks 3 and 4, the SVE/bioreclamation system will be specified. General design sub-tasks will include: specifying transport piping layout and construction requirements; specifying extraction and injection well requirements; detailing equipment compound layout and construction requirements; defining electrical power distribution and systems control requirements; and sizing equipment. A set of construction drawings will be generated to facilitate the move from design to construction and allow the acquisition of a building permit. The design will comply with all relevant electric, building, and fire codes.

In general, the system design will allow application of SVE/air injection for bulk hydrocarbon removal and bioreclamation. Piping system will be specified such that air injection or SVE may be accomplished at each well used as part of the remediation system. Piping will be placed below ground surface and will be constructed of polyvinylchloride. Well head connections will be made within a traffic-rated vault box. With respect to extraction/injection wells, every effort will be made to incorporate existing monitoring wells into the system. The following factors will be considered in specifying an existing monitoring well for use: well diameter, well screen depth below ground surface; well screen length; well screen position relative to statistically high and low groundwater elevation; well screen position relative to the vertical hydrocarbon impact distribution; well location relative to major hydrocarbon impact area(s); and well construction in general. **At minimum, it is anticipated that Monitoring Wells U-1 and U-3 will be used as part of the system.** New wells will be specified as necessary. **It should be noted that air injection will take place via vadose zone injection, and injection into the groundwater using diffusers placed in wells.** The use of air sparge wells will be considered.

The equipment compound will be located in a manner that minimizes impact to business operations at the site. The compound will be fenced to secure equipment and above-grade conduit. Electric power will be brought to the equipment compound on a temporary basis and, depending on the atmospheric discharge abatement unit specified, natural gas may be brought to the compound. As inferred by the previous statement, equipment to be specified will include an atmospheric discharge abatement unit. Other equipment that will be specified are: a vacuum pump, an air injection pump (it is conceivable that one pump can accomplish both objectives), valves, pressure gauges, flow measuring devices, and a systems control panel.

Task 6: Permitting

Once the design in complete, permits will be obtained from the building department (planning department review may be necessary), the fire department, and the Bay Area Air Quality Management District (BAAQMD). With respect to the BAAQMD, an Authority to Construct and Permit to Operate are necessary for the proposed atmospheric discharge of treated soil vapor.

Tasks 7: Construction

With the acquisition of the necessary permits, construction will begin. The equipment procurement process will be initiated before construction begins so that equipment delivery will occur immediately before or during the construction phase. Additionally, a health and safety plan will be prepared for use during construction. Construction will include: trenching at the site to install subsurface transport piping; possible well installation; well head connections and vault box placement; equipment compound installation; and equipment placement and connection.

Task 8: System Start-Up and Operation

System start-up will consists of initial system optimization and completion of a source test as required by the BAAQMD. Once start-up is complete, initial system operation will proceed with an emphasis on effective bulk hydrocarbon mass removal through volatilization. At some point during system operation, the emphasis will shift from volatilization to biodegradation. The primary difference between the two modes of system operation is the subsurface flow rate of soil vapor/air. The shift in operational modes will be initiated based on an analysis of the hydrocarbon concentration decay trend for extracted soil vapor, and on the relative composition of the extracted vapor-phase hydrocarbons (molecular weight shift to heavier compounds). Additionally, data resulting from periodic bioreclamation assessments will be considered. Based on experience gained from remediating similar sites, it is anticipated that the volatilization mode of operation will extend for approximately 6 months.

Task 9: Operational Data Collection and Performance Reporting

PACIFIC will implement a monthly operation and maintenance program and produce performance reports on a quarterly basis. Data collection will be conducted to monitor system performance with respect to remedial objective achievement and regulatory permit compliance. Data to be collected will include system flow rates, influent and effluent hydrocarbon concentrations, and system run time. As previously stated, bioreclamation assessments will also be periodically conducted. Additionally, respiration tests will be performed to monitor biodegradation rates.

IMPLEMENTATION SCHEDULE

A tentative implementation schedule is shown on Figure 1.

If you have any questions, please call.

Sincerely,

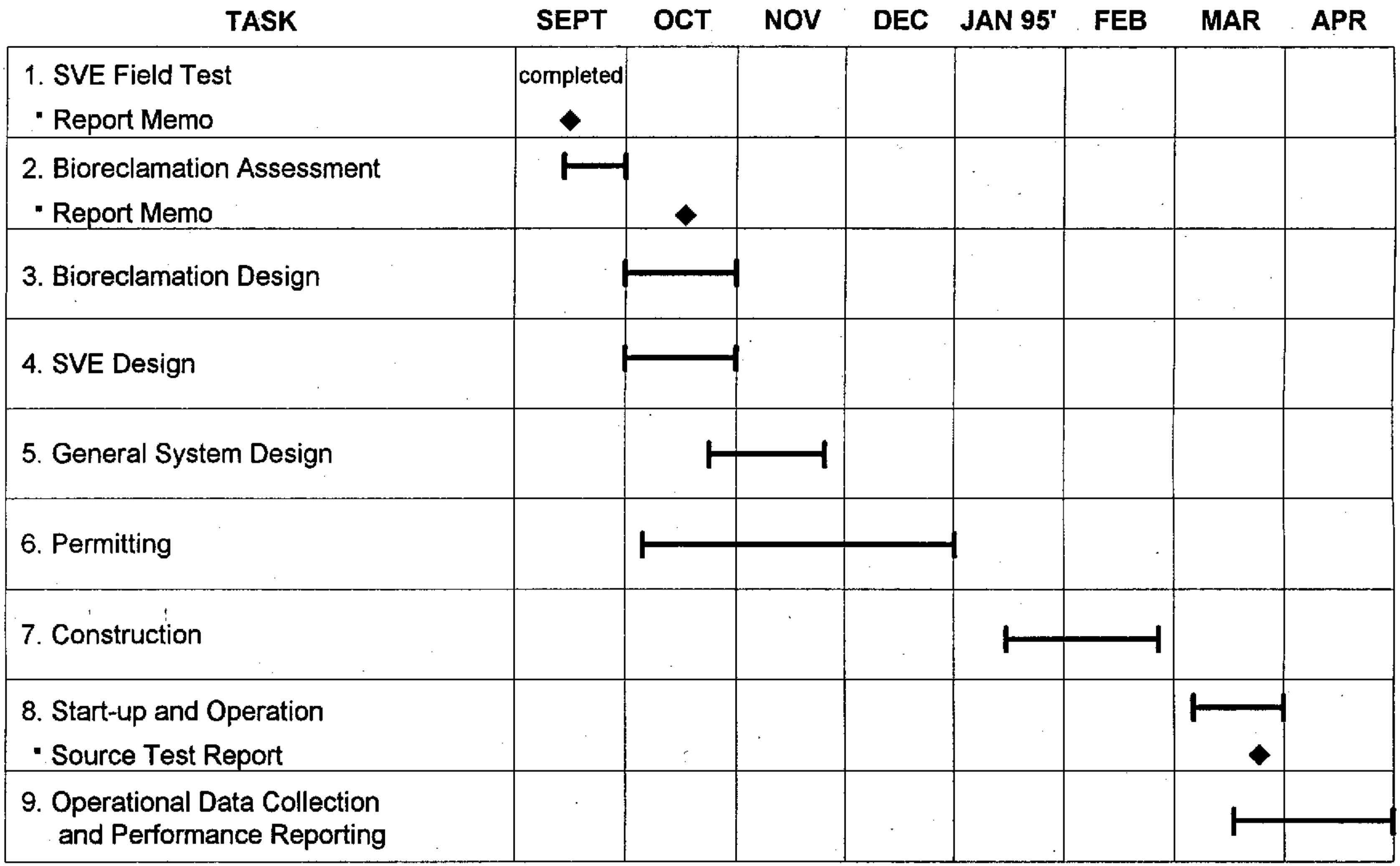
Pacific Environmental Group, Inc.

Robert L. Giattino
Project Engineer

Joseph Muzzio
Project Geologist
CEG 1672

Attachments: Figure 1 - Tentative Implementation Schedule

cc: Ms. Juliet Shin, Alameda County Health Care Services



PACIFIC ENVIRONMENTAL GROUP, INC.

UNOCAL SERVICE STATION 5760
376 Lewelling Boulevard
San Lorenzo, California

TENTATIVE IMPLEMENTATION SCHEDULE

FIGURE: 1
PROJECT: 310-058.3A