COST AND PERFORMANCE REPORT

Air Sparging, In Situ Bioremediation, and Soil Vapor Extraction
at the Texas Tower Site, Fort Greely, Alaska

September 1998

Prepared by:
U.S. Army Corps of Engineers
Hazardous, Toxic, Radioactive Waste
Center of Expertise

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: Texas Tower Site
Location: Fort Greely, Alaska
Technology: Air Sparging, In Situ Bioremediation, Soil Vapor Extraction
Type of Action: Corrective Action (under State of Alaska Underground Storage Tank Regulations [18AAC78])

TECHNOLOGY APPLICATION (2,5)

Period of Operation: Full-scale operation - February 1994 to February 1996

Quantity of Material Treated During Application: Approximately 6,300 cubic yards (yd^3) of contaminated soil (a portion of which contained groundwater) was treated in situ.

BACKGROUND (1,4)

Site Background:

- The Texas Tower Site is located at the U.S. Army's Fort Greely military facility. Ft. Greely is located approximately five miles south of Delta Junction, Alaska, near Fairbanks.
- The Texas Tower Site consists of four buildings surrounded by a six-foot high chain-link fence.
- During demolition of one of the buildings in 1990, a release of petroleum hydrocarbons was discovered.
- The release was reported to have originated from an underground fuel line that had supplied heating oil to the demolished building from an aboveground storage tank (AST).

Waste Management Practices that Contributed to Contamination: Leak from fuel line

Site Investigation: Phase I site investigation activities included an electromagnetic survey, active and passive soil gas monitoring and analysis, and test pit excavations. Phase II site investigation activities included the soil and groundwater sampling described below.

Soil

- Nine soil borings were collected during the site investigation and analyzed for:
  - — Volatile organic compounds (VOC)
  - — Total petroleum hydrocarbons (TPH)
  - — Diesel range organics (DRO)
- Data indicated that contamination extended vertically from the ground surface to 50 feet below ground surface (bgs) and horizontally over an area of approximately 5,655 square feet (ft^2).
- Levels of DRO contamination ranged from Not Detected (ND) to 740 milligrams per kilogram (mg/kg) and levels of TPH ranged from ND to 9,200 mg/kg. Average concentrations of DRO were 500 mg/kg. It was estimated that approximately 2,500 pounds of DRO were present in the contaminated soil.
- No VOC contamination at levels above cleanup standards was detected in any of the nine soil borings.
- In four of the nine soil borings, levels of DRO contamination exceeded the standard of 100 mg/kg established by the Alaska Department of Environmental Conservation (ADEC) under the state's underground storage tank (UST) regulations (18 AAC 78.315).

Groundwater

- In 1991 and 1992, three monitoring wells were sampled for TPH and diesel-range petroleum hydrocarbons (DRPH).
- TPH was detected in two of the three monitoring wells; concentrations ranged from ND to 14.3 milligrams per liter (mg/L).
- DRPH concentrations ranged from 0.085 to 18.6 mg/L.

Historical Activities Prior to Technology Application (1):

- In 1990, contaminated soil at the site was excavated to a depth of approximately 15 ft (approximately 2,000 yd^3). The excavated soil was treated thermally off site.
- In 1993, the excavated area was backfilled with clean fill.

SITE LOGISTICS/CONTACTS

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MATRIX AND CONTAMINANT DESCRIPTION

MATRIX IDENTIFICATION

Soil (in situ)
Groundwater (in situ)

SITE STRATIGRAPHY (1)

- Subsurface materials encountered in all soil borings were generally uniform throughout the project site, from ground surface to 65 ft bgs.
- Soils consisted mainly of sand, gravel, cobble, and silt.
- Groundwater was encountered between 23 and 50 ft bgs, with a saturated zone approximately 27 ft thick.

- The inferred groundwater gradient at the site was to the north-northwest, with a hydraulic gradient of approximately 0.008 ft per ft.
- Four distinct zones were observed through the total depth of the borings; the units were identified as A, B, C, and D and are described as follows:

Unit A: Sand, fine to very coarse, and gravel (surface to 30 feet bgs)
Unit B: Sand, fine to very coarse, with some gravel and silt (30 to 40 feet bgs)
Unit C: Silt, sand, gravel, and cobble (35 to 50 feet bgs)
Unit D: Sand, fine to coarse, with silt and some gravel, very dense (50 to 65 feet bgs)

CONTAMINANT CHARACTERIZATION

Semivolatile and volatile nonhalogenated hydrocarbons - diesel fuel

CONTAMINANT PROPERTIES (1,6)

- Diesel fuel (No. 2 fuel oil) consists primarily of unbranched paraffins (straight chained alkanes) with a flash point between 110° and 190°F (43-88°C)
- Approximately one-half of the diesel fuel appeared to be within the range of volatile hydrocarbons
- Little preexisting natural weathering of the contaminant was evident
- Toxicity: High
- Flammability: High
- Solubility: 13 - 1,780 ppm at 20°C

MATRIX CHARACTERISTICS AFFECTING TREATMENT COST OR PERFORMANCE (1)

Parameter	Value
Soil classification	Primarily sand with some silt, gravel, and cobble at various depths
Clay content and/or particle size distribution	Clay content: low Particle size: fine to coarse
Hydraulic conductivity/water permeability	Moderate to high
Moisture content	2.8 to 4.0% from 10 to 25 feet bgs 19.8 to 23.0% at 30 feet bgs 7.3 to 9.9% at 49 to 54 feet bgs
Air permeability	Information not available
pH	6.0 to 7.0
Porosity	25 to 50%
Total organic carbon	Information not available
Nonaqueous phase liquids	None identified
Contaminant sorption	Information not available
Lower explosive limit	Information not available
Presence of inclusions	Information not available
Nitrogen concentration	Soil - 6 ppm Groundwater - <1 ppm
Biological oxygen demand	Information not available
Humic content	Low

TREATMENT SYSTEM DESCRIPTION

PRIMARY TREATMENT TYPES

Air Sparging, In Situ Bioremediation, Soil Vapor Extraction

SUPPLEMENTARY TREATMENT TECHNOLOGY TYPES

None

TIMELINE (1,2)

Date	Activity
1990	Petroleum contamination identified at Texas Tower Site
1990	2,000 yd^3 of contaminated soil excavated and thermally treated offsite
1991 to 1993	Phase I and II site investigation and feasibility study conducted
July 1993	Excavated area backfilled
August 1993	Delivery order awarded to Beck Environmental
August to September 1993	Treatability studies conducted
November 1993 to January 1994	Treatment system constructed and installed by Beck Environmental
February 1994 to February 1996	Treatment system operated and monitored by AGRA Earth & Environmental, Inc.
April 1996	Soil and groundwater closure samples collected and analyzed
April 1997	Treatment system operated and monitored by AGRA Earth & Environmental, Inc.

TREATMENT SYSTEM (1,5,7)

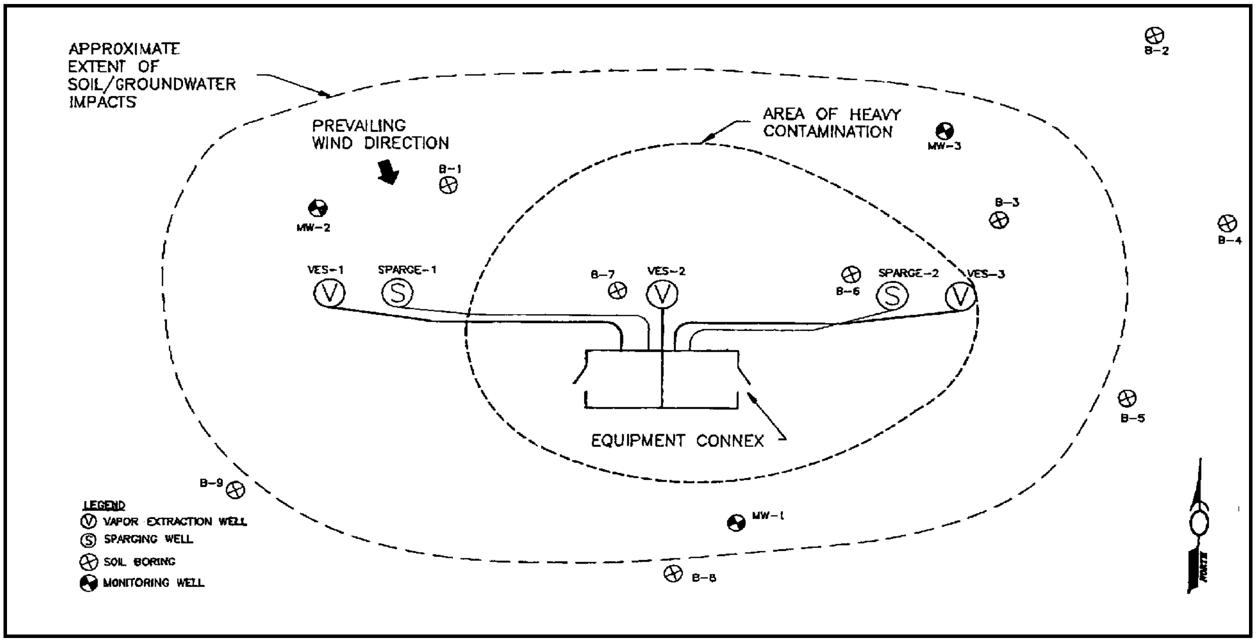

Figure 1. Treatment System Layout (No scale) (2)

Construction

- As shown in Figure 1, the treatment system included two air sparging wells, three soil vapor extraction (SVE) wells, and associated equipment for adding nutrients. In addition, a number of wells were installed for monitoring of groundwater.
- The contractor mobilized equipment for the treatment system by barge from Sumner, Washington.
- An equipment enclosure building, including remote monitoring equipment, also was installed at the site.

Pilot Test

- In August 1993, USACE contracted with Beck Environmental to design and install an in situ bioremediation system to reduce levels of residual diesel in the soil and groundwater; the system consisted of SVE and air sparging.
- Beck Environmental and AGRA Earth & Environmental conducted a pilot test on September 4, 1993 at the Texas Tower Site. The pilot test consisted of a test of the SVE and air sparging system and a biotreatability study.
- For the SVE and air sparging test, a Rotron DR-404 blower was used to pull air from a monitoring well at a rate of 80 cubic foot per minute (cfm) while a compressor was used to inject air into a sparge well.

- The effective radius of influence for the SVE well, defined as the distance at which the vacuum influence was equal to 1 percent of the operating vacuum, was approximately 70 ft.

- Measurements of the SVE air stream by organic vapor meter ranged from 285 ppm after 5 minutes to 265 ppm after 20 minutes.

- A composite grab soil sample and a groundwater sample were taken from the Texas Tower Site and shipped to the contractor's laboratory in Kirkland, Washington for a two-week biotreatability test.

- Groundwater and soil samples were analyzed to determine growth of heterotrophic bacteria and corresponding concentrations of petroleum.

- Application of heat to the groundwater did not appear to increase the effectiveness of the treatment; results of the study of culture growth indicated similar trends at high concentrations of nutrients in both low and high temperature environments.

- Analysis of aerated groundwater samples, both with and without added nutrients demonstrated a reduction in petroleum concentrations that was greater than the reduction obtained without aeration.

- On the basis of the results of the pilot test, the contractor concluded that the site was amenable to remediation by a combination of air sparging, in situ bioremediation, and SVE.

Air Sparging System

- Two air sparging wells were drilled to a depth of 55 feet bgs and constructed of 2-inch-diameter galvanized steel pipe.

- The wells were installed through the long axis of the contamination zone (12 to 32 ft bgs).

- Each well had 5 feet of 0.020-inch slot "V" wire screen at the base of the saturated zone.

- The first 45 feet and the last 5 feet of each well were solid pipe; the last 5 ft served as a collection sump for siltation that might occur during a sparge cycle.

- A Cyclo Blower Model 3LDL5 was used to inject air in the wells; flow control valves allowed manual control of the air flow rate and pressure to each of the sparging wells.

SVE System

- Three SVE wells were drilled to 52 feet bgs, constructed of 4-inch-diameter polyvinyl chloride (PVC) pipe, and screened with 0.050-inch slot "V" wire screen from 12 to 32 feet bgs. The wells were used as extraction and monitoring wells.

- Soil vapor was removed from the wells by an EN-12 Rotron Blower capable of a maximum flow rate of 600 cfm at 0 pounds per square inch (psi) vacuum and 200 cfm at 3.6 psi. Vacuum lines from the SVE wells were equipped with a flow control valve, an air velocity monitoring port, and a sampling port.

- Vapors extracted from the subsurface were directed through a 55-gallon condensate tank that preceded the blower. No air pollution control devices were incorporated into the SVE system.

- The exhaust from the SVE system was vented to the atmosphere through a 4-inch-diameter exhaust stack extending to 6 feet above the top of the blower.

- The exhaust stack was equipped with an air velocity monitoring port, an air sampling port, and a combustible gas indicator (CGI). The CGI continuously monitored the lower explosive limit (% LEL) of the air stream and would shut the system down if the LEL exceeded 20%.

- According to the USACE, no offgas treatment was incorporated into the design because the emissions were below regulatory levels.

<u>Operation</u>

- The air sparging system provided from 23 to 60 cfm of air to the saturated zone during operation of the system.

- The air sparging system was shut down temporarily in January 1995, June 1995, and October and November 1995 for maintenance and repair; the system also was shut down from February to April 1995 because the groundwater levels were below the screen intervals of the sparge wells.

- The SVE system removed an average of 400 cfm of vapor from the vadose zone.

- Measurements by photoionization detector (PID) taken from the exhaust stack ranged from 165 ppm at startup to ND in February 1996, when the system was shut down.

- On August 15, 1995, the contractor injected 4,000 gallons of nutrient solution (using a mixture of 50 lbs of fertilizer to 1,000 gallons of water) into the SVE wells. The fertilizer contained 17 lbs of ammonium nitrate per 50 lb bag of fertilizer (32% ammonium nitrate by weight).

- The remediation equipment enclosure was separated into potentially hazardous and nonhazardous areas by a wall. The air sparging equipment was installed on the nonhazardous side. The SVE system, made up of explosion-proof (Class 1, Division 2D) equipment, was installed on the hazardous side. All electrical equipment was equipped with low voltage protection. In addition, the LEL in the exhaust from the SVE system was monitored continuously, and the monitoring equipment was set to shut the system down automatically if the LEL exceeded 20 percent.

- The entire treatment system was monitored remotely. The system monitored the LEL of the SVE exhaust and the operational status of the equipment and ventilation systems in the enclosure. The equipment could be shut down automatically (or remote manually) if operating parameters were exceeded.

- The enclosure for the remediation equipment was not staffed during normal operation. Site workers wore level D personal protective equipment during the monthly monitoring events.

- For demobilization, the equipment enclosure was removed from the site, and all SVE and air sparging wells were removed and abandoned in accordance with the project specifications.

System Monitoring Requirements (5)

Media Monitored	Frequency	Parameters Monitored
Air Sparging System		
Air in sparging system	At startup, four days after startup, weekly for the first month, and once a month until the system was shut down	Sparge line pressure and air flow rate
Groundwater	Monthly	Water level in monitoring wells
Groundwater	Monthly	Benzene, toluene, ethylbenzene, and xylene (BTEX), DRO, dissolved oxygen (DO), pH, temperature, and conductivity
In Situ Bioremediation		
Groundwater	August 15 and September 28, 1995	Carbon dioxide (CO_2) and oxygen (O_2) levels
Groundwater	August 1994	Bacteria
SVE System		
Ambient air	February and August 1994	BTEX, gasoline-range organics (GRO)
Extracted vapors	At startup, four days after startup, weekly for the first month, and once a month until the system was shut down	Concentrations of organic vapor in air stream, air flow rates, vacuum at condensate tank, percent LEL

OPERATING PARAMETERS AFFECTING TREATMENT COST OR PERFORMANCE (2, 5)

Air Sparging	
Air flow rate	23 to 60 cfm
Pressure at monitoring point	2 to 5 psi
In Situ Bioremediation	
pH	6.0 to 7.0
Temperature	30 to 60°F
Microbial activity	106 colony forming units per milliliter
Oxygen uptake rate (average)	30 mg O_2/L soil gas/day
Carbon dioxide evolution (average)	20 mg CO_2/L soil gas/day
Hydrocarbon degradation (average)	Information not available
Nutrient and other amendments	Fertilizer (32% ammonium nitrate by weight)
SVE System	
Air flow rate	400 cfm (total system)
Vacuum	50" WC (measured across blower)

Closure (2,3)

- A closure report for the application was submitted to the State of Alaska in April 1997.
- According to USACE, the state of Alaska accepted the closure report for the application. For the application, USACE was required to apply the "best available technology" for a duration that would perform to the maximum extent practicable (a point of diminished returns as evidenced by a lack of contaminants in the off gas).

TREATMENT SYSTEM PERFORMANCE

- **PERFORMANCE OBJECTIVES (2)**
- The following remedial goals were specified for soil and groundwater at the Texas Tower site:

Matrix	Contaminant	Remedial Goal
Soil	Total BTEX Benzene DRO	10 mg/kg 0.10 mg/kg 100 mg/kg
Groundwater	Benzene Toluene Ethylbenzene Xylenes Hydrocarbons	0.005 mg/L 1.0 mg/L 0.70 mg/L 10.0 mg/L 0.10 mg/L

TREATMENT PERFORMANCE DATA (2)

- During closure, a total of 10 soil samples was collected from five soil borings at depths of 20 and 35 ft bgs; a split spoon sampler was used. The samples were analyzed by Superior Analytical Laboratory for the following groups of contaminants:

  — GRO by EPA Method 8015
  — BTEX by EPA Method 8020
  — DRO by EPA Method 8100-M
  — VOCs by EPA Method 8260
  — Semi volatile organic compounds (SVOCS) by EPA Method 8270

- AGRA Earth & Environmental collected groundwater samples from vapor extraction, air sparging, and groundwater monitoring wells. The samples were analyzed by Superior Analytical Laboratory for the contaminant groups listed above.
- AGRA Earth & Environmental reported that most measured values were lower than the remedial goals. Results of analysis showed that concentrations of contaminants exceeded specific remedial goals in three soil sample locations and three groundwater sample locations. In addition, two soil sample locations and one groundwater sample locations contained detectable concentrations of specific contaminants or groups of contaminants for which there were no corresponding remedial goals, referred to below as "other". The reported concentrations that

were greater than their respective remedial goals, and other closure sampling results, are provided below:

Matrix	Contaminant	Remedial Goal	Closure Sampling Results Exceeding Remedial Goals	Other Closure Sampling Results	Sample Location
Soil	Total BTEX	10 mg/kg	18.9 mg/kg	-	CB-1 (35')
	GRO	None	-	990 mg/kg	CB-1 (35')
	DRO	100 mg/kg	2,000 mg/kg	-	CB-4 (35')
	DRO	100 mg/kg	3,000 mg/kg	-	CB-4 (20')
	DRO	100 mg/kg	2,700 mg/kg	-	CB-5 (20')
	VOCs	None	-	ND	CB-5 (20')
	SVOCs	None	-	1.8 mg/kg[1]	CB-1 (35')
Groundwater	BTEX	11.705		0.0037 mg/L	VES-2
	GRO	0.10 mg/L (as hydrocarbons)	0.21 mg/L		VES-2
	VOC	None	-	0.0181 mg/L[2]	VES-2
	SVOC	None	-	0.2 mg/L[3]	VES-2
	DRO	0.10 mg/L (as hydrocarbons)	5 mg/L		VES-2
	DRO	0.10 mg/L (as hydrocarbons)	0.77 mg/L		AS-2
	DRO	0.10 mg/L (as hydrocarbons)	0.13 mg/L		MW-5

Notes:
ND Not detected
[1] 2-methyl-naphthalene detected at 1.8 mg/kg
[2] 1,3,5-trimethylbenzene detected at 0.0068 mg/L and p-isophopyltoluere detected at 0.0043 mg/L
[3] bis(2-ethylhexyl)phthalate detected at 0.20 mg/L

- No additional information about the concentrations of specific contaminants or contaminant groups in soil or groundwater at the site was provided in the references available.

- As discussed above, the State of Alaska accepted the closure report for this application. USACE performed a "mini-risk assessment" to show that the concentration of contaminants did not pose a sufficient risk to warrant additional remedical activities.

- On the basis of the quantitative results and the air flow rates for the SVE system, AGRA Earth & Environmental estimated that approximately 1,300 lbs of contaminants had been removed from the vadose zone by the SVE system. That total consisted of 829 lbs of DRO, 418 lbs of GRO, and 55 lbs of total BTEX compounds. The estimate does not include contaminants removed from the saturated or vadose zones through biodegradation.

- The highest removal rates for DRO and GRO were 5.9 lbs per day and 1.6 lbs per day, respectively.

- Although results of monitoring suggested that biological activity is present at the site, no estimate was made of the mass of hydrocarbons degraded through biological activity.

- The areal extent of the contamination was estimated to be 5,655 ft^2 before treatment and 730 ft^2 after treatment; a reduction of approximately 87 percent.

- AGRA Earth & Environmental reported that the results of analyses of soil borings indicated that, when treatment had been completed, contamination was limited to two isolated areas at the site. The first area was a zone near CB-1 approximately 15 to 20 feet thick, containing elevated concentrations of BTEX and GRO. The second area was a zone from CB-4 (approximately 15-20 feet thick) to CB-5 (approximately 20-25 feet thick). In the second zone, concentrations of DRO ranged from 2,000 to 3,000 mg/kg.

Material Balance: No information is currently available to correlate the mass of contaminants at the site before treatment with the mass after treatment. For example, no information is available to match the concentrations measured in the nine original soil borings and the five soil borings collected at closure. In addition, no information is available to correlate data from groundwater monitoring wells with data from extraction wells.

PERFORMANCE DATA QUALITY (2)

- The contractor performed monitoring activities in accordance with the ADEC UST regulations (18 AAC 78) and the requirements of the Quality Assurance Project Plan (QAPP), which had been approved by ADEC.

- USACE North Pacific Division Laboratory (NPDL) prepared a chemical quality assurance report (QAR) for the analytical data produced during the investigation.

- During the cleanup process, quality control (QC) samples were submitted to Superior Analytical Laboratory, and quality assurance (QA) samples were submitted to NPDL.

- NPDL submitted split samples to Applied Research & Development in Mt. Vernon, Illinois for analysis.

- The NPDL QA/QC report verified that all results were accurate, except the results of VOC analysis for 1,3,5-trimethylbenzene and p-isopropyltoluene in three water samples.

TREATMENT SYSTEM COST

PROCUREMENT PROCESS (5)

- The procurement process was a firm, fixed-price contract competitively solicited by request for proposals. Contractors' proposals were evaluated against technical evaluation criteria that included the contractor's qualifications, experience, and training. The contractor was selected based on consideration of a combination of technical qualifications and proposed costs.

- The contract was separated into one base item, preparation of the work plan, and two optional items, construction of the system and operation of the system. This approach was used to allow the government to cease the contract after the work plan had been prepared if the contractor submitted a poor work plan or if it was determined that the treatment process would not work.

TREATMENT SYSTEM COST (3)

- USACE identified the following proposed costs for the application:

Preparation of work plan	$33,110
Construction	$145,420
Operation	$117,230
TOTAL	**$295,760**

- No information is available comparing actual costs with proposed costs.

REGULATORY/INSTITUTIONAL ISSUES

- Cleanup criteria for the Texas Tower Site were included in the original USACE solicitation; the criteria were based on the ADEC regulations that govern remediation of USTs (18 AAC 78).

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED (5)

- The total proposed cost for the air sparging, in situ bioremediation, and SVE system at the Texas Tower Site was $295,760, including $145,420 for construction, $117,230 for operation, and $33,110 for work plan preparation.

- A unit cost of treatment of $47 per yd^3 was calculated from the total cost of $295,760 to remediate 6,300 yd^3 of in situ soil and groundwater.

- Because the site is isolated, the USACE reported that the cost of transportation of the equipment to the site and setup at the site was a significant portion of the total cost of the project.

- Costs of operation were kept low by monitoring the operation of the remediation system remotely. The system therefore could be unstaffed, except for monthly sampling events. This savings in operating costs was not quantified for this application.

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

- Over the two years during which the system operated, approximately 1,300 lbs of contaminants were removed from the vadose zone. Those contaminants consisted of 829 lbs of DRO, 418 lbs of GRO, and 55 lbs of total BTEX compounds. The estimate above does not include contaminants removed through biodegradation.

- Concentrations of contaminants in treated soil and groundwater met the remedial goals in all samples with the exception of three soil sample locations and three groundwater sample locations. Because the soil samples were from locations that had not been sampled prior to the design of the treatment system, the USACE concluded that the results suggested an additional “hotspot” outside of the original treatment area. Based on the results of a “mini-risk assessment” performed by USACE, no additional remedial activities were warranted. The State of Alaska accepted the closure report for this application.

- The operation contractor cited the following reasons, why no additional remedial activities were necessary: The leaking fuel lines that had been the source of the release had been removed; highly contaminated soil had been excavated and treated off site; no compounds for which maximum contaminant levels (MCLs) have been established had been detected at concentrations above MCLs during more than two years of monitoring; and the potential for exposure from residual hydrocarbons was negligible.

OTHER OBSERVATIONS

- USACE Alaska District operated the system remotely by a state-of-the-art monitoring and telemetry system. The USACE estimates that in situ treatment of soils was considerably less expensive than the conventional method of excavation and thermal treatment off site.

REFERENCES

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