Final
June 5, 2000

COST AND PERFORMANCE REPORT

Biosparging of Contaminated Groundwater
T-Dock Site, South Prudence Bay Island Park
Portsmouth, Rhode Island

June 2000

SITE INFORMATION

IDENTIFYING INFORMATION (7)

Site Name: T-Dock Site, South Prudence Bay Island Park
Location: Portsmouth, Rhode Island
Operable Unit: Not Applicable
CERCLIS #: Not Applicable
ROD Date: Not Applicable
Technology: Biosparging
Type of Action: Remedial

Figure 1 shows the location of South Prudence Bay Island in Rhode Island, and Figure 2 shows the location of the T-Dock area to be remediated.

TECHNOLOGY APPLICATION

Period of Operation (3,7,10):
Pilot Test – October 1996 through January 1997
Full-Scale Operation – February 1998 through February 9, 2000

Quantity of Material Treated During Application (5,6,7):
Based on a total recoverable petroleum hydrocarbon (TRPH) screening analysis, the groundwater contaminant plume area was estimated to be approximately 35,000 square feet. The average depth to groundwater at the site is generally 10 to 12 feet below the ground surface (bgs), but decreases to 4 to 6 feet bgs in the southernmost portion of the site adjacent to Narragansett Bay.

In addition to remediation of contaminated groundwater, contaminated source area soil in the vadose zone has been excavated and treated using ex-situ bioremediation. This report only addresses groundwater remediation at the site.

BACKGROUND

Site Background and History (1,2,6):

- The T-Dock site is a two-acre parcel of land at the southern edge of the South Prudence Bay Island Park, which is located on the Narragansett Bay in Portsmouth, Rhode Island. The majority of the site is covered with grass; however, a small portion of the western side of the site is covered with dense shrubs and vines.

- The South Prudence Bay Island Park was purchased by the US Navy in 1942 and was primarily used as an ammunition storage site. Ships offloaded ammunition at the site prior to undergoing repairs in Newport, Rhode Island. Mine assembly maintenance and support activities took place at the site during the 1940s and early 1950s. A portion of the site was reportedly used as a municipal landfill, also in the 1940s and 1950s. The site was maintained in caretaker status from 1953 until 1980, at which point the US Department of the Interior granted the land to the Rhode Island Department of Environmental Management (RIDEM), and designated that the land be used as a public recreational park. The area is currently open to the public for fishing, biking, hiking, hunting, swimming, boating and picnicking.

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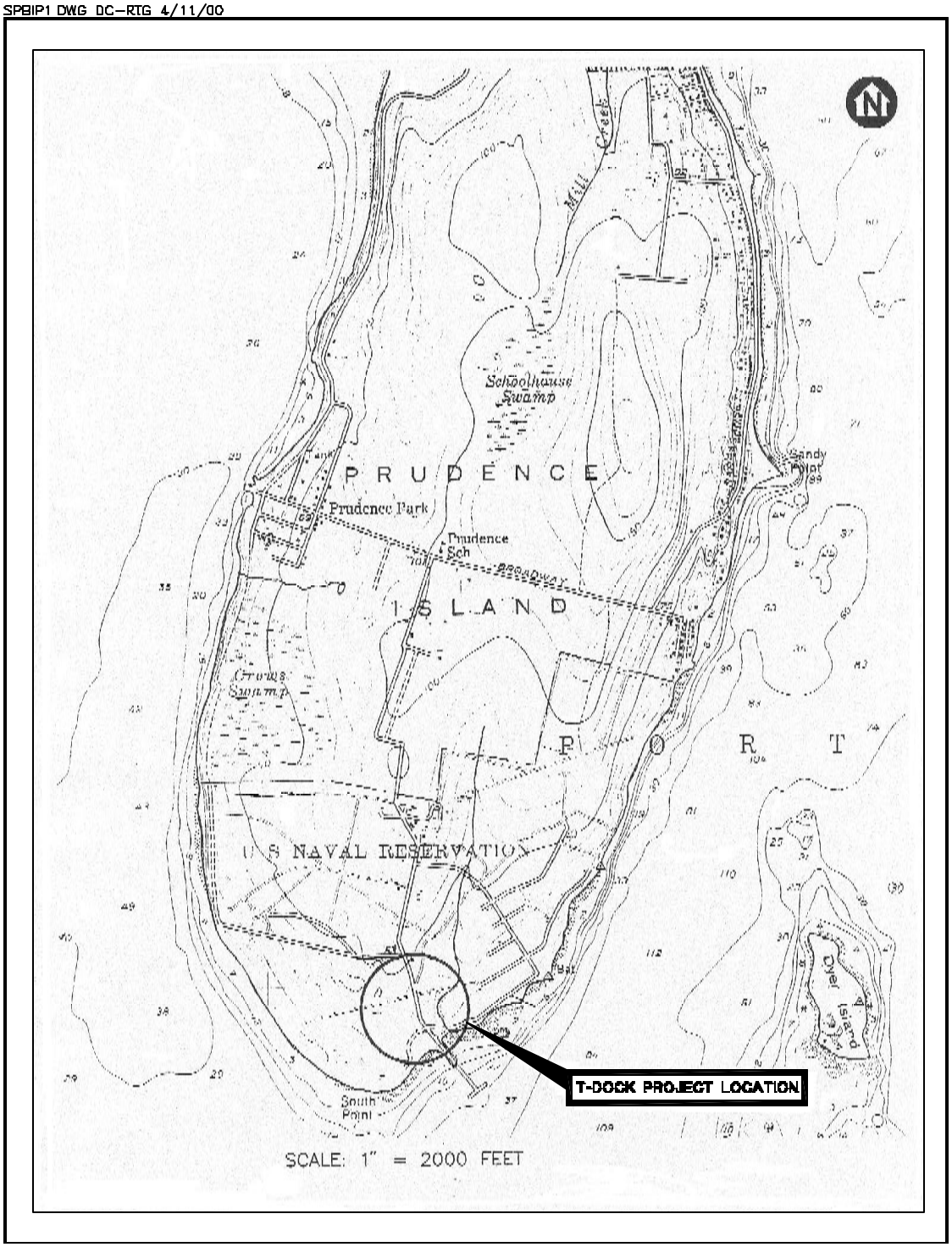

Figure 1. Location of South Prudence Bay Island Park in Portsmouth, Rhode Island

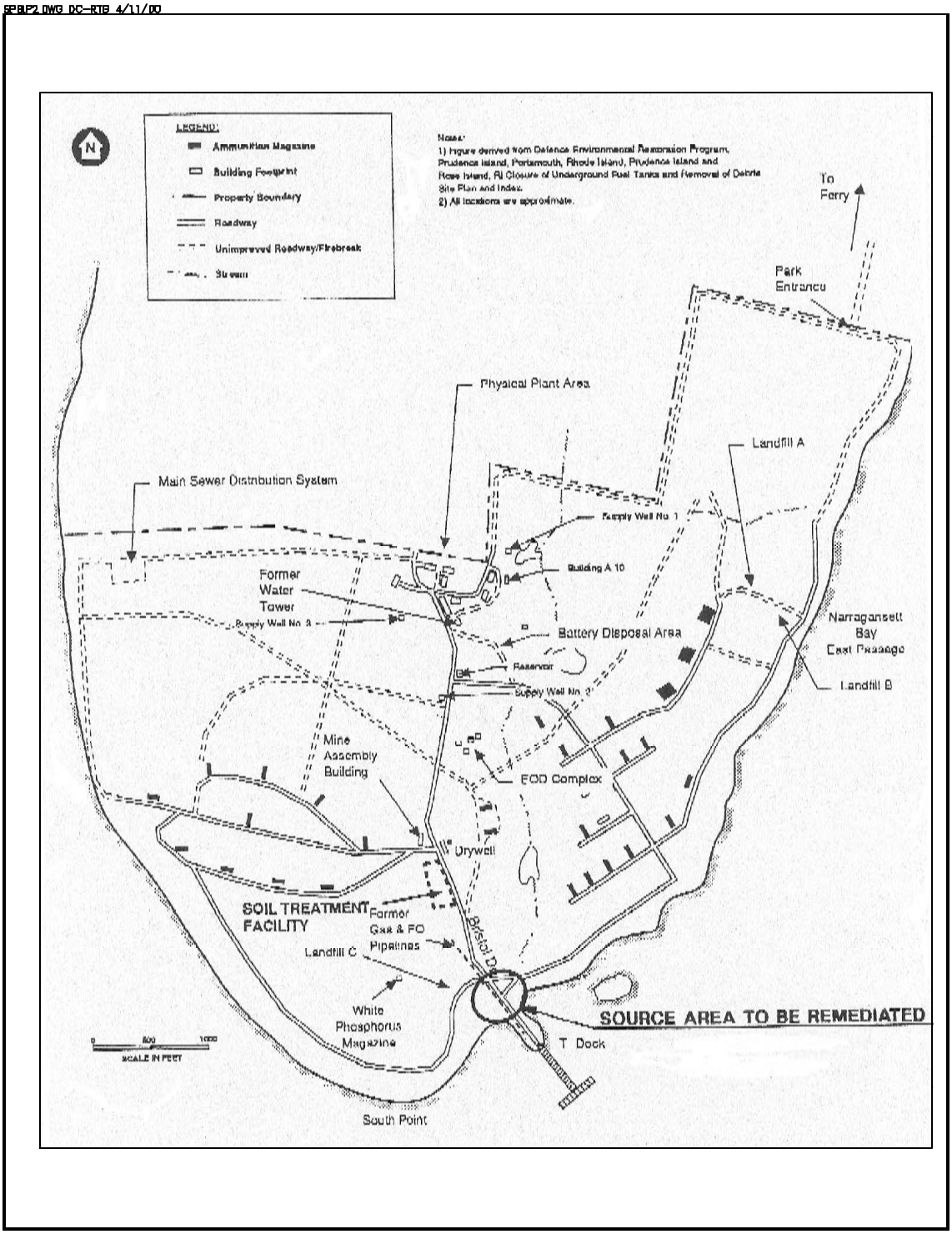

Figure 2. Location of T-Dock Area to be Remediated

- When it was operational, the T-Dock area was used for transferring munitions and other materials to and from military ships. One 10,000-gallon gasoline underground storage tank (UST) and one 5,000 gallon fuel oil UST were located approximately 400 feet northwest of the T-Dock area. The tanks were connected by pipes to a fuel distribution system located on the west side of the T-Dock access road. No information regarding the construction of the fuel distribution system is available. The tanks were emptied and removed in 1985 during a project managed by RIDEM. No information is available regarding the condition of the removed tanks, or regarding the soil and groundwater in the area of the tanks. Sections of the pipelines near the T-Dock were removed in 1992. No evidence of contamination was observed in the areas surrounding the removed sections in 1992. When excavation and remediation of vadose zone soils began in 1997, significant contamination was evident in the area adjacent to the pipeline, and this area was referred to as the "source area". It is unclear whether the contamination was from the pipelines themselves, the fueling point nearby, or from Landfill C also located in this area.

SIC Code:

9711 (National Security**)**

Waste Management Practices that Contributed to Contamination (2):

Underground fuel storage tanks and an associated distribution system were operated at the site from the 1940s until 1985.

Site Investigations (1,2,3):

- RIDEM has conducted several investigations at the site, including preparation of a Preliminary Assessment (PA) Report in 1985, and sampling and analysis of soil, water and sludge from unspecified locations in 1984 and 1987. Investigations of bunkers, buildings and landfills, and removal of seven underground storage tanks from various locations were conducted from 1985 through 1986.

- The USACE completed an Inventory Project Report (IPR) for the site in 1991. In addition, the US Army Corps of Engineers, North Atlantic Division, New England District (CENAE) conducted the following projects from 1991 through 1992:

  - Sampling and analysis of fluids from electrical transformers and three USTs (two of the USTs were near the T-Dock area and the third was elsewhere on the island);
  - Removal of the USTs and some of the transformers;
  - Demolition of several small buildings;
  - Removing or closing in place of fuel pipelines near the T-Dock site;
  - Removal and disposal of landfilled materials;
  - Demolition and disposal of a water tower;
  - Securing several magazine structures; and
  - Sampling and analysis of two active water supply wells at the site.

- A Site Investigation (SI) was performed by CENAE in December 1994 to address potential contamination at the former landfills, the sewer distribution system, the battery disposal area, firebreaks, the physical plant area, and the fuel distribution and storage system, including two former USTs. The SI identified several potential areas of environmental concern. The assessment was based on a visual site inspection, geophysical survey, a soil gas survey and sampling and analysis of subsurface soil, groundwater, surface water, sediment, wastewater and sludge. A preliminary risk evaluation (PRE) was conducted as a part of the SI.

- CENAE conducted a Supplemental Site Investigation and developed a Remedial Alternatives report for the T-Dock area in March 1996. The investigation was designed to identify the extent of petroleum-contaminated soils and groundwater in the vicinity of the T-Dock area, and to evaluate possible remedial alternatives. The investigation included completion of soil borings, collection of soil and groundwater samples, measurement of groundwater levels, and performance of an elevation and location survey. Soil and groundwater samples were screened in the field and analyzed in a laboratory.

- Between October 1996 and January 1997, a pilot test and treatability study for biosparging combined with soil vapor extraction (SVE) was conducted in a portion of the T-Dock site that was estimated to be representative of the entire site. The Interim Status Report, dated 13 February 1997 summarized the field program and presented the preliminary results of the SVE, biosparging, and aquifer pumping test.

Previous Removal Actions (5):

Prior to implementation of biosparging at the site, remedial actions conducted at the T-Dock site included the 1985 removal of one 10,000-gallon gasoline UST and one 5,000-gallon fuel oil UST, and the 1992 removal of the pipeline sections between the USTs and the fuel distribution point. No information is available regarding the condition of the removed tanks, or of the soil and groundwater in the area of the tanks. No evidence of petroleum contamination was observed in the soil surrounding the removed pipeline sections that were removed in 1992. When excavation and remediation of vadose zone soils began in 1997, significant contamination was observed in a portion of the area adjacent to the former pipeline. This area is referred to as the "source area". It is unclear whether the contamination was from the pipelines themselves, the fueling point nearby, or from Landfill C also located in this area.

Remedy Selection (1):

Based upon a detailed analysis of the alternatives, the CENAE determined that in-situ, low-flow air sparging, or biosparging, would be the best technology for remediation of the groundwater at the T-Dock site. This technology was selected because it was estimated that it would:

- Mitigate the mass of contaminants at the source in a shorter time period than the other alternatives;
- Achieve the remedial action objectives; and
- Be cost-effective.

SITE LOGISTICS/CONTACTS (**12**)

Role	**Contact Information**
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MATRIX AND CONTAMINANT DESCRIPTION

MATRIX IDENTIFICATION

Groundwater (in situ)

SITE GEOLOGY/STRATIGRAPHY (1, 3,5)

Subsurface soils at the site are primarily sandy silts from just below the surface to 14 feet bgs. Below 14 feet bgs, soils are coarser and consist of sands, gravelly sands, and presumed weathered bedrock. The bedrock underlying Prudence Island is the Rhode Island Formation. The depth of the bedrock at the T-Dock site has not been definitively determined, but the deepest boring was advanced to 22 feet bgs without encountering bedrock. Weathered schist and rock fragments were found in the bottoms of the deepest borings (18 to 22 feet bgs), and it is estimated that bedrock is present just below these borings.

The depth to groundwater at the site is generally 10 to 12 feet bgs, and decreases to 4 to 6 feet bgs in the southernmost portion of the site adjacent to the bay. The road leading to the T-Dock and adjacent areas were constructed on top of 8 to 10 feet of compacted fill. Several wells (all pilot study wells, monitoring wells MW-304, MW-107, MW-3, and MW-5 and sparge wells 1 through 6) were constructed in the fill area, and therefore, the depths to groundwater in these wells are 8 to 10 feet deeper than other wells.

The predominant direction of groundwater flow at the T-Dock site is towards the southeast, which is perpendicular to the shore. Testing indicates that the groundwater at the site is tidally influenced.

CONTAMINANT CHARACTERIZATION

Primary Contaminant Group: Organic Compounds - Volatiles (Nonhalogenated)

Key Specific Contaminants (8): Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)

Table 1 lists selected properties for the key specific contaminants of concern at the T-Dock site.

Table 1. Contaminant Properties (9)

Property	Units	Benzene	Toluene	Ethylbenzene	Xylene
Chemical Formula	-	C_6H_6	$C_6H_5CH_3$	$C_6H_5C_2H_5$	$C_6H_4(CH_3)_2$
Molecular Weight	g/mole	78.11	92.14	106.17	106.17
Specific Gravity (at 20°C)	-	0.88	0.87	0.87	0.86 - 0.88
Vapor Pressure (at 20°C)	mm Hg	95.2	28.1	7	10
Boiling Point	°C	80.1	110.6	136.2	138.3 –144.4
Octanol-Water Partition Coefficient	log K_{ow}	132	537	1,100	1,830
Soil-Water Partition Coefficient	log K_{oc}	83	300	1,410	240

Nature and Extent of the Contaminants (2,3,8):

A pilot test and treatability study were conducted in February 1997. Prior to the pilot test, three rounds of groundwater samples were collected from the eight monitoring wells at the site, and the maximum contaminant concentrations detected in each well are shown in Table 2. The monitoring well locations are presented in Figures 3 and 4. Based on a TRPH screening analysis, the surface area of groundwater contaminant plume was estimated to be approximately 35,000 square feet.

Table 2. Maximum Groundwater Contaminant Concentrations (1996)

Contaminant (µg/L)	Cleanup Goals (µg/L)	GMW-301	GMW-302	GMW-303	GMW-304	GMW-305	GMW-306	RW-301	MW-114
Benzene	5	640	146	236	2050	142	1290	156	<0.63
Toluene	1,000	336	199	240	3850	1400	7830	3100	<0.63
Chlorobenzene	100	<250	<125	93	<1250	<125	<2500	<250	<0.63
Ethylbenzene	700	1,300	964	1060	3470	1020	2480	687	<0.63
M,P,-Xylene	10,000	3,200	2530	3700	11000	2590	5720	2530	<0.63
O-Xylene	10,000	268	200	<250	2660	1230	3250	1070	<0.63
TPH (mg/L)	NA	18	13.7	13.1	45.2	23.8	53.5	15.3	0.017

Note: Shaded concentrations are above drinking water standards.
NA: Not applicable, no cleanup goal exists for TPH

In February 1998, prior to start up of the biosparging system, a baseline sampling event was conducted at the site. Eleven monitoring wells were sampled during this event, and BTEX compounds were detected in ten of the eleven wells. BTEX compounds were detected above remedial action levels in five wells, and the results for these five wells are presented in Table 3. Figure 5 shows groundwater contamination contours at the site prior to operation of the treatment system. Figure 6 shows the locations of the sparge wells and monitoring wells. All samples were analyzed for BTEX compounds using EPA Method 8021A.

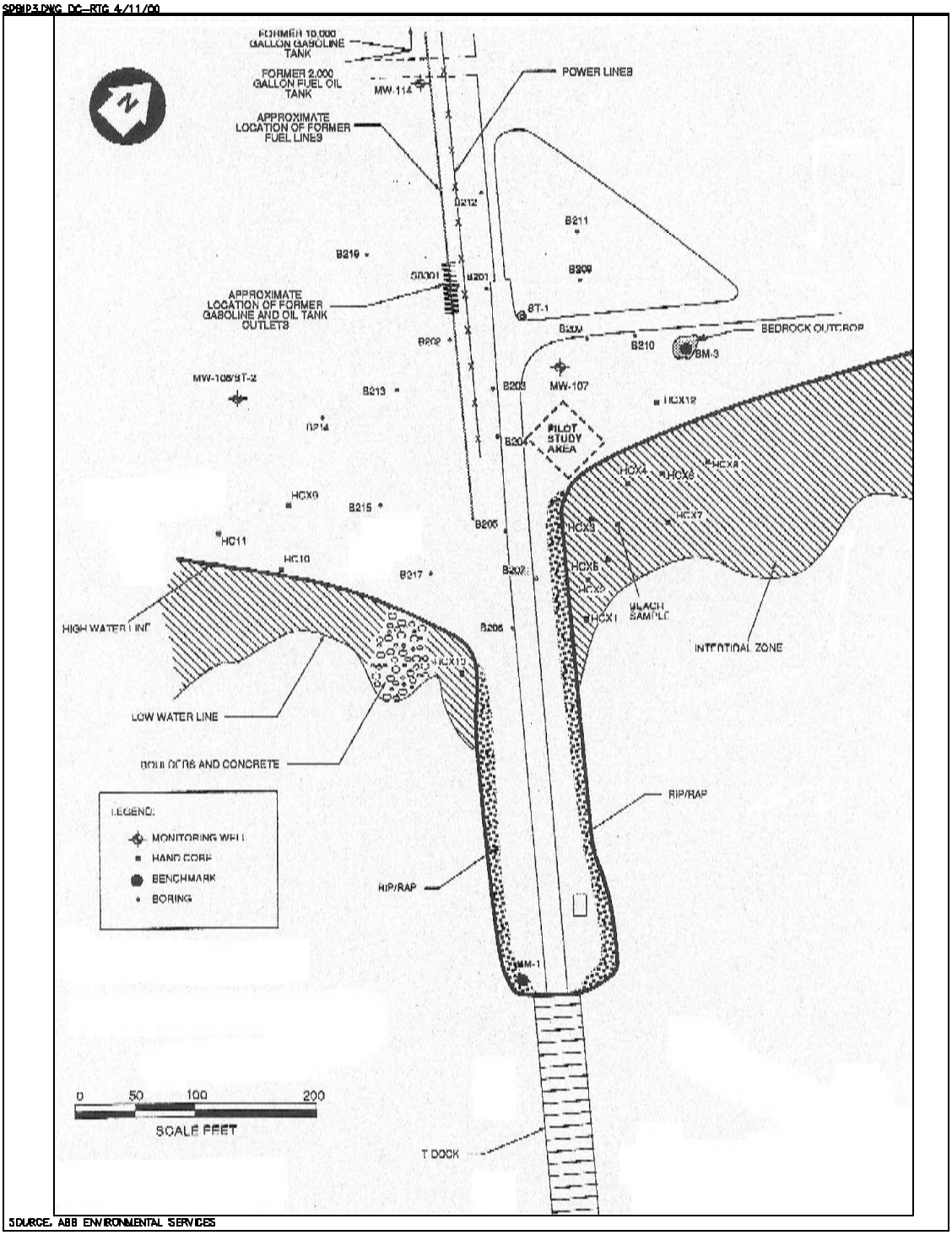

Figure 3: Location of Pilot Study Area

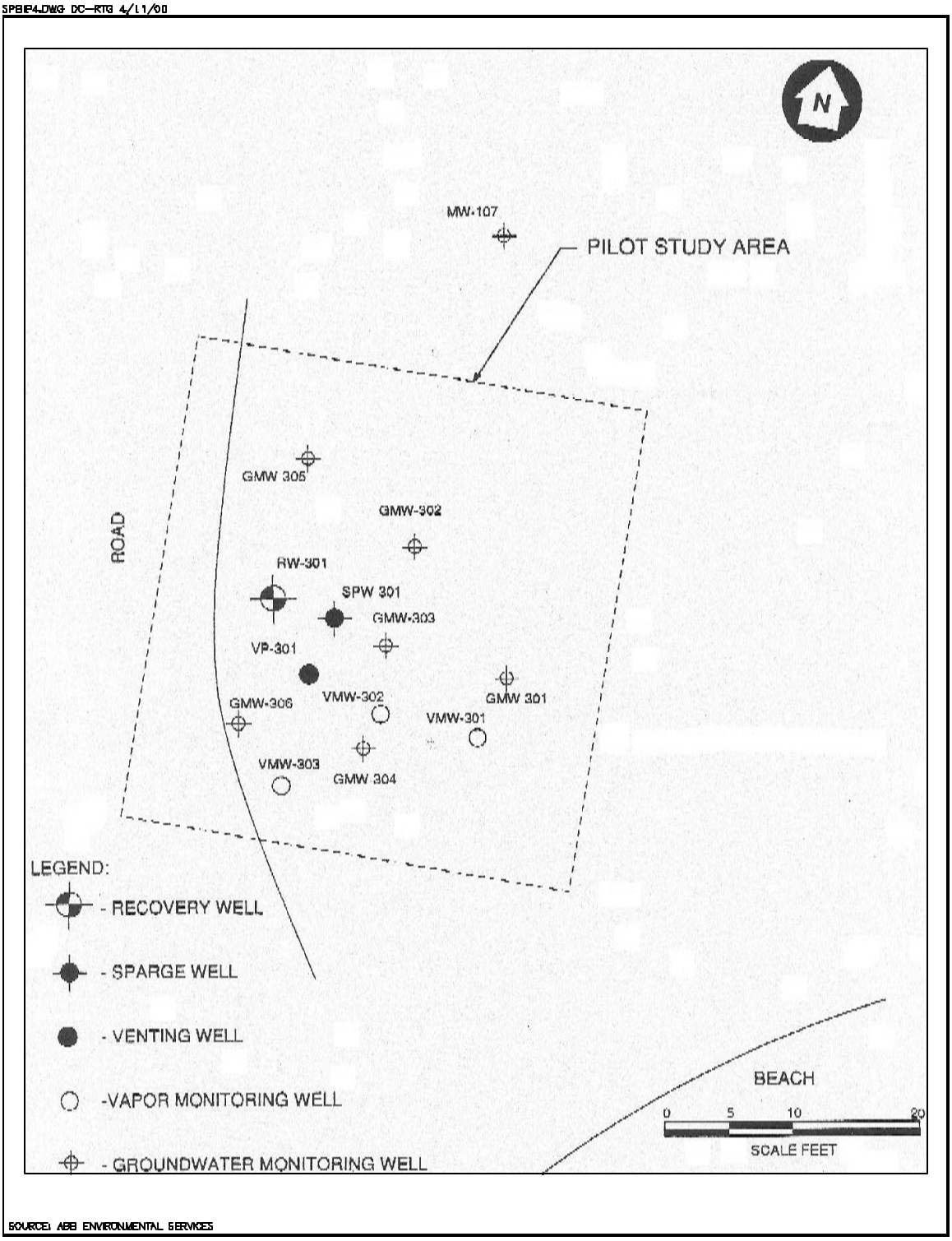

Figure 4: Pilot Study Well Locations

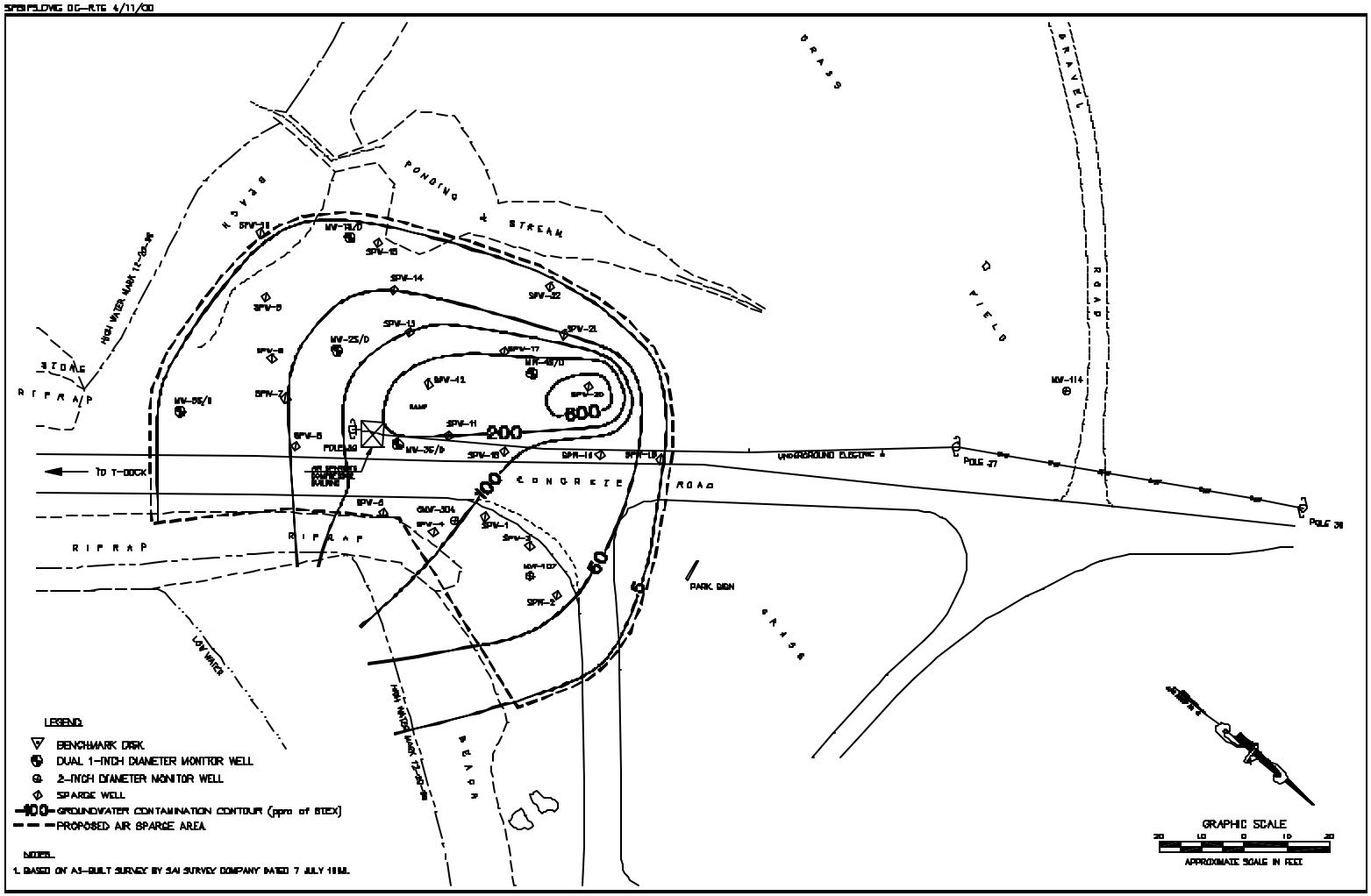

Figure 5: Groundwater Contamination Contours

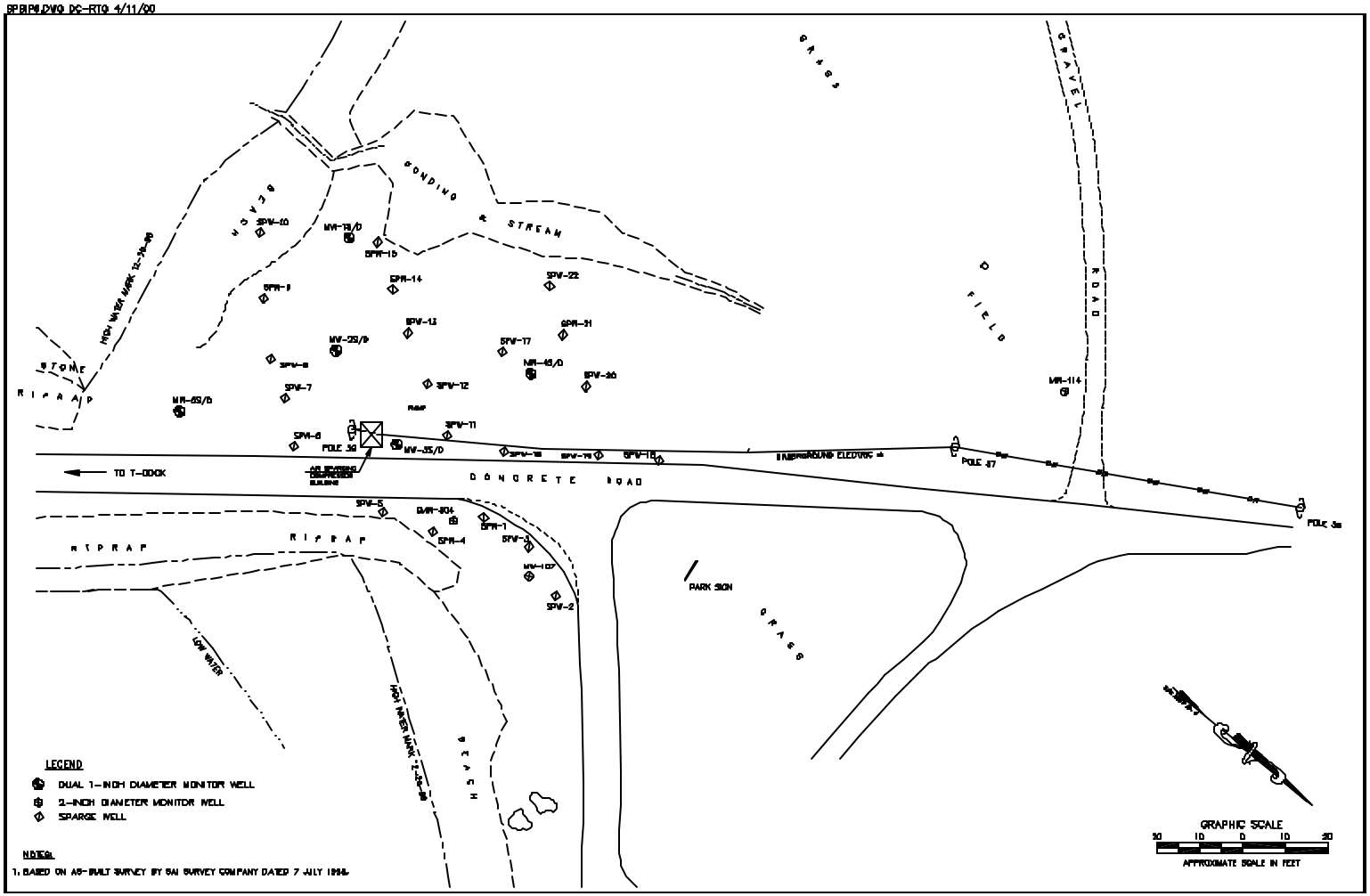

Figure 6: Location of Sparge Wells, Monitoring Wells, and Compressor Building at T-Dock Site

Table 3. Maximum Groundwater Contaminant Concentrations (February 1998)

Contaminant	Cleanup Goal (µg/L)	MW-2D (µg/L)	MW-3S (µg/L)	MW-3D (µg/L)	MW-4S (µg/L)	GMW-304 (µg/L)
Benzene	5	5.4	90	100	35	640
Toluene	1,000	5.1	260	25	26	720
Ethylbenzene	700	36	1,800	250	320	1,800
Xylene	10,000	2,000	7,000	1,000	1,000	6,100

Note: Shaded concentrations are above drinking water standards.

MATRIX CHARACTERISTICS AFFECTING TECHNOLOGY COST OR PERFORMANCE

Table 4 lists selected characteristics of the T-Dock site as determined during the pilot test and treatability study.

Table 4. Matrix Characteristics

Characteristic	Value	Measurement Procedure
Soil Classification (3)	Ranges from sand (SP, SW) to silt (ML) and gravel (GW)	Unified Soil Classification System
Clay Content and/or Particle Size Distribution	Information is not available	Information is not available
Hydraulic Conductivity (3)	3 ft/day	Derived from the measured transmissivity and an aquifer thickness of 10 feet.
Porosity	Information is not available	Information is not available
Presence of NAPLs (3)	Not Detected	Not Applicable

TECHNOLOGY SYSTEM DESCRIPTION

PRIMARY TECHNOLOGY

Groundwater In-Situ - **Biosparging**

SYSTEM DESCRIPTION AND OPERATION

System Description (4,6,7,10)

Biosparging consists of injection of air into the subsurface below the water table, to induce volatilization and to enhance biological degradation of organic compounds present in groundwater and saturated soil. SVE is commonly employed in conjunction with biosparging so that air emissions from the system can be captured and treated, and because SVE can enhance the performance of the biosparging technology.

Based on a pilot test, it was determined that SVE would not enhance treatment system performance at the T-Dock site, and that biosparging alone would be adequate to remediate the groundwater. The T-Dock remediation system consisted of:

- An air compressor and blower to supply and deliver air to the sparge system;
- 22 sparge wells, each screened over the bottom two feet of its depth; and
- 13 monitoring wells for collection of air and groundwater samples during system operation.

Pilot Test and Treatability Study (3,4)

A combined pilot test and treatability study was completed for the site between October 1996 and January 1997. The objective of the study was to determine the effectiveness of a combination of SVE and biosparging. The test was conducted in an area that was considered to be representative of conditions at the entire T-Dock site. The pilot system consisted of one sparge well (SPW-301), six groundwater monitoring wells (GMW-301 through GMW-306) and one vapor extraction well (VP-301). Groundwater samples were collected at three times during the study; prior to start up, during sparging, and upon completion of the test. The results of the pilot test indicated that the SVE well did not establish a significant zone of influence/capture. In addition, soil characteristics at the site (fine-grained, silty sands) and the presence of localized perched groundwater may have contributed to the limited effectiveness of the SVE well. It was determined, however, that biosparging would be an effective method for remediating the groundwater at the site.

After the pilot test, a study was conducted to determine the feasibility of operating a low-flow air sparging system without SVE. The objective of this system was to limit the air injected into the groundwater thereby minimizing the volatilization of contaminants, while still providing a sufficient amount of oxygen to induce aerobic degradation of the BTEX compounds. In order to operate such a system, it was necessary to prove that volatile air emissions from the system would be below RIDEM air emissions standards. Calculations based on expected groundwater concentrations were performed to determine the operating range for the proposed sparging system that would maintain air emissions below the RIDEM standards. The calculations were based on conservative assumptions regarding the size of the plume and contaminant concentrations. The study concluded that pulsed air injection at a rate of 1 cfm for twenty minutes per hour would maintain emissions levels below the RIDEM standards, and therefore no air emissions permits would be required.

System Operation (6,7)

Prior to installation of the in-situ groundwater treatment system, it was necessary to better delineate the dimensions of the contaminant plume. To achieve this, fifteen boreholes were completed at the site. Two groundwater samples were taken from each borehole and analyzed on-site for BTEX. This investigation determined the dimensions of the plume, and was used to select the locations of additional sparge and monitoring wells.

Twenty-one additional sparge wells were installed at the site (one sparge well had already been installed during the pilot test). Sparge wells were installed to depths from 15 feet bgs to 28 feet bgs. Well screens were installed in the bottom two feet of all wells. A diagram of a typical air sparge well is presented in Figure 7.

Ten new monitoring wells were installed at the site. The monitoring wells were installed to depths from 8 feet bgs to 26 feet bgs. The ten wells were actually five locations with two nested wells in each location. One well in each nest was screened at a shallow depth and the second well was screened deeper. In addition, GMW-304 from the pilot test, and two additional monitoring wells (MW-107 and MW-114) from previous investigations were used, for a total of thirteen monitoring wells.

A rotary lobe, positive displacement blower was installed to process atmospheric air through a distribution manifold and into the individual supply lines for each sparge well. The distribution manifold was equipped with a flow meter and throttle valve for each well. The manifold was modified after treatment had begun to allow for the addition of a pressure meter for each of the wells. A schematic of the sparge system is presented in Figure 8. A control panel was installed in the blower building, however the control panel was not equipped with a programmable logic controller (PLC) to allow for remote monitoring of the system as was proposed in the work plan. Because of this, system monitoring was performed daily by on-site personnel.

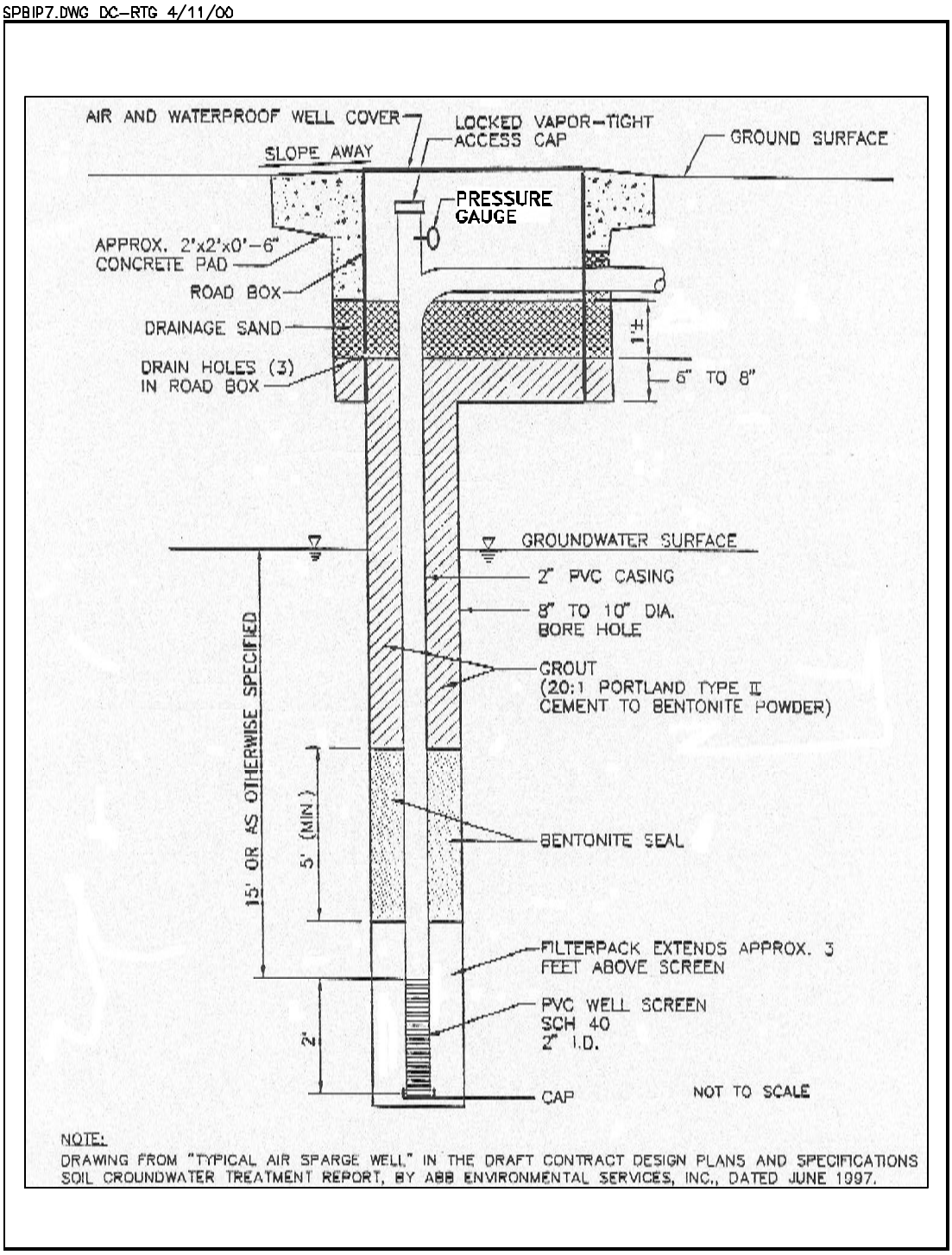

Figure 7: Diagram of Typical Air Sparge Well

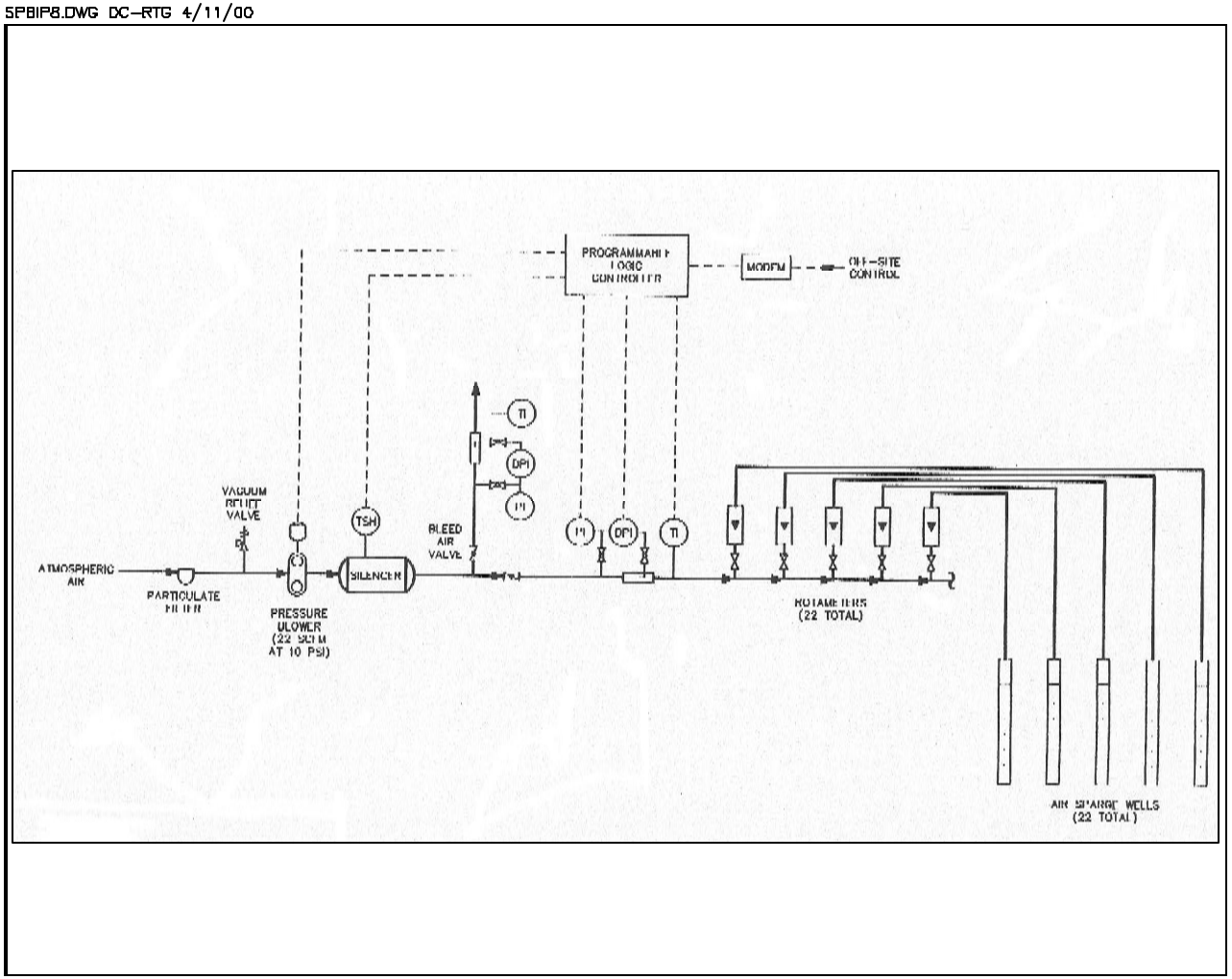

Figure 8: Air Sparging Process Flow Diagram

Prior to start up, baseline groundwater sampling was conducted at each of the thirteen monitoring wells. Start up and testing of the biosparging system was conducted over a three-month period. Testing activities included balancing treatment performance with minimization of air emissions. At startup, air was supplied to the sparge wells at a continuous rate of 1 cfm. Air samples were collected using a closed chamber method and were analyzed for VOC concentrations at startup and after 30 days of system operation. Once the samples were analyzed and emissions levels were determined to be well below RIDEM standards, air sampling was cancelled. The flow rate and operating pressures were adjusted from design specifications of 1 cfm and 6 to 7 psi, to between 0.2 to 9.5 cfm and 6 to 15 psi. Flow rates to each well were adjusted throughout the project as necessary to address areas of higher contaminant concentrations.

Long-Term Operation (8,7,10)

Groundwater samples were collected quarterly from the thirteen monitoring wells starting at the commencement of treatment operations in February 1998. The samples were analyzed for BTEX compounds using EPA Method 8021A. Analytical results for these samples were used to determine if the cleanup goals were being met. When the groundwater analytical results demonstrated attainment of cleanup goals, the air sparging system was shut down on February 9, 2000. One additional sampling event was conducted on March 15, 2000.

Operation of the system was checked daily by on-site personnel. The control panel monitored total air flow through the system as well as temperature and pressure of the process air. An engineer visited the site at least once per month to inspect and service the equipment as necessary.

Personnel Requirements (7)

Long-term O&M of the system required daily observation of the system by one person, monthly maintenance visits by an engineer and quarterly groundwater sampling events.

Health and Safety Requirements

All contractor and subcontractor personnel who performed work on-site complied with the Site Safety and Health Plan, which was developed in accordance with the requirements set forth in 29 CFR 1910.120 (OSHA's Hazardous Waste Operations and Emergency Response Standard) and 29 CFR 1926.65 (OSHA's Safety and Health Regulations for Construction), the USACE Safety and Health Requirements Manual EM 385-1-1, and the contractor's corporate health and safety program plan.

Modified level D personal protective equipment (PPE) was used during activities for delineation of the nature and extent of contamination, installation of the remediation technology, and long-term monitoring.

OPERATING PARAMETERS AFFECTING TECHNOLOGY COST OR PERFORMANCE

Table 5 lists design and actual values for parameters associated with operation of the biosparging system at the T-Dock site. The parameters were selected for this report based on USACE guidance contained Guide to Documenting and Managing Cost and Performance Information for Remediation Projects, FRTR, October 1998.

Table 5. Operating Parameters (6)

System Parameter	Design	Actual
Air Flow Rate	1 cfm	0.2-9.5 cfm
Operating Pressure/Vacuum	6-7 psi	6-15 psi
Air Injection Frequency	1cfm	Continuous

TIMELINE (1,2,3,4,7,8,10)

Date	Activity
1985	Preliminary Assessment (PA), Removal of USTs
1991	USACE completed Inventory Project Report (IPR)
1991-1992	Removal of Fuel Distribution Lines from T-Dock Area
December 1994	Final Site Investigation Report
March 1996	Supplemental Site Investigation and Remedial Alternatives Report including groundwater sampling and recommendation for air sparging and SVE
October 1996-December 1996	Pilot testing of air sparging and SVE
February 1997	Results of pilot test indicate that biosparging is an effective method of remediation and that SVE has limited effectiveness at the site.
June 2, 1997	Feasibility study completed for installing a low-flow air sparge system without SVE
July 1997	Contract Design Plans and Specifications and Draft Operations and Maintenance Plan completed
July 15, 1997	Draft Final Work Plan Submitted
September 1997	Plume characterization boring program conducted
November 1997	Additional sparge and monitoring wells installed
February 1998	Baseline sampling conducted
February 1998	Startup and testing of system
March 1998	Long term monitoring and quarterly sampling started
February 9, 2000	System shutdown
March 15, 2000	Sampling event
Scheduled for Fall 2000	Decontamination and demobilization
Scheduled for Fall 2000	Site restoration complete

TECHNOLOGY SYSTEM PERFORMANCE

CLEANUP GOALS/STANDARDS (2,5)

The following groundwater remedial action objectives (RAOs) for the T-Dock site were based on the preliminary risk evaluation:

- Minimize/mitigate the mass of contaminants at the site;
- Prevent receptor contact with groundwater having carcinogens in excess of MCLs and a total excess cancer risk of greater than 10E-4 to 10E-6;
- Prevent receptor contact with groundwater having non-carcinogens in excess of MCLs, health based ARARs and a total hazard index greater than 1;
- Reduce further migration of contaminants from the source to potential future receptors and areas such as the beach; and
- Restore the contaminated groundwater to a level protective of human health and the environment as soon as practicable, for the area from the estimated source area to the outer boundary of the contaminant plume.

Groundwater treatment objectives for this project were determined based on federal and state drinking water regulations and are provided in Table 6. Objectives were only established for BTEX compounds.

Table 6. Groundwater Cleanup Goals

Contaminant	Remedial Action Goal (µg/L or ppb)
Benzene	5
Ethylbenzene	700
Toluene	1,000
Xylene	10,000

PERFORMANCE DATA (8)

Table 7 provides all of the quarterly groundwater monitoring data that has been generated since the biosparging system began operation.

PERFORMANCE DATA ASSESSMENT (8)

- Contaminant concentrations at monitoring wells MW-1S, MW-1D, MW-2S, MW-2D MW-3D, MW-5D, MW-107 and MW-114 were all below the standards by the end of the first year of remediation. Of these monitoring wells, only MW-5D was sampled during the second year of remediation, and no contaminants were detected above the remedial standards.

- MW-4S and MW-4D were not sampled during the 12 month (4th quarter) sampling event, however, they were both sampled at 18 months. No BTEX compounds were detected above remediation action levels in either well at 18 months.

- The concentration of ethylbenzene in MW-5S was above the remedial standard during the January 1999 sampling event. This was the only sampling event conducted at this well.

- Several contaminant concentrations at MW-3S and MW-304 were above remedial standards after one year of remediation, however, no contaminants were detected above the remedial standards in MW-3S after two years of remediation.

- Just prior to system shut down in February 2000, all monitoring wells (except MW-5S, which was dry) were sampled. All contaminant levels in all monitoring wells were below clean up levels, with the exception of benzene in MW-304, which was detected at 9.1 µg/L. The reason why MW-304 did not reach the clean up goal for benzene was not apparent.

- The air emissions from the biosparging system have met the RIDEM air emission standards throughout the two years of system operation.

PERFORMANCE DATA QUALITY (6,7)

Site activities and sample handling during operation of the biosparging system were performed in accordance with the Contractor Quality Control Plan (CQCP) prepared for the investigation and submitted as a part of the Work Plan. The CQCP was reviewed by CENAE and finalized in May 1997. Field quality control issues included chain of custody seals missing from one cooler, and coolers arrived at the laboratory too warm twice.

Table 7. Summary of Quarterly Groundwater Monitoring Results (all results are shown in µg/L)

Well ID	Analyte	Clean-up Goal (µg/L)	Results by Sampling Event (µg/L)								
			Feb-98	Mar-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99	Nov-99	Feb-00
			Baseline	*1 Month*	*3 Months*	*6 Months*	*12 Months*	*18 Months*	*21 Months*	*24 Months*	*24 Months*
MW-1S	Benzene	5	4.7	0.73J	BRL	1.9	3	NS	NS	NS	1.0U
	Toluene	1,000	4.4	0.61J	BRL	1.1	0.87J	NS	NS	NS	1.0U
	Ethylbenzene	700	41	0.76J	BRL	0.83J	1.0U	NS	NS	NS	1.0U
	Xylene (total)	10,000	230	4.8	BRL	2.3	1.0U	NS	NS	NS	1.0U
MW-1D	Benzene	5	4.4	1.1	BRL	1.3	2.1	NS	NS	NS	1.0U
	Toluene	1,000	4.2	1.5	BRL	0.82J	0.51J	NS	NS	NS	1.0U
	Ethylbenzene	700	19	3.6	BRL	1.0U	1.0U	NS	NS	NS	1.0U
	Xylene (total)	10,000	130	7.2	BRL	1.4	1.0U	NS	NS	NS	1.0U
MW-2S	Benzene	5	20 U	1.0 U	BRL	1.0U	1.9	NS	NS	NS	1.0U
	Toluene	1,000	19	1.0U	BRL	1.0U	1.0U	NS	NS	NS	1.0U
	Ethylbenzene	700	430	1.7	BRL	0.52J	0.63J	NS	NS	NS	1.0U
	Xylene (total)	10,000	1,300	0.94J	BRL	0.72J	0.79J	NS	NS	NS	1.0U
MW-2D	Benzene	5	***5.4***	2.3	BRL	***24***	0.53J	NS	NS	NS	1.0U
	Toluene	1,000	5.1	2.4	BRL	45	1.0U	NS	NS	NS	1.0U
	Ethylbenzene	700	36	8.6	BRL	470	1.0U	NS	NS	NS	1.0U
	Xylene (total)	10,000	200	100	BRL	740	1.0U	NS	NS	NS	1.0U
MW-3S	Benzene	5	***90***	***59***	***21***	0.81J	***22***	***27***	2.3	BRL	4.7
	Toluene	1,000	260	260	55	1.0U	11	20	3.3	6.2	1.0U
	Ethylbenzene	700	***1,800***	***1,600***	***1,000***	1.0U	440	440	94	160	4.3
	Xylene (total)	10,000	7,000	6,500	2,000	1.0U	5,400	530	73	110	1.6
MW-3D	Benzene	5	***100***	12	1.4	1.6	0.60J	NS	NS	NS	1.0U
	Toluene	1,000	25	5.4	BRL	1.0U	1.0U	NS	NS	NS	1.0U
	Ethylbenzene	700	250	34	2.1	0.81J	1.8	NS	NS	NS	1.0U
	Xylene (total)	10,000	1,000	230	9.6	2.0	0.86J	NS	NS	NS	1.0U
MW-4S	Benzene	5	***35***	NS	NS	1.6	NS	2.9	NS	NS	2.4
	Toluene	1,000	26	NS	NS	0.97J	NS	0.92J	NS	NS	0.87J
	Ethylbenzene	700	320	NS	NS	15	NS	4.1	NS	NS	1.5
	Xylene (total)	10,000	1,000	NS	NS	59	NS	1.8	NS	NS	5.9
MW-4D	Benzene	5	2.5	NS	NS	NS	NS	1U	NS	NS	1.0U
	Toluene	1,000	2	NS	NS	NS	NS	1U	NS	NS	1.0U
	Ethylbenzene	700	13	NS	NS	NS	NS	1U	NS	NS	1.0U
	Xylene (total)	10,000	48	NS	NS	NS	NS	1U	NS	NS	1.0U

Table 7. Summary of Quarterly Groundwater Monitoring Results (all results are shown in µg/L) (Continued)

Well ID	Analyte	Clean-up Goal (µg/L)	Results by Sampling Event (µg/L)								
			Feb-98	Mar-98	Jul-98	Oct-98	Jan-99	May-99	Aug-99	Nov-99	Feb-00
			Baseline	*1 Month*	*3 Months*	*6 Months*	*12 Months*	*18 Months*	*21 Months*	*24 Months*	*24 Months*
MW-5S	Benzene	5	NS	NS	NS	NS	50U	NS	NS	NS	NS *
	Toluene	1,000	NS	NS	NS	NS	84	NS	NS	NS	NS *
	Ethylbenzene	700	NS	NS	NS	NS	***1,700***	NS	NS	NS	NS *
	Xylene (total)	10,000	NS	NS	NS	NS	5,800	NS	NS	NS	NS *
MW-5D	Benzene	5	NS	NS	NS	2.2	1.2	1.3	NS	NS	.5J
	Toluene	1,000	NS	NS	NS	1.0U	0.57J	1U	NS	NS	1.0U
	Ethylbenzene	700	NS	NS	NS	1.9	1.8	1U	NS	NS	1.0U
	Xylene (total)	10,000	NS	NS	NS	0.84J	3.9	1U	NS	NS	1.0U
GMW-304	Benzene	5	***640***	***510***	***280***	***280***	***62***	***37***	***32***	2.7	**9.1/11****
	Toluene	1,000	720	***3,200***	340	120	27	66	26	9	4.9/15**
	Ethylbenzene	700	***1,800***	***1,700***	***1,400***	***920***	570	270	330	120D	83/110**
	Xylene (total)	10,000	6,100	6,700	5,900	2,700	560	350	350	240D	110/186**
MW-107	Benzene	5	4.3	4.7	2.4	1.0U	1.0U	NS	NS	NS	1.0U
	Toluene	1,000	190	96	9.3	3.4	1.0U	NS	NS	NS	1.0U
	Ethylbenzene	700	99	40	24	3	1.0U	NS	NS	NS	1.0U
	Xylene (total)	10,000	250	140	57	32	1.0U	NS	NS	NS	11
MW-114	Benzene	5	BRL	BRL	1.9	NS	1.0U	NS	NS	NS	1.0U
	Toluene	1,000	BRL	BRL	6.5	NS	1.0U	NS	NS	NS	1.0U
	Ethylbenzene	700	BRL	6.1	28	NS	1.0U	NS	NS	NS	1.0U
	Xylene (total)	10,000	BRL	25	72	NS	1.0U	NS	NS	NS	1.0U

Shaded entries indicate results above clean-up goals.

NS = Not Sampled
BRL = Below Reporting Limit
U = Undetected
D = Diluted
J = Estimated
*** - No Water in Well**
**** - GMW-304 resampled on March 15, 2000**

All off-site testing was performed by a CENAE-validated laboratory. All laboratory data was validated by the lab and by the remediation contractor. In addition, other CENAE validated labs were used to check the contractor's laboratory results (10% QA samples). No laboratory quality control issues were identified. All data generated for this project was determined to be usable.

Groundwater sampling was conducted in accordance with the specifications in the USACE document EM 200-1-3, "Requirements for the Preparation of Sampling and Analysis Plans". The contractor quality control engineer verified that testing procedures and results conformed to contract requirements.

COST OF THE TECHNOLOGY SYSTEM

PROCUREMENT PROCESS (7)

USACE awarded the contract to perform the site investigation, the pilot study and system design to ABB Environmental Services (now Harding Lawson Associates). This work was performed under an Architect/Engineering services (A/E) contract with CENAE. The contract to construct the system and provide long-term O&M services was awarded to Roy F Weston (WESTON). The contract for construction and O&M was negotiated under CENAE's cost-reimbursable $50 million Remedial Action Contract (RAC) with WESTON.

WESTON subcontracted with the following companies for completion of this remedial action:

Subcontractor	Tasks
Severn Trent Laboratories	Groundwater sample analysis
Air Toxics Ltd.	Air sample analysis
Atlantic ECO/TEX	Groundwater sampling using direct push technology and on-site analysis of groundwater samples to delineate the horizontal and vertical extent of the plume
New England Boring	Monitoring well and sparge well installation

COST DATA (11)

The original estimated cost for the groundwater remediation project was $295,330 and the actual total project cost was $280,946. Groundwater remediation at this site consisted of treatment of a 35,000 square-foot plume of contamination. Table 8 summarizes the total costs for installation and operation of the biosparging system. The costs include projected demobilization costs.

Table 8. Summary of Remediation Costs for the T-Dock Site

Task	Description	Estimate	Actual
1100-1500	Start-up Submittals/Plans	$9,946	$12,500
4100	Well Installation (21 sparge wells: 15-28 feet bgs; and 10 monitoring wells: 8 to 26 feet bgs)	$74,459	$65,845
4200	Sparging System Installation	$75,313	$50,820
4300	Startup and Testing	$50,984	$39,215
5100	Long Term Monitoring	$6,306	$4,542
5200	Inspection (Milestone)	$29,755	$25,000
5300	Sparge Evaluation	$2,500	$ 2,824
6300	Final Demobilization	$6,542	$18,000
7000	In-Scope Modifications	-	-
	(Geoprobe Plume Delineation)	$11,700	$11,700
9000	1999 Management/Administration	$7,500	$20,000
9987-9995	WESTON Management Costs	$20,325	$30,500
	Totals:	**$295,330**	**$280,946**

REGULATORY/INSTITUTIONAL ISSUES

RIDEM was the lead agency for the T-Dock site remediation project. Applicable regulations included the following (6):

- Code of Rhode Island Rules, RIDEM Division of Air Resources, Air Pollution Control Regulation No. 9, Air Pollution Control Permits, Amended August 1996.
- RIDEM Division of Air and Hazardous Materials, Air Pollution Control Regulation No. 22, Air Toxics, Amended November 1992.
- Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases, DEM-DSR-01-93, RIDEM division of Site Remediation., Amended August 1996.
- Rules and Regulations for Groundwater Quality, RIDEM division of Groundwater and ISDS, Amended May 1195.

RIDEM indicated that an air discharge permit was not necessary for the biosparging system construction and operation. The system however, was required to operate within the RIDEM air quality standards. Table 9 lists the groundwater clean up goals established for the T-Dock site.

Table 9. Groundwater Cleanup Goals

Contaminant	Remedial Action Goal (µg/L or ppb)
Benzene	5
Ethylbenzene	700
Toluene	1,000
Xylene	10,000

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED (11,12)

Actual permit and operating costs for the sparging system were below cost estimates. The costs were lower than estimated because once the system was operational, maintenance costs were lower than expected. In addition, money was saved because air was not pulsed, but provided continuously to the sparge wells. A remote monitoring system was not used for this project as was originally planned, but was replaced by daily monitoring by on-site personnel. Sparge evaluation, management and administration costs were higher than originally anticipated. As of February 2000, estimates for project demobilization costs were higher than the original budget estimate.

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED (12)

- It is recommended that pressure meters be installed on the distribution systems for future biosparging applications to allow for monitoring the air pressure entering the sparge wells.

- Equipment requirements should be critiqued for each site that biosparging is proposed for to determine if all equipment is really needed. At the T-Dock site, it was determined that the remote monitoring system could be replaced at a lower cost by using local personnel for site inspections, so remote monitoring was not implemented.

OTHER OBSERVATIONS AND LESSONS LEARNED (12)

- The T-Dock site is located on an island, and this presented unique problems at the site in terms of obtaining equipment and site mobilization. Costs may be reduced for a site that is more accessible.

- The electrical system on the island was outdated and only supplied one-phase power. The biosparging equipment was manufactured for three-phase power and had to be adapted to the islands electric system. Costs may be reduced for a site that already has three-phase power.

REFERENCES

1) Final Site Investigation Report, South Prudence Bay Island Park, Portsmouth, Rhode Island, ABB Environmental Services, Inc., December 1994.

2) Supplemental Site Investigation and Remedial Alternatives Report, T-Dock Area, South Prudence Bay Island Park, Portsmouth, Rhode Island, ABB Environmental Services, Inc., March 1996.

3) Interim Status Report-T-Dock Area Pilot Test and Treatability Study, South Prudence Bay Island Park, Portsmouth, Rhode Island, ABB Environmental Services, Inc., February 13, 1997.

4) Low-Flow Air Sparging (Biosparging), T-Dock Area, South Prudence Bay Island Park, Portsmouth, Rhode Island, ABB Environmental Services Inc., June 2, 1997.

5) Construction Contract with WESTON (Contract: DACW33-95-D-0004, Task Order 0011 which was awarded to WESTON on June 25, 1997).

6) Final Contract Design Plans and Specifications for Soil and Groundwater Remediation, South Prudence Bay Island Park, Rhode Island, ABB Environmental Services, Inc., July 1997.

7) Draft Final Work Plan for T-Dock Area Remedial Action, South Prudence Island Park, Portsmouth, Rhode Island, Weston, 15 July 1997.

8) Groundwater Sampling Summary, T-Dock Remedial Action, Prudence Island, Rhode Island, as of November 1999.

9) Verschueren, Karel, Handbook of Environmental Data of Organic Chemicals, 2nd Edition, Van Nostrand Renhold Company, New York, 1983.

10) Phone conversation between Alison Johnson of Radian International and Christine Johnson-Battista of USACE, New England District on February 29, 2000.

11) Summary Report for Sparge System Costs, Prudence Island, Rhode Island, February 2000.

12) Phone conversation between Alison Johnson of Radian International and Christine Johnson-Battista of USACE, New England District on March 2, 2000.

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