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Biological Remediation of Contaminated Soils at Los Angeles Air Force Base: Facility Design and Engineering Cost Estimate

by C.D. Montemagno and R.L. Irvine

Environmental Assessment and Information Sciences Division,
Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

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Abstract

This report presents a system design for using bioremediation to treat contaminated soil at Fort MacArthur near Los Angeles, California. The soil was contaminated by petroleum products that leaked from two underground storage tanks. Laboratory studies indicated that, with the addition of water and nutrients, soil bacteria can reduce the petroleum content of the soils to levels that meet regulatory standards. The system design includes soil excavation, screening, and mixing; treatment in five soil-slurry/sequencing-batch reactors; and dewatering by a rapid-infiltration basin. System specifications and cost estimates are provided.

1 Introduction

The Fort MacArthur facility of Los Angles Air Force Base (LAAFB) is located on the crest of a hill adjacent to the Pacific Ocean in Southern California (Figure 1). During World War II, the fort was used as a harbor defense and anti-aircraft artillery post. In 1982, the Fort MacArthur facility was transferred to the U.S. Air Force and is currently a residential and support facility of LAAFB. In 1985, base personnel discovered two abandoned 20,000-gal concrete underground storage tanks (USTs) at Fort MacArthur. It is thought that the U.S. Army installed the USTs during World War II as a fuel supply for a nearby bunker.

During preparation of the site for closure in 1988, two soil samples were obtained from between the tanks at a depth of 25 ft and analyzed for total petroleum hydrocarbon (TPH) concentrations. The TPH contents of the samples ranged from 300 to 900 mg/kg of soil.[1] Based on these results, the Los Angles Fire Department issued a safety/life violation and instructed the Air Force to assess the site to determine the extent of contamination in both soil and groundwater and to recommend a cleanup action.

Phase 1 and 2 site assessments determined that about 1,000 yd^3 of contaminated silty clay soil was generally contained in a zone 10 ft thick at depths of 25-35 ft below the ground surface.[2,3] The extent of contamination was found to be limited to the soil near the USTs. No contaminants were detected in any of the monitoring wells drilled around the site.

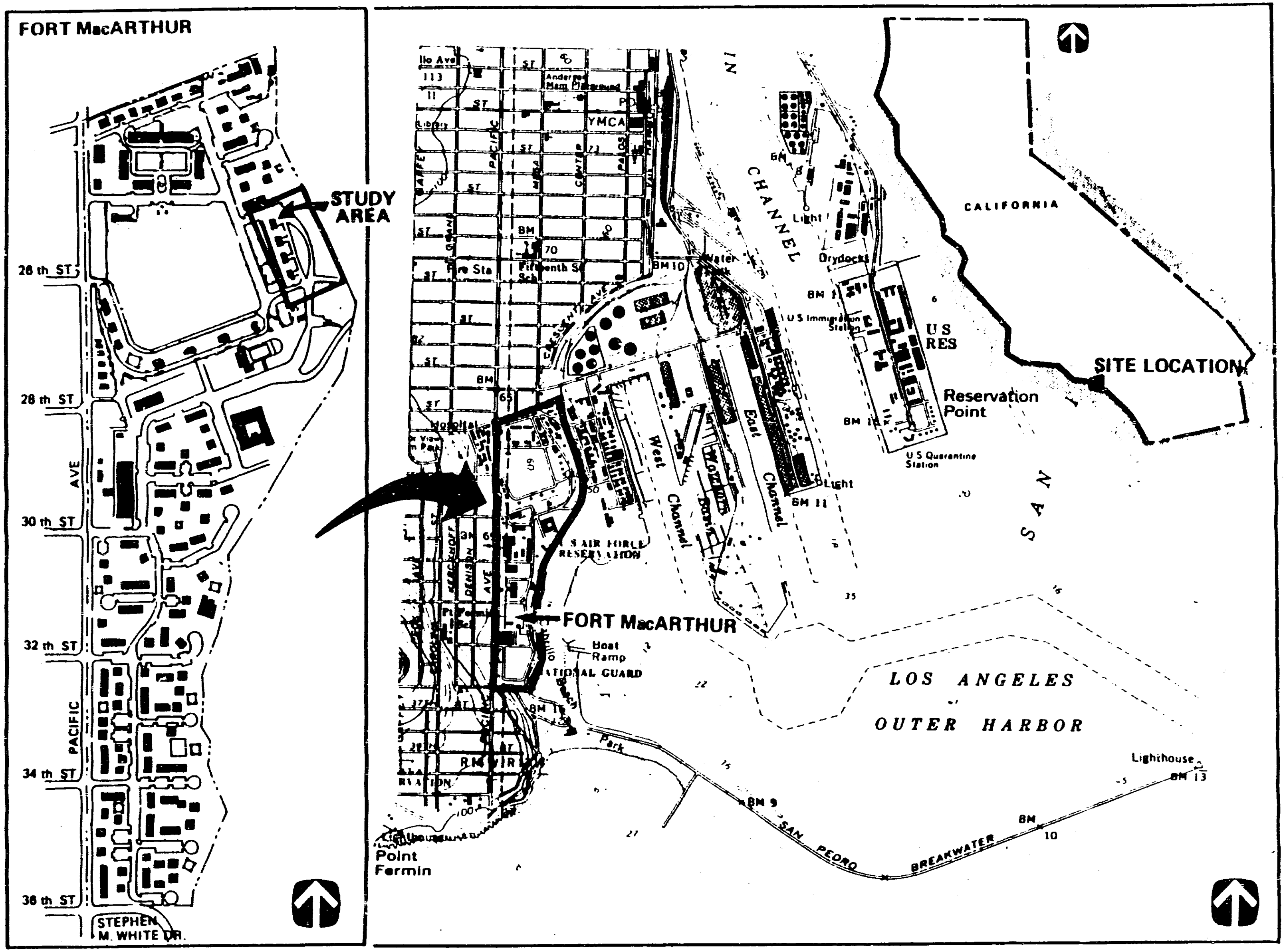

FIGURE 1 Location of the Fort MacArthur Remedial Action Site (Source: Ref. 3)

The applicability and effectiveness of in-situ bioremediation techniques were assessed in initial treatability studies at Argonne National Laboratory (ANL) and the University of Notre Dame (UND). For these studies, a 20-ft continuous soil core sample (sectioned into clear polyvinyl chloride [PVC] casings 15 in. long and 5.25 in. in diameter) was obtained from the contaminated zone (Figure 2).[4] A composite sample containing drill cuttings from the most contaminated soils was also obtained for study.

In the laboratory, the sectioned core samples were first characterized in terms of TPH concentration, hydrodynamic and physical properties, chemical characteristics, microbial content, and degradative activity. Among other things, the results from these analyses showed that the soils with moderate TPH and nutrient levels also possessed a relatively large and active microbial population. From gas chromatography (GC) scans of soil extracts, it was determined that the primary source of contamination was most likely from weathered leaded gasoline.

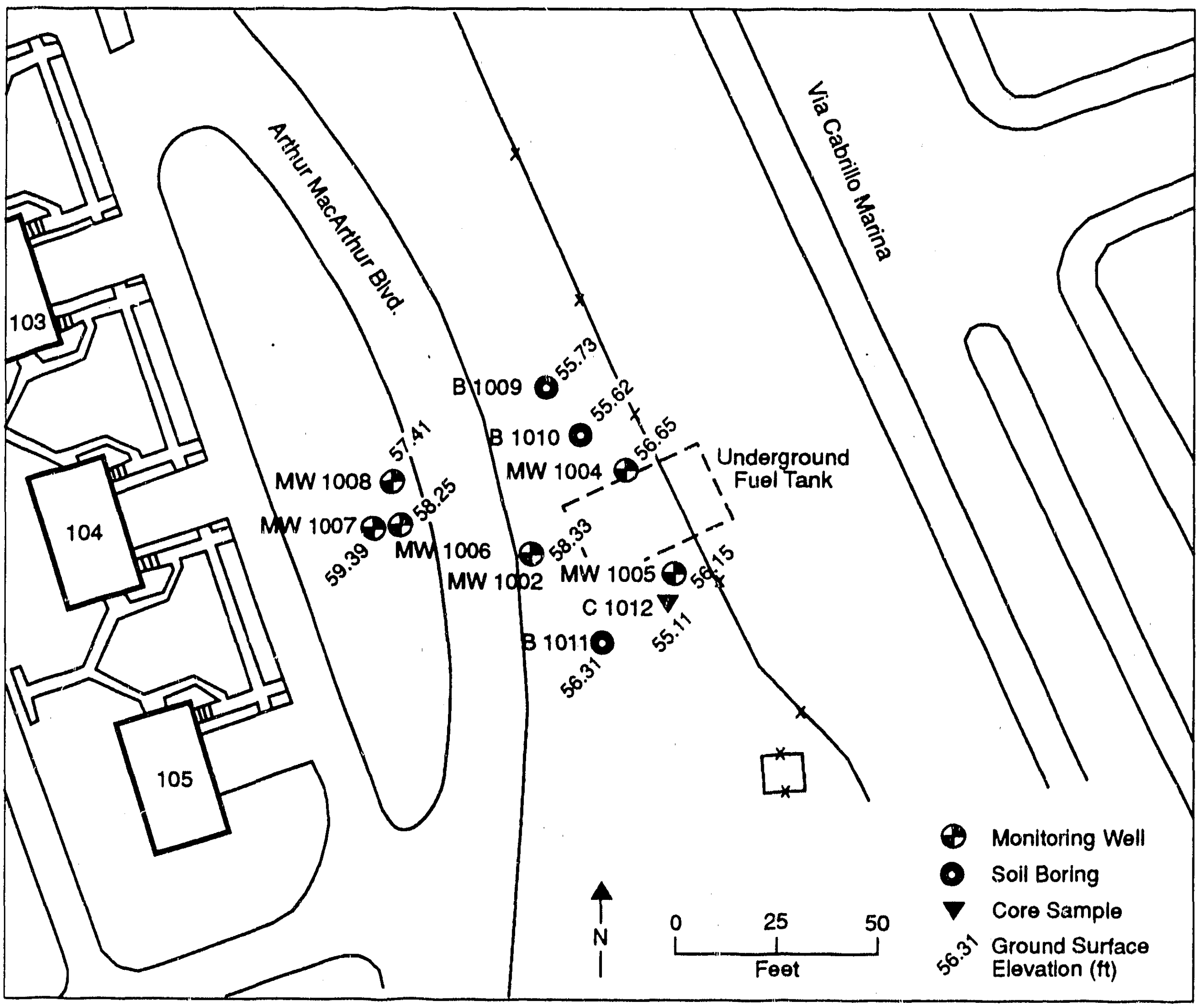

FIGURE 2 Locations of Soil and Groundwater Sampling at the Fort MacArthur Remedial Action Site (Source: Adapted from Ref. 4)

Following the initial characterization of the soil, the soil cylinders were converted into physical models for evaluation of in-situ treatment potential. During the study period, a progressive reduction in hydraulic conductivity was observed for each pore volume* of water passed through the system. The conductivity was further reduced by precipitates that formed after nutrients were added. These observations, coupled with results of field pump tests that indicated the presence of soil fractures and discrete flow patterns, led to a decision to abandon the in-situ treatment option and to begin investigating the feasibility of using an on-site soil slurry treatment system.

*Pore (or void) volume is the volume of space between soil particles.

2 Laboratory Results of Soil Slurry Treatment

The composite soil sample containing the drill cuttings was used for all slurry reactor studies. Analyses were performed at ANL and UND for the parameters listed in Table 1. The slurries were created by combining 1 kg of moist soil with 4 L of tap water and thoroughly mixing for 8 h. Of the resulting dilute soil mixture, 0.5 L (12% by weight soil to water) was distributed to each of five slurry reactors. Mixing and oxygen were provided with a Phillips and Bird paddle flocculation mixer run continuously at 100 rpm. During sampling, the mixing speed was increased to 300 rpm. The conditions established in each of the five slurry reactors were as follows:

- Reactor 1 -- Slurry only
- Reactor 2 -- Slurry plus 2 mg/L ammonia added on days 0 and 1
- Reactor 3 -- Slurry plus an acclimated seed (50 mL of a 10% slurry obtained from a reactor containing organisms grown in soil containing hydrocarbons)
- Reactor 4 -- Slurry plus acclimated seed (as above) plus 2 mg/L ammonia added on days 0 and 1
- Reactor 5 -- Slurry plus 30 mL sulfuric acid (pH = 2.6)

As shown in Figure 3, the microbial populations present in Reactors 2, 3, and 4 reduced the TPH concentrations in the initial slurry from over 400 mg/kg to below 100 mg/kg in less than 3 d and to less than 30 mg/kg in less than 4 d. (In Reactor 5, TPH levels decreased somewhat due to heat generated by acidification.) Evidence of biodegradation in these reactors was obtained by monitoring oxygen uptake rates (OURs) of the slurry. The OURs typically ranged from 1 to 3 mg/L·h during the study period. As demonstrated by the gas chromatography scans shown in Figure 4 for Reactor 2, the soil microbes consumed virtually all of the identified (i.e., numbered) hydrocarbons present in the soil without producing residual or recalcitrant compounds. The GC scans shown in Figure 5 show that essentially no removal of hydrocarbons was observed in the control reactor (Reactor 5). Similar results were obtained (data not shown) in earlier reactor studies where 5 g/L of sodium chloride was added to simulate possible high salt concentrations that could exist in the reactor as a result of using groundwater at the treatment site as process water for making the soil slurry. In conclusion, the laboratory data demonstrate that soil slurry bioremediation is an effective means of treating the TPH-contaminated soils.

TABLE 1 Analytic Results for a Composite Soil Sample from the Contamination Zone and a Sample of Site Groundwater

Parameter and Unit	Measured Value
Site Soil	
Physical Characteristics (%)[a]	
Hydraulic conductivity (ft/d)	0.1
Porosity	65.0
Sand content	22.2
Silt content	31.0
Clay content	46.8
Solids content	61.7
Chemistry (mg/kg dry weight)[a]	
Total hydrocarbons	
Soxhlet extraction, gravimetric measurement	300-1,000
Heated purge and trap, GC with flame ionization detection	440
Total volatiles	129,000
Chemical oxygen demand	16,000
Total Kjeldahl nitrogen	630
Total phosphate	10.2
Cation exchange capacity (meq/100 g)	17
pH (standard units)	7.2
Site Groundwater (mg/kg)	
Total dissolved solids	6,500
Anions	
NO_2^-	3
NO_3^-	20
Cl^-	700
SO_4^{2-}	1,247
F^-	100
PO_4^{3-}	5
Cations	
Na^+	450
NH_4^+	2
K^+	10
Ca^{2+}	2,100
Mg^{2+}	780
Fe^{3+}	22

[a]Except as noted for hydraulic conductivity, cation exchange capacity, and pH.

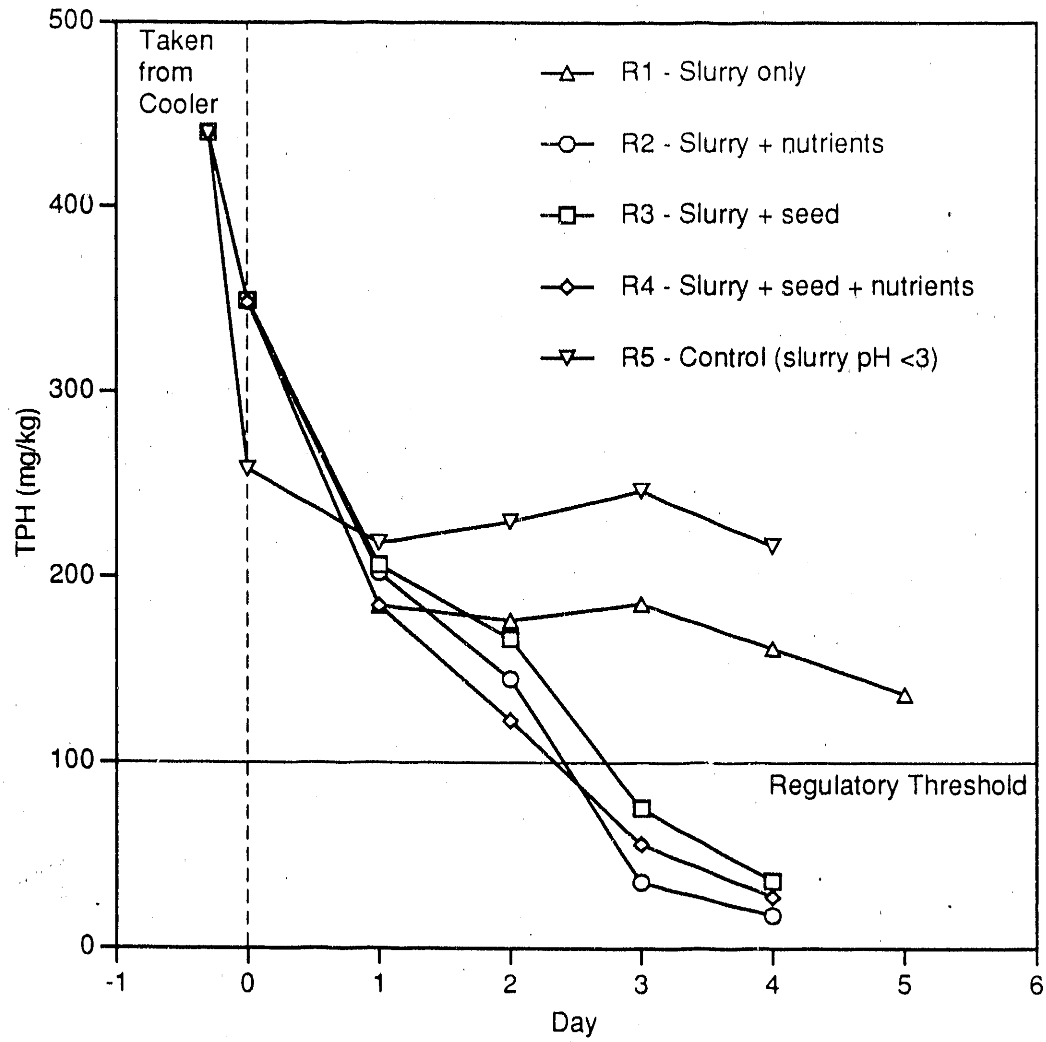

FIGURE 3 Removal of TPH by Soil Slurry Reactors

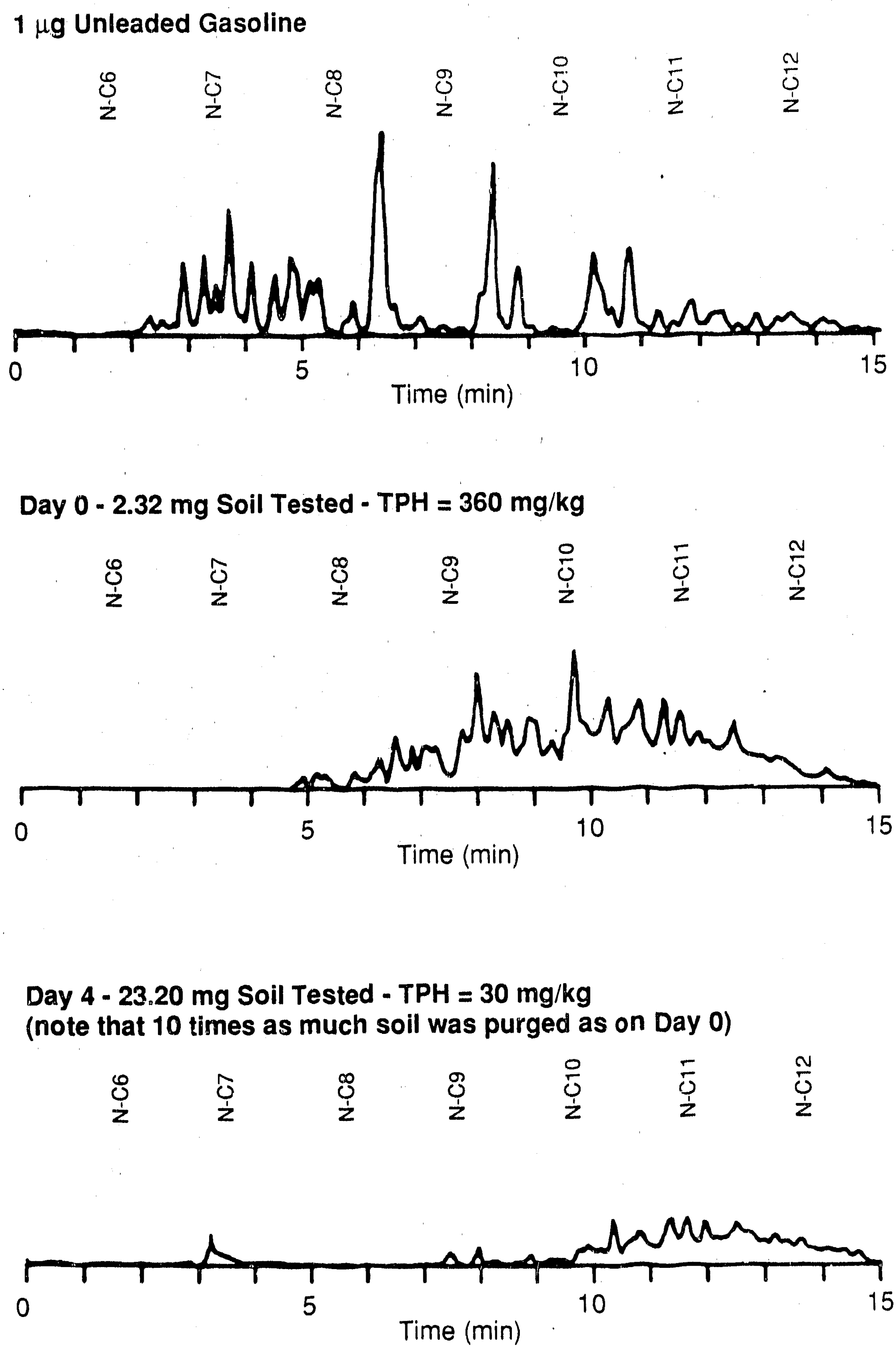

FIGURE 4 GC Chromatograms of Gasoline Standard and Reactor 2 Slurry

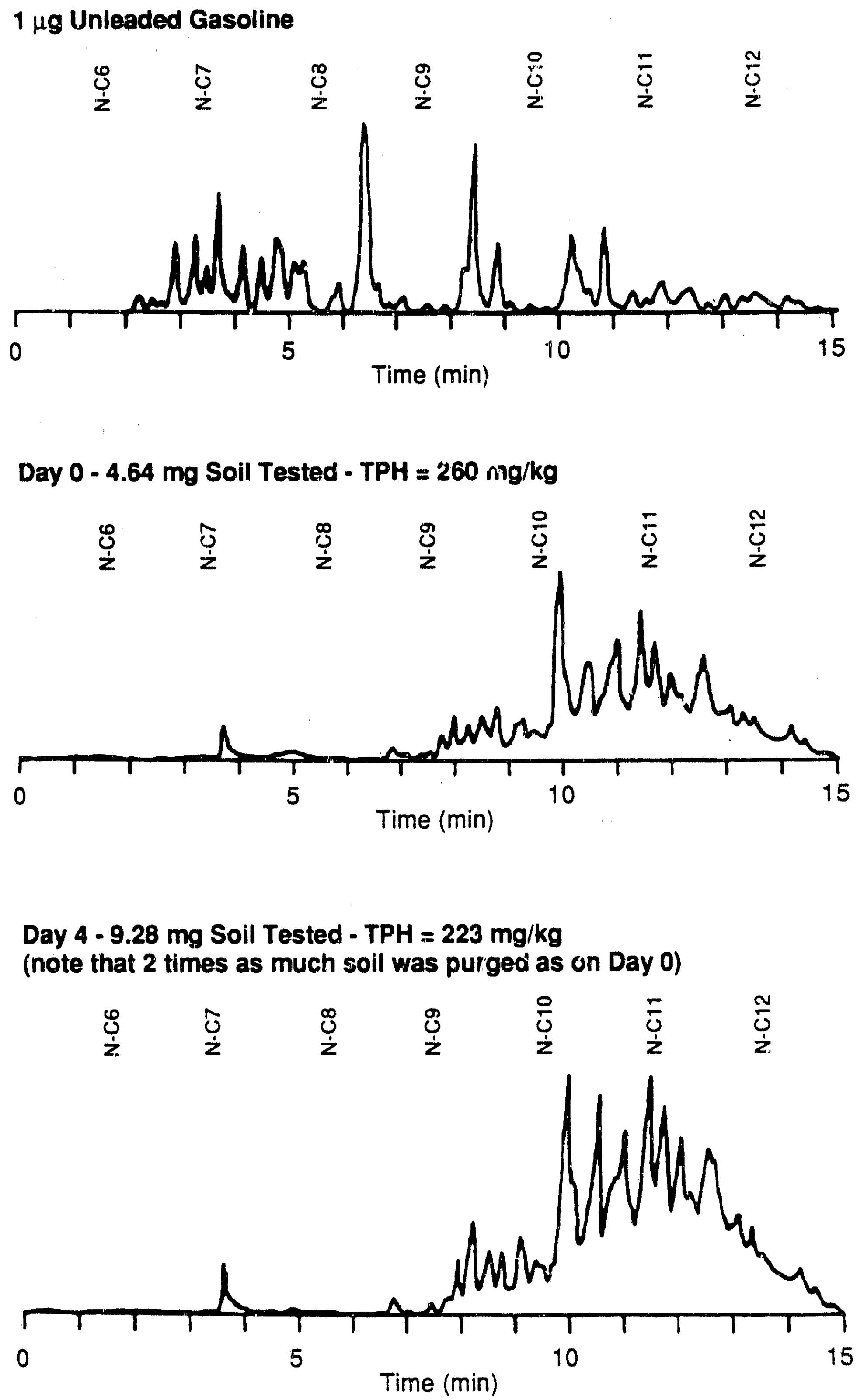

FIGURE 5 GC Chromatograms of Gasoline Standard and Reactor 5 Slurry

3 Slurry Reactor Field Design and System Description

The proposed remediation plan calls for excavating 1,000 yd^3 of contaminated soil at the Fort MacArthur site and transporting it to nearby Edwards Air Force Base (EDAFB), where it will be treated using a slurry-phase bioremediation system that will be constructed within the confines of EDAFB. Included in the remediation effort will be the complete restoration of the Fort MacArthur site to its original condition and ground surface elevations.

Off-site treatment of the soil was deemed necessary for two reasons. First, limited space at the Fort MacArthur site and the residential character of the area prohibited construction and operation of an on-site treatment facility. Second, EDAFB personnel have expressed interest in having the treatment system constructed at their base so that it will be available for future use.

The soil-slurry bioremediation system depicted in Figure 6 consists of the following components: a vibrating screen with hopper, elevator, and wash system for removing aggregates larger than 0.5 in. in diameter; a 4,000-gal (20-yd^3) steel mixing tank for initial slurry preparation; five 24,000-gal (119-yd^3) welded-steel soil-slurry/sequencing-batch reactors (SS/SBRs); a lagoon for slurry dewatering; and a steam-cleaning area for washing contaminated soil aggregates and returning the wash water to the SS/SBRs for treatment.

3.1 Soil Screening and Slurry Mixing Tank

As illustrated in Figures 6 and 7, the first steps in the treatment process are the screening of the soil to remove large aggregates and the preparation of a soil slurry. The contaminated soil is loaded into a hopper using a front-end loader and fed via an elevator to a vibrating screen with water spray bars. The double-deck vibrating screens are supported by the elevator and positioned directly over the mixing tank so that soil particles less than 0.5 in. in diameter will be washed through the screens directly into the mixing tank below. Gravel and aggregates larger than 0.5 in. will be diverted via a chute away from the mixing tanks and onto a concrete pad for subsequent washing and disposal. The volume of water added to the screens and to the mixing tank will be adjusted to yield the desired soil:water ratio of about 1:3 by volume. After screening and water addition, the slurry will be continuously mixed for an additional 10 min using a pivoting-shaft, propeller pit mixer (5 hp) before being pumped to one of the reaction tanks for treatment.

The screening/mixing tank system can be operated continuously or in batches. For batch operation, the volume per batch will be 4,000 gal (20 yd^3) of slurry. Each batch will consist of about 3,000 gal (15 yd^3) of water and 1,000 gal (5 yd^3) of contaminated soil. A total of five slurry batches will be required to fill one reaction tank. The 30-min batch mixing operation can be broken down as follows:

- Screening -- 10 min for a production capacity of 0.5 yd^3/min
- Mixing -- 10 min (includes nutrient addition)
- Pumping to reaction tank -- 10 min at 400 gal/min

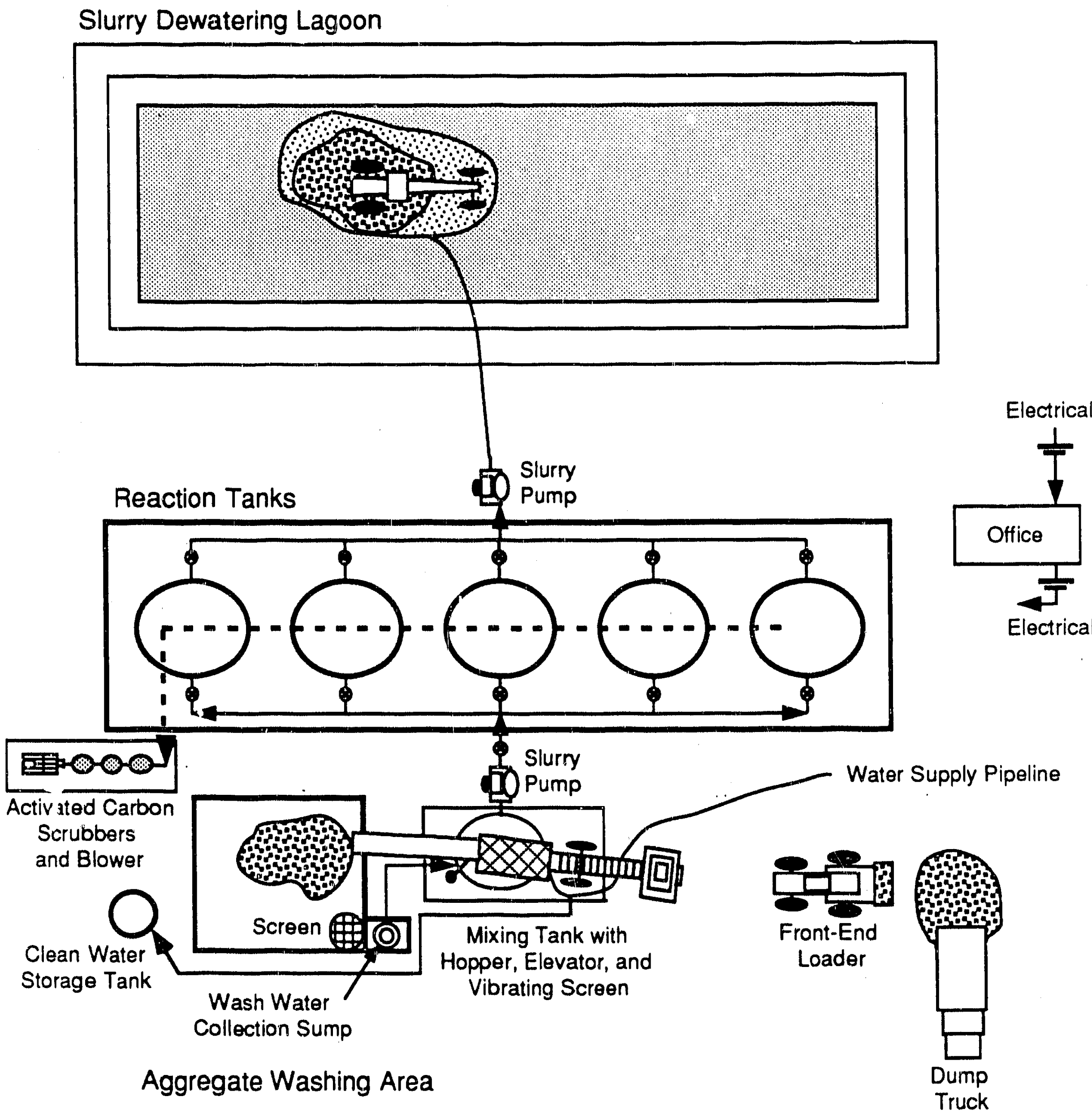

FIGURE 6 Plan View of the SS/SBR System Design

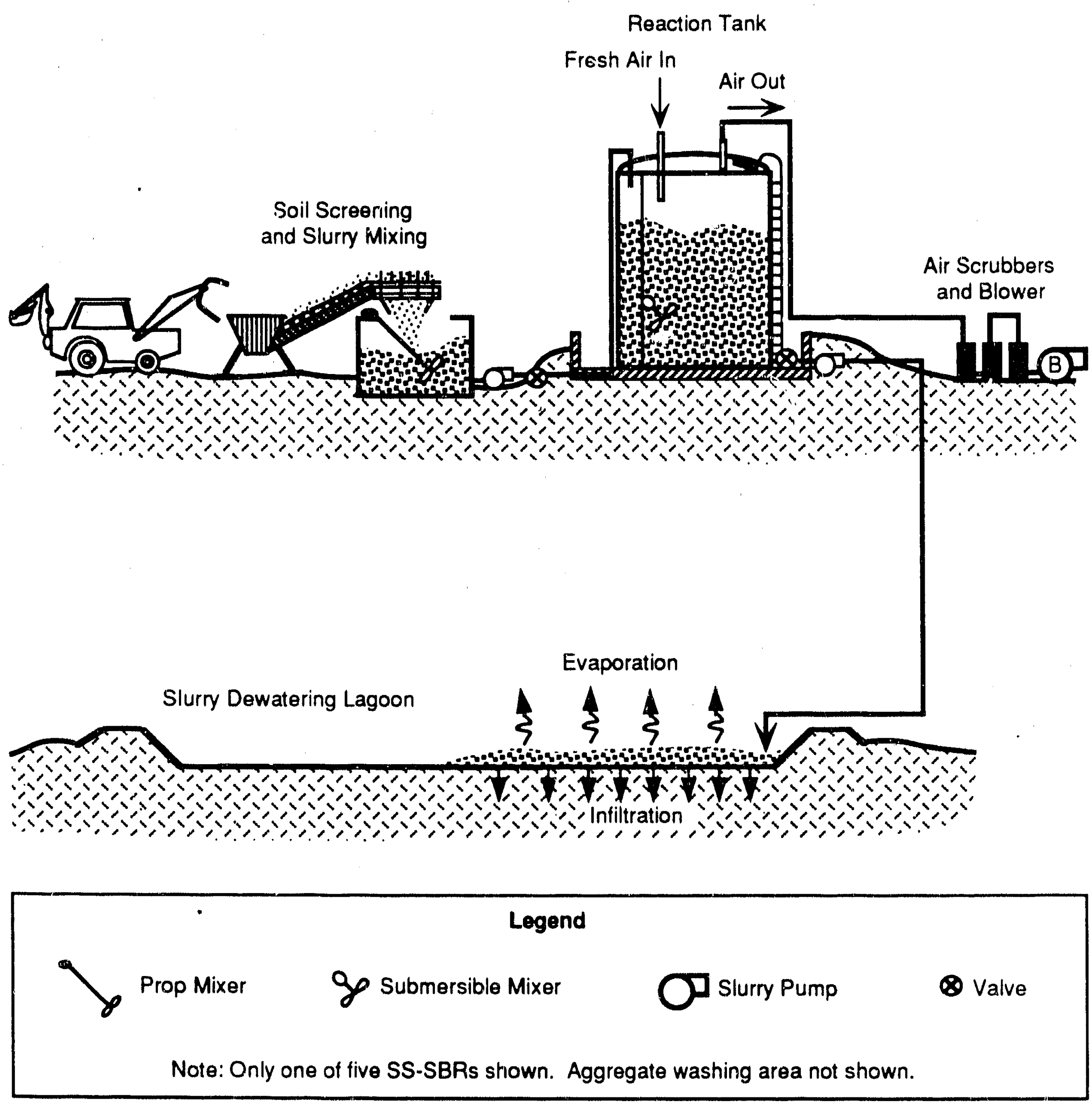

FIGURE 7 Elevation View of the SS/SBR System Design

Since each slurry batch will require about 30 min preparation time, the minimum time required to fill each reaction tank will be 2.5 h. The minimum required water supply rate (pumping rate from supply well to screens and mixing tank) for this operation is 150 gal/min if all needed water is added during screening and mixing. The slurry pump will have a design capacity of 400 gal/min at 30 ft total dynamic head and will be driven by a 20-hp, gasoline-fueled engine.

The mixing tank will be the first system set up during the construction period. Initially, it will be used to establish an acclimated seed material while construction of the SS/SBRs and other system components is being completed.

3.2 Reaction Tanks

The SS/SBR system consists of five closed tanks constructed of welded steel 0.375 in. thick. The tanks will be placed on a reinforced concrete pad (6 in. thick by 116 ft long by 28 ft wide) that will have a 4.5-ft-high concrete wall on all four sides. The concrete pad and wall are designed to contain spills in the event of tank failure and are designed to hold about 1.5 times the volume of all five tanks. The tank interiors will be coated with a corrosion- and abrasion-resistant epoxy resin and the exteriors with red-oxide primer. Welded steel tanks were selected over the four other tank options (i.e., fiberglass, Nalgene,™ bolted steel, and reinforced concrete -- see Sec. 4) because of their strength, durability, and relative ease of installation. Each tank is 15 ft in diameter and 18 ft high with a total capacity of about 23,800 gal (118 yd^3). The tanks will have a freeboard of at least 2 ft and a maximum operating volume of about 20,700 gal (102 yd^3). The tanks will be equipped with a conical roof 0.25 in. thick, a 24-in. manhole with gasket, 6-in.-diameter bulkhead steel pipe fittings, a mixer bridge and guide rail, a 24-in. cleanout, a drain, a level indicator, and a ladder. The headspace of the tanks will be vented by an activated-carbon air scrubber with saturation indicators and a 250-ft^3/min blower for the removal and entrapment of volatile organics. A submersible propeller (7.4 hp) mixer will agitate and aerate the slurry.

The reaction tanks will be operated on a 7-d cycle, allowing for draw and fill on the first day followed by 6 d of reaction, as illustrated in Figure 8. During each day of the 5-d work week, only one reactor is drawn and filled. After the reaction period, all but 6-9 in. of treated slurry will be withdrawn from the reactor and pumped to the slurry dewatering beds. The proposed design does not call for the recovery and recycle of process water. The slurry that is left in the tank

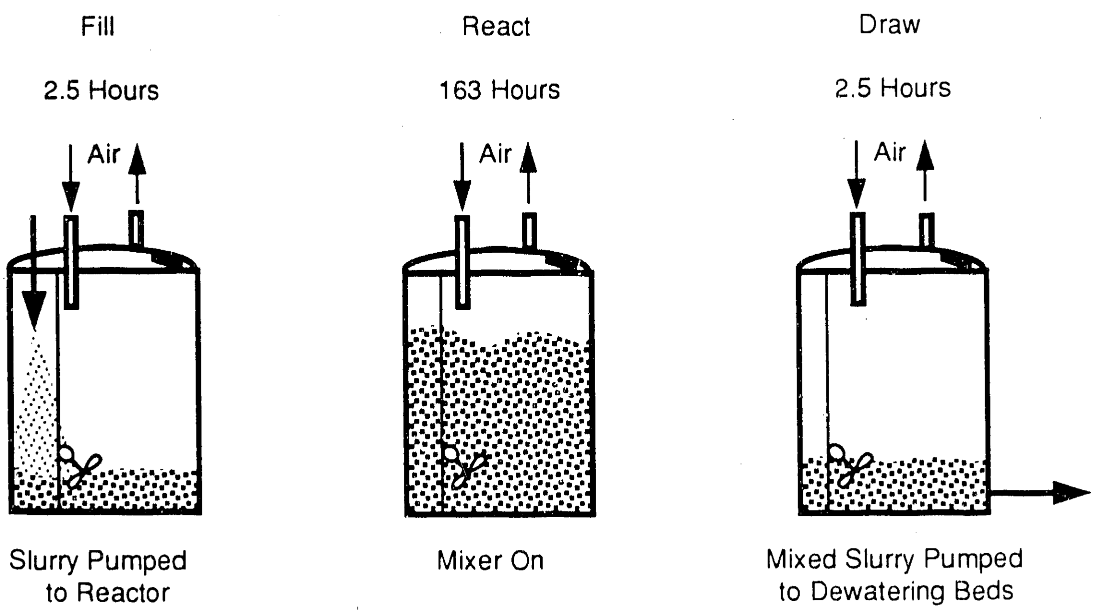

FIGURE 8 Operating Periods for the SS/SBR System (Notes: A 6- to 9-in. layer of slurry is left in bottom of each reaction tank at the end of draw cycle for seeding next slurry batch. Air scrubber system and mixer are on at all times.)

provides an acclimated seed material for the next reaction cycle. A continuous supply and circulation of fresh air is maintained in the reactor headspace by the air scrubber/blower system mounted on the concrete pad and connected via PVC ducting to the top of each tank. The relatively long reaction period (over 6 d) will ensure essentially complete removal of all targeted organics.

3.3 Aggregate Steam Cleaning

During initial soil screening, aggregates larger than 0.5 in. in diameter will be conveyed to a concrete pad (28 by 28 ft by 6 in. thick) for steam cleaning to remove organics. The pad will be sloped to divert the contaminated wash water to a 3,800-gal holding sump constructed on one side of the wash pad. The wash water will be pumped to the mixing tank and eventually to one of the reaction tanks for treatment. The area will also serve as a platform for cleaning residual organics from all equipment, including the front-end loader and dump trucks, after use.

3.4 Treated Soil Dewatering

Several options are available for dewatering the treated soil. The first, simplest option is a shallow rapid-infiltration lagoon, or basin, sized to allow infiltration and evaporation of one batch of slurry per day (15,000 gal of water). Option 1 is the least expensive dewatering system, provided that there is no need to recover and reuse or treat process water and that soil infiltration rates are sufficiently high. The second option is Option 1 with a bottom seal and drain system to collect and recycle water. Option 2 would eliminate the discharge of process water into the ground. The third option consists of five sludge drying beds similar to municipal systems. Each bed would hold sludge from one reactor for one week, after which dewatered soil would be removed by truck and the bed refilled with sludge. Option 3 includes a drain system for water removal but assumes that the native soil would retain water sufficiently to serve as a bottom seal for the bed.

The proposed dewatering system is Option 1, the rapid-infiltration basin. The basin will have a total volume of 1,000 yd^3 and dimensions of 100 by 100 ft by 3 ft deep. The basin will be large enough to accumulate all the soil to be treated. It is assumed that the proposed water-supply well will provide all process water needed and that no recycling or treatment will be necessary. (Laboratory analysis of slurry water showed that it typically contains less an 2 mg/L TPH and less than 10 mg/L chemical oxygen demand -- these levels meet both state and federal standards.) The final design of the system may change if the on-site soil cannot accommodate rapid infiltration.

4 Project Costs

Itemized costs for all components of the treatment system are listed in Table 2. Estimates of the total capital and operating costs are shown in Tables 3 and 4, respectively. The estimates were developed through conversations with suppliers and contractors and review by a California architecture and engineering firm.[5]

4.1 Capital Costs

The capital costs listed in Table 3 have been summarized from the individual component costs listed in Table 2. The costs associated with some components, such as tanks, piping, and reinforced concrete work, include delivery, installation, and contractor profit. The total capital cost exclusive of salvage value is $436,490.

Also listed in Table 3 are salvage values of some capital equipment. Mixing tanks, process tanks, and piping are considered to have a salvage value of one-half of their original cost. Other equipment, such as pumps, screen and elevator, and mixers, have a salvage value that is some fraction of the operating life remaining after treatment multiplied by the initial cost. For this equipment, the operating life after treatment is assumed to be 95.4 wk -- 104 wk (i.e., assumed total operating life for the equipment) minus 8.6 wk (time in use for this project). The total salvage value of the equipment is $197,740. Thus, the net chargeable capital cost for the remediation of 1,000 yd^3 of contaminated soil is $238,750.

4.2 Operating Costs

Operating costs are listed in Table 4. Labor costs were based on an 8-h work day and 40-h work week for each of two system operators. The total number of hours for the ANL project supervisor includes time spent overseeing construction of the facility as general contractor plus time managing the operation of the facility. The total operating cost for the 60-d remediation period is $187,100.

4.3 Total Cost

Table 5 provides the total cost of remediation of 1,000 yd^3 of contaminated soil.

TABLE 2 Component Quantities, Specifications, and Costs for an SS/SBR System at Edwards AFB

Component and Function	Quantity	Specifications	Cost ($) Per Item	Labor	Total
Soil Screening and Mixing Tank					
Concete pad - base for mixing tank	1	Dimensions are 18 ft x 18 ft x 8 in., reinforced with steel to bear 1 ton/ft^2	560	1,040	1,600
Mixing tank - to mix a 12% slurry	1	Open steel tank with 12-ft dia., 6-ft ht., and 0.375-in. wall thickness; interior coated with abrasion-resistant epoxy resin	–	–	5,600
Screen and elevator - to remove aggregates larger than 0.5 in.	1	Screen: double-deck vibrating screens 8 ft long and 4 ft wide with 0.5-yd^3/min capacity, mounted 150-gal/min spray bars Elevator: 24-ft drop chute, 2-ft width, 24-ft length, and 5-yd^3 hopper	–	–	12,500
Mixer - for mixing tank	1	6-ft, pivoting-shaft, propeller mixer; wall attachment plates; 5-hp, 3-phase motor	–	–	5,200
Slurry pump - to move slurry from mixing tank to reaction tanks	1	4-in. pump for 1.5-in.-dia. solids, silicon carbide impeller and seals, gasoline-fueled 20-hp engine, 400 gal/min at 1,170 rpm	–	–	8,500
Pipeline - to provide process water	–	Capacity is 150 gal/min	–	–	20,000

TABLE 2 (Cont'd)

Component and Function	Quantity	Specifications	Cost ($)		
			Per Item	Labor	Total
Soil cover - to cover excavated soil	10,000 ft^2	Woven polyethylene	–	–	500
Soil mixing total	–	–	–	–	53,900
Reaction Tanks					
Concrete pad - base for reaction tanks	1	Dimensions are 127 ft x 39 ft x 8 in., reinforced with steel to bear 1 ton/ft^2	8,560	15,900	24,460
Concrete spill wall - to contain spills	1	Dimensions are 332 ft x 4.5 ft x 8 in., reinforced and sealed	3,520	8,900	12,420
Reaction tanks	5	24,000-gal total capacity, steel, plastic, or concrete - see Options 1-5			
Option 1		ASTM A-36 carbon steel, 15-ft dia. x 18-ft height x 0.375-in. wall thickness, interior coated with hard epoxy resin, exterior coated with red-oxide primer, conical roof 0.25 in. thick, 24-in. manhole with gasket, 4-in. bulkhead fittings, mixer bridge, 24-in. cleanout, drain, level indicator, exterior ladder	27,700	–	138,500

TABLE 2 (Cont'd)

Component and Function	Quantity	Specifications	Cost ($) Per Item	Labor	Total
Option 2		Closed-cover fiberglass, 0.625-in. wall thickness, equipped as described in Option 1	45,800	–	229,000
Option 3		Nalgene™ (high-density polyethylene), 11.8-ft dia. x 27.4-ft height, equipped as described in Option 1	22,800	–	114,000
Option 4		12-gauge bolted steel, interior epoxy coating, equipped as described in Option 1	15,800	–	79,000
Option 5		Reinforced concrete, equipped as described in Option 1	18,000	–	90,000
Plumbing - to connect mixing and reaction tanks	–	Steel or CPVC - see Options 1 and 2			
Option 1 - CPVC	450 ft	6-in.-dia. pipe	21	–	9,4[illegible]
	12	6-in. flanged diaphragm valves	642	–	7,704
	2	4-in. check valves	540	–	1,080
	20 ft	4-in. suction hose	10	–	200
	as needed	4- and 6-in. fittings, misc.	–	–	1,500
		CPVC plumbing subtotal	–	1,920	26,188[a]

TABLE 2 (Cont'd)

Component and Function	Quantity	Specifications	Cost ($) Per Item	Labor	Total
Option 2 - Steel	450 ft	6-in.-dia. pipe	15	–	6,858
	12	6-in. flanged diaphragm valves	450	–	5,400
	2	4-in. check valves	350	–	700
	20 ft	4-in. suction hose	10	–	200
	as needed	4- and 6-in. fittings, misc.	–	–	2,850
		Steel plumbing subtotal	–	2,500	22,210[a]
Submersible mixers - for reaction tanks	5	Carbide-steel propeller, 7.4-hp drive motors, 16-ft mast and hoist with 33-ft cable (e.g., Davis EMV FC3601)	11,200	–	56,000
Air scrubbers and biower - to vent headspace and trap volatiles	3 scrubbers 1 blower	Activated-carbon scrubbers with saturation indicators, 400 lb of activated carbon (e.g., Tigg Corp. NITOX 150 XP), 250-ft^3/min blower with 0.5-hp drive motor, spark-proof vent fans, ducting	–	–	10,400
• Slurry pump - to move slurry to drying beds	1	150-gal/min pump, 5-hp gasoline engine, positive suction head of 16 ft	–	–	4,500

TABLE 2 (Cont'd)

Component and Function	Quantity	Specifications	Cost ($)		
			Per Item	Labor	Total
Site office - for personnel and site management	1	10- x 30-ft mobile trailer; contains changing area, storage for personal protection gear, break area, restroom, and office; has special shower room with large holding tank	–	–	20,000
Fuel tanks - to store fuel for equipment	2	200-gal aboveground tank for gasoline, 500-gal aboveground tank for diesel fuel	–	–	1,200
Reaction tank total	–	Option 1 for reaction tanks, Option 2 for plumbing	–	–	289,690
<u>Steam-Cleaning Equipment</u>					
Concrete pad - base for cleaning equipment	1	Dimensions are 28 ft x 28 ft x 8 in., reinforced and sloped, 12-in. wall on 3 sides	1,565	3,035	4,600
Sump - to collect and store wash water	1	8-ft dia. x 10-ft depth, 8-in. wall thickness, reinforced, 3,800-gal capacity	–	–	2,960
Sump pump - to move wash water from sump to mixing tank	1	150-gal/min capacity at 20-ft head and 1,750 rpm, 2-hp 3-phase drive motor, floats, switches, control box	–	–	2,800

TABLE 2 (Cont'd)

Component and Function	Quantity	Specifications	Cost ($) Per Item	Labor	Total
Steel plumbing - to connect sump and mixing tank	250 ft	3-in. pipe	9	–	2,125
	1	3-in. gate valve	250	–	250
	2	3-in. check valve	260	–	260
	as needed	3-in. fittings, misc.	–	–	480
		Plumbing subtotal	–	480	3,738[a]
Storage Tank - to supply water to steam unit	1	Conical-bottom Nalgene™ tank, 1,000-gal capacity, 2-in. bulkhead fittings, 4-leg stand	–	–	2,500
Steam-cleaning total	–	–	–	–	16,598
<u>Drying Beds</u>					
Option 1 - shallow lagoon	1	1,000-yd^3 rapid-infiltration basin, dimensions are 100 x 100 x 3 ft, capacity is 15,000 gal/d or 1,000 yd^3 (all soil to be treated)	–	–	3,000
Option 2 - shallow lagoon with water recycle	1	Option 1 with bottom seal and drain to recover water for reuse, increased size and retention time may be needed	–	–	10,000-15,000[b]

TABLE 2 (Cont'd)

Component and Function	Quantity	Specifications	Cost ($) Per Item	Labor	Total
Option 3 - municipal sludge drying beds	5	Dimensions are 20 x 80 ft, 1.5-ft max. liquid depth, 4-ft x 8-in. concrete retaining wells, 4-in. underdrain piping, 12-in. gravel layer, 9-in. sand layer, concrete truck track	–	–	35,000-40,000[c]
Sludge drying total	–	Option 1	–	–	3,000
<u>Electrical Supply</u>					
System connection[d]	1	Fused disconnect, 3 phase, 480 V, 400 A	–	–	3,000
	1	Transformer for lighting, 480 to 120/240 V	–	–	7,500
		Subtotal			10,500
Branch circuits and motor loads	5	For reaction tank mixers, 480 V	–	–	6,150
	1	For mixing tank mixer, 480 V	–	–	1,130
	1	For sump pump, 480 V	–	–	1,000
	1	For blower, 240 V	–	–	500
		Subtotal			8,780

TABLE 2 (Cont'd)

Component and Function	Quantity	Specifications	Cost ($) Per Item	Labor	Total
Yard and office loads	–	For yard, 1 phase, 120/240 V, 100 A, main switchboard, outdoor lighting, outlets, etc.	–	–	3,750
	–	For office, 1 phase, 120/240 V, 100 A, main switchboard	–	–	1,500
		Subtotal	–	–	5,250
Electrical total	–	–	–	–	24,530

[a]Includes 20% contractor profit.

[b]Cost depends on native soil characteristics and underdrain specifications.

[c]Assumes that native soil characteristics preclude need for bottom seal.

[d]Does not include main power supply lines and poles at treatment site.

TABLE 3 Capital Costs for an SS/SBR System at Edwards AFB

Item and Component	Cost ($)	Salvage Value ($)[a]
Soil Screening and Slurry Mixing Tank		
Concrete pad	1,600	0
Mixing tank	5,600	2,800[b]
Screen and elevator	12,500	11,466
Prop mixer	5,200	4,768
Slurry pump	8,500	7,795
Pipe for water supply	20,000	0
Storage plastic	500	0
Subtotal	53,900	26,829
Reaction Tanks		
Concrete pad	24,460	0
Concrete spill wall	12,420	0
Reaction tanks (Option 1)	138,500	69,250[b]
Steel piping, valves, and fittings (Option 2)	22,210	11,105[b]
Submersible mixers	56,000	51,352
Air scrubbers and vent fans	10,400	5,200[b]
Slurry pump	4,500	4,127
Site office	20,000	18,340
Fuel tanks	1,200	600
Subtotal	289,690	159,974
Aggregate Steam Cleaning		
Concrete pad	4,600	0
Sump	2,960	0
Pump	2,800	2,568[b]
Steel piping, valves, and fittings	3,738	1,869[b]
Water storage tank	2,500	1,250[b]
Subtotal	16,598	5,687
Treated Soil Dewatering		
Shallow lagoons (Option 1)	3,000	0
Subtotal	3,000	0
Electrical		
Disconnect	3,000	1,500[b]
Transformer	7,500	3,750[b]
Branch circuits and motor loads	8,780	0
Yard and office loads	5,250	0
Subtotal	24,530	5,250
Totals		
Total, all items	387,718	197,740
Contingencies at 10%	38,772	
Engineering design cost	10,000	
Total capital costs	436,490	
Job chargeable costs	238,750	

[a]Salvage value = initial cost x (104 wk - 8.6 wk)/104 wk; assumed total operating life is 2 yr (i.e., 104 wk) and time in use for project is 60 d (8.6 wk).

[b]Assumed salvage value of one-half initial cost.

TABLE 4 Operating Costs for a 60-Day Remediation Period

Item	Cost ($)
Site Excavations and Transport	
Site excavation and restoration at LAAFB	88,000
Site preparation at EDAFB (eg., clearing and grading at tank location)	3,000
Transport of contaminated soil from LAAFB to EDAFB	6,000
Transport of clean soil from EDAFB to LAAFB	6,000
Subtotal	103,000
Rentals and Expendables	
Front-end loader (1-2 yd^3) for 60 d	13,500
Steam-cleaning/spray unit for 60 d	4,000
Pick-up truck	1,500
Nutrients (1,300 lb)	1,100
Fuel	1,000
Electricity	1,000
Oxygen supply	1,200
Incidentals	2,000
Subtotal	25,300
Project Personnel	
Supervisor at $60/h x 640 h[a]	38,400
Laborers, 2 at $30/h x 320 h	19,200
Security guard at LAAFB, 1 at $30/h x 40 h	1,200
Subtotal	58,800
Total Operating Costs	187,100

[a]Includes 160 h for 20-d construction and startup period plus 480 h of project supervision and management during 60-d operating period.

TABLE 5 Total Costs for SS/SBR Soil Remediation for the Fort MacArthur Site

Item	Cost Less Salvage Value ($)
Capital Costs	
Soil screening and slurry mixing tank	27,071
SS-SBRs	129,716
Aggregate steam cleaning	10,911
Treated soil dewatering	3.000
Electrical	19,280
Contingency	38,772
Engineering design and specifications	10,000
Net chargeable capital cost	238,750
Operating Costs for 60-Day Period	
Site excavations and transport	103,000
Rentals and expendables	25,300
Project personnel	58,800
Total operating cost	187,100
Total Project Cost	425,850

5 References

1. Berry, P., Los Angeles Air Force Base, El Segundo, Calif., personal communication (July 1988).

2. Van Allen, K.W., L.A. Hamilton, and C.R. Comstock, *Fort MacArthur-Los Angeles Air Force Base Underground Storage Tank Environmental Assessment*, Roy F. Weston, Inc., Concord, Calif. (Jan. 1989).

3. Star, I., et al., *Phase II UST Site Investigation, Fort MacArthur Air Force Base, San Pedro, California*, Tetra Tech Report TC 3808-01, Pasadena, Calif. (Sept. 1989).

4. Treweek, G., Tetra Tech, Inc., Pasadena, Calif., personal communication (Aug. 1989).

5. Bachmann, C., M.E.I., Ltd., Temecula, Calif., personal communication (Aug. 1990).

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