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BASE REALIGNMENT AND CLOSURE FOCUSED FEASIBILITY STUDY AREA 2 HERNDON ANNEX WITH TRANSMITTAL LETTER NTC ORLANDO FL
11/15/1999
HARDING LAWSON ASSOCIATES

Harding Lawson Associates

November 15, 1999

Commanding Officer
Southern Division
Naval Facilities Engineering Command
ATTN: Barbara Nwokike, Code 1873
2155 Eagle Drive
Charleston, SC 29406

Subject: **Final BRAC Focused Feasibility Study**
Study Area 2, Herndon Annex
NTC Orlando, Florida
Contract No. N62467-89-D-0317/107

Dear Barbara:

Enclosed is the Final BRAC Focused Feasibility Study, Study Area 2, Herndon Annex. This document identifies and evaluates remedial alternatives for the benzene detected in the groundwater beneath Herndon Annex and the adjacent Azalea Park Neighborhood. This document also now includes the Final Natural Attenuation Monitoring Work Plan for Herndon Annex.

The Draft Natural Attenuation (NA) Monitoring Work Plan was issued on September 10, 1999. Regulator comments received have been addressed in a Response To Comments letter, and the work plan revised accordingly.

Should you have any questions or need additional information, please do not hesitate to call me at (407) 522-7570.

Sincerely,

HARDING LAWSON ASSOCIATES

John Kaiser
Program Manager

Enclosure

cc: File
Wayne Hansel, Southern Division
Nancy Rodriguez, USEPA Region IV
David Grabka, FDEP
Alan Aikens, CH2M HILL
Steve McCoy, Tetra Tech
Rick Allen (HLA)

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BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY

STUDY AREA 2

HERNDON ANNEX
NAVAL TRAINING CENTER, ORLANDO, FLORIDA

UNIT IDENTIFICATION CODE: N65928
CONTRACT NO. N62467-89-D-0317/107

NOVEMBER 1999

SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORTH CHARLESTON, SOUTH CAROLINA
29419-9010

**RESPONSE TO USEPA REGION IV COMMENTS
DRAFT NATURAL ATTENUATION MONITORING WORK PLAN
STUDY AREA 2 HERNDON ANNEX, NTC ORLANDO**

1. **Data presented in the first figure of Appendix A contradicts the statement at the bottom of page 5 that: "*In no instance was there an increase in the concentration of benzene.*" The first figure in Appendix A shows that benzene concentrations in monitoring wells OLD219C and OLD208C increased between the March, 1995 and August-November, 1997 sample events. Further, the benzene concentration in well OLD208C in December, 1998 remained higher than the concentration observed in March, 1995. In addition, Table A-1 shows that two wells (OLD220B and OLD221C) with benzene concentrations 9-10 times the MCL for benzene in December, 1998, were not sampled in previous events, so this report contains no data to support the statement that benzene concentrations are not increasing. The last sentence on page 5 should be deleted.**

   HLA concurs that this statement is confusing and will strike it from the document.

2. **The March 1995 concentration for benzene in well OLD219C is plotted on the first figure in Appendix A, but is shown as "n/a" on Table A-1. Either the table or figure should be corrected.**

   There was an error in the graph presented in Appendix 1, HLA will correct the graph.

3. **Statements on page 7 regarding HLA's conclusions about the dissolved oxygen levels are unclear. One statement says that the data in Table A-1 indicates that the aquifer beneath the site is anaerobic. Another statement reads: "*HLA concluded that the DO levels are ????? and may not be as high as detected and may not be readily available to microorganisms.*" What does "?????" mean? "*Accurate DO readings are somewhat problematic...*" Why are they problematic? Please explain how DO readings were taken.**

   EPA Guidelines for MNA Evaluations (Wiedemeier and others, 1998, p. 38, Section 2.3.2.2 Dissolved Oxygen) state "Anaerobic bacteria generally cannot function at dissolved oxygen concentrations greater than about 0.5 mg/L ..." Based on this criterion and the data presented in Table A-1, this aquifer is aerobic. What is HLA's conclusion regarding the observed dissolved oxygen levels? The work plan does not describe what will be done to acquire reliable dissolved oxygen data during future sampling events. In addition, with this levels of dissolved oxygen we should be seeing more significant reductions of benzene.

   Dissolved oxygen (DO) readings were taken using low flow sampling techniques and samples collected for analysis using flow through methods. The samples were analyzed using a colormetric method employed in the field. Sampling and analytical methods used for this program were consistent with EPA guidance and all possible measures were taken to minimize introduction of ambient oxygen into the samples prior to analysis.

   Based solely on the results from the DO analysis, the aquifer would be considered aerobic.

However upon review of other natural attenuation parameters, that include redox, methane and ferrous iron, it appears the aquifer is anaerobic. HLA recognizes the data are conflicting, but after review of all information believes anaerobic conditions are favored.

The evidence that indicates an anaerobic environment is based upon the detection of low redox values (-98mv to –205mv) in wells where benzene was present. In addition to the low redox, methane was also detected suggesting methanogenesis could be supported and both ferrous and ferric iron were detected suggesting some iron reduction would be supported. Conversely, nitrate was detected which indicates conditions may not be homogeneous since nitrate would e expected to be depleted if iron reduction or methanogenesis were the predominant conditions.

Looking at the data as a whole, HLA concludes that anaerobic conditions are predominant, but there may be aerobic pockets. HLA agrees with the statement that benzene degradation would be expected to be more rapid if oxygen was available at concentrations detected in groundwater. Benzene is degraded more slowly under anaerobic conditions, thus supporting the conclusion that subsurface conditions appear to predominantly support anaerobic processes.

In response to this comment, HLA has revised the section on page 7 and has also modified the document to recommend low flow sampling techniques.

4. **The text on page 5 states "The site screening data are consistent with a benzene plume that has migrated onto Herndon Annex and whose source is depleted." The data presented in Appendix A indicate that benzene concentrations are stable in well OLD208C (page 6) and decreasing slowly in other monitoring wells, despite relatively high dissolved oxygen concentrations in the aquifer (Table A-1). The stable or slow decrease in benzene concentrations in an aerobic aquifer does not appear to be consistent with a depleted source.**

Referring to our response to comment 3, the overall data would support a conclusion that the aquifer is predominantly anaerobic; and under anaerobic conditions we would expect to see slow degradation of benzene. Therefore observations are consistent with the depleted source. Furthermore, if there were an ongoing source, one would expect to see much higher concentrations of benzene plus the presence of other constituents.

5. **Section 1.3.2 describes a BIOSCREEN model for the site. The estimated half-life for benzene is based on the "historical data" from well OLD210C. However, the data presented in Appendix A indicate that the behavior of the benzene concentration in well OLD210C is unusual relative to the other wells at the site. For example, the first figure in Appendix A shows that in 1995 the concentration in well OLD210C was similar to the concentration in the other wells. By the end of 1998, the concentration in well OLD210C was "non-detect", while the concentrations in the other wells remained similar to the results obtained 4 years earlier in 1995. The data from well OLD210C is not the most appropriate data to use for input to a groundwater model.**

EPA did not evaluate any other aspects of the BIOSCREEN model, however, if the estimated time for monitored natural attenuation (MNA) to reduce benzene concentrations across the site to the MCL is 30 years (page 10) based on the results from well OLD210C, the estimated

time for clean-up may be under-estimated.

Seasonal effects on benzene concentrations in groundwater have not been evaluated at this site. The data regarding longer-term trends in benzene concentrations are inconsistent or not indicative of effective reductions in concentration by natural attenuation. The data presented in this report appear to be insufficient for determination of a site-specific degradation rate, so clean-up time estimates can not be made from site-specific data.

It is always more valuable to utilize site data to estimate biodegradation rates than to rely upon literature values which (1) have no bearing on the site being evaluated and (2) usually cover such a wide range of values that it would be difficult to determine what value should be used. HLA understands that more data is needed to develop a reliable model and has recommended that more data be collected. However, HLA believes that it was appropriate to use the data from well OLD210C to estimate the biodegradation rate to develop a preliminary model for estimating purposes. This well had the longest data history and is indicative of what may be occurring in the groundwater plume. The model was fit to benzene results that had been observed along the flowpath. HLA understands this is a starting point and will modify the model as more data becomes available.

6. **The groundwater sampling plan (page 12) indicates that after the first 4 years of natural attenuation monitoring, monitoring will continue on an annual basis for the remaining 26 years which are estimated to be required for monitored natural attenuation (MNA) to be completed. Once the progresses of MNA is documented using the early years of data, a case could be made the sample frequency could be diminished because MNA is a process which proceeds without human intervention. It may be possible to reduce the long-term sampling, analysis and reporting expenses once good base line data is available. A proposal should be made in estimates of future costs for this project which allow for diminished sampling, <u>if</u> the base line data show that contaminant concentrations are decreasing as predicted <u>and if</u> land-use and other relevant conditions in the area remain unchanged.**

HLA concurs with this comment and has made this assumption within the costing of the applicable remedial alternatives in the Final Focused Feasibility Study.

<u>REFERENCES</u>

USEPA, 1996, Region 4, Science and Ecosystem Support Division, Environmental Investigations Standard Operating Procedures and Quality Assurance Manual, May 1996.

Wiedemeier, T.H., M.A. Swanson, D.E. Moutoux, E.K. Gordon, J.T. Wilson, B.H. Wilson, D.H. Kampbell, P.E. Haas, R.N. Miller, J.E. Hansen, F.H. Chapelle, 1998, TECHNICAL PROTOCOL FOR EVALUATING NATURAL ATTENUATION OF CHLORINATED SOLVENTS IN GROUND WATER, USEPA Office of Research and Development, Washington DC 20460, EPA/600/R-98/128, September 1998 <u>(http://www.epa.gov/ada/report.html).</u>

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY

STUDY AREA 2, HERNDON ANNEX

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

November 1999

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY

STUDY AREA 2, HERNDON ANNEX

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

Unit Identification Code: N65928
Contract No. N62467-89-D-0317/107

Prepared by:

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Prepared for:

Department of the Navy, Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
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Barbara Nwokike, Code 1873, Engineer-in-Charge

November 1999

CERTIFICATION OF TECHNICAL DATA CONFORMITY (MAY 1987)

The Contractor, Harding Lawson Associates, hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0317/107 are complete and accurate and comply with all requirements of this contract.

DATE: November 15, 1999

NAME AND TITLE OF CERTIFYING OFFICIAL: John Kaiser
Task Order Manager

NAME AND TITLE OF CERTIFYING OFFICIAL: Richard Allen
Project Technical Lead

(DFAR 252.227-7036)

The engineering evaluations and professional opinions rendered in this planning document that describes the Feasibility Study for Herndon Annex, Study Area 2, Naval Training Center, Orlando, Florida, were conducted or developed in accordance with commonly accepted procedures consistent with applicable standards of practice. This document is not intended to be used for construction of the selected alternatives.

HARDING LAWSON ASSOCIATES
2590 Executive Center Circle East
Tallahassee, Florida 32301

Willard R. Murray, Ph.D.
Professional Engineer No. 39866
Expires February 28, 2001

Date: 11/15/99

EXECUTIVE SUMMARY

This Focused Feasibility Study (FFS) addresses benzene-contaminated groundwater detected beneath the Herndon Annex and the adjacent Azalea Park Neighborhood at the Naval Training Center (NTC), Orlando, Florida. This report includes a summary of the environmental site screening conducted by Harding Lawson Associates (HLA), on behalf of the Naval Facilities Engineering Command, Southern Division, evaluation of natural attenuation and a recommended monitoring work plan, identification and screening of remedial technologies, and development and evaluation of remedial alternatives. This report concludes with a comparative analysis of the remedial alternatives to support the Orlando Partnering Team's (OPT) selection of the final site remedy.

Environmental Site Screening: HLA (formerly ABB Environmental Services, Inc. [ABB-ES]), conducted a site screening study at the Herndon Annex between 1994 and 1997 (HLA, 1999b). This investigation was conducted in four distinct phases, with the intent of locating and identifying any compounds that may be present at concentrations in excess of environmental screening criteria (e.g., drinking water standards). The Phase I field investigation found no contamination exceeding screening criteria in either soil or groundwater; however, geophysical investigations identified potential past landfilling activities onsite indicating the need for additional investigation.

The Phase II investigation discovered the presence of benzene in exceedance of the state maximum contaminant level (MCL) of 1 microgram per liter (ug/L). A supplemental Phase II investigation was then conducted to identify the source of benzene contamination. This investigation indicated that an upgradient source may have existed, including a potential fuel and/or chlorinated solvent source at a former firefighter training area that allegedly operated from 1947 to 1962, but not specific source for the benzene contamination was found. Additional releases from Herndon Annex could not be discounted.

Subsequently, HLA conducted a Phase III investigation to better define the location and depth of benzene contamination in the groundwater. Benzene continued to be the dominant compound detected in the groundwater, particularly along the eastern boundary of Herndon Annex. The low number of positive detections above 40 feet below land surface (bls) would seem to limit the likelihood of a surface release on Herndon Annex.

Due to the presence of benzene above the state MCL along the eastern property boundary of Herndon Annex, a Phase IV investigation was conducted. This last investigation focused on additional mapping of the benzene plume in the deep surficial aquifer, including the extension of the groundwater investigation into Azalea Park, east of Herndon Annex. This investigation also included the sampling of surface water in Lake Barton and a natural attenuation (NA) evaluation of the benzene plume.

These four site investigations confirmed that a benzene plume was present under Herndon Annex with a maximum concentration of 83 ug/L, and under the Azalea Park Neighborhood with a maximum concentration of 53.5 ug/L. These benzene concentrations were based on the installation and sampling of groundwater monitoring wells. Most of the groundwater plume exceeding the benzene MCL on Herndon Annex is located in the southeastern portion of the site and in the western portion of the Azalea Park Neighborhood near the drainage ditch. However, a small groundwater plume was detected in the northeast corner of Herndon Annex near the intersection of the drainage ditch and Lake Barton.

Evaluation of Natural Attenuation: NA was identified as a potential remedy for groundwater at Study Area 2. Subsequently, HLA prepared a Natural Attenuation Monitoring Work Plan (Appendix A) to estimate the rate of natural degradation of benzene at the site. In general, the Phase IV data support a conclusion of anaerobic biodegradation of the benzene in groundwater at Study Area 2. Based on the observed decreasing trends of the benzene plume and the presence of biological activity in the subsurface, it is likely that biodegradation is responsible for attenuation of the benzene plume. However, since the predominant conditions appear to be anaerobic, specifically sulfate reducing and methanogenic, rates of benzene biodegradation would be relatively slow compared to rates that would be expected under aerobic conditions.

Based on a review of the Phase IV NA data trends, the benzene concentrations are stable in one well (OLD0208C) and in the other three wells for which there is history, benzene concentrations are beginning to decrease. However, additional data are needed to confirm these apparent trends. Overall, benzene levels appear to be either stable or decreasing and there is no evidence to suggest the plume will expand beyond current boundaries.

The results from analyzing the decreasing trends indicate that approximately 30 years are required to achieve the MCL for benzene across the entire site. This estimate of the cleanup time should be verified as more data are collected. The work plan presented in Appendix A describes the proposed sampling and analysis program for groundwater at Study Area 2 to support this ongoing NA evaluation.

Summary of Herndon Annex Remedial Technology Identification: Based on the detection of benzene exceeding the state MCL, HLA prepared a brief memorandum identifying potential remedial technologies to address the benzene plume beneath Herndon Annex and the Azalea Park Neighborhood (HLA, 1999a). The preliminary identification of treatment technologies included:

- No Action
- Natural Attenuation (NA)
- Hydraulic Containment
- Permeable Reactive Wall
- Enhanced Bioremediation
- Air Sparging and Soil Vapor Extraction (AS/SVE)
- Pump and Treat, and
- Excavation/Clearing of Drainage Ditch with Aeration

To support the selection of a final remedy for the study area, HLA prepared this FFS to screen the preliminary list of treatment technologies, develop a short list of remedial alternatives and evaluate these alternatives in accordance with U.S. Environmental Protection Agency (USEPA) guidance (USEPA, 1988). The state and federal MCL of 1 ug/L for benzene was used as the cleanup goal for the evaluation of remedial alternatives within this FFS.

Preliminary Screening of Remedial Technologies and Development of Remedial Alternatives: The primary goal for remediating the site groundwater is to restore the aquifer to beneficial use by reducing the toxicity, mobility and/or volume of benzene contamination. HLA conducted a limited screening of remedial technologies to be used for the development of remedial alternatives that can accomplish this goal. In accordance with the National Contingency Plan (NCP, 1990), a range of remedial alternatives was developed, including the No Action alternative.

Table ES-1 presents the preliminary screening of remedial technologies. This screening results in the elimination of AS/SVE, permeable reactive wall, ex-situ organic adsorption using GAC (pump and treat) and expansion/clearing of the drainage ditch with aeration of surface water. However, the No Action, NA, enhanced bioremediation and ex-situ air stripping technologies were retained for the development of remedial alternatives. The No Action, NA and enhanced bioremediation technologies were retained as stand-alone remedial alternatives, while ex-situ air stripping was retained in combination with enhanced bioremediation, as follows:

- Alternative No. 1 - No action
- Alternative No. 2 - Natural attenuation (NA)
- Alternative No. 3 – Enhanced Bioremediation (ORC slurry injection) and,
- Alternative No. 4 - Enhanced bioremediation (solid phase ORC) with ex-situ air stripping

The No Action alternative (No. 1) was retained in accordance with the NCP to provide a baseline comparison to the three remaining remedial alternatives. Under the No Action alternative, no remedial action would be conducted at either Herndon Annex or the Azalea Park Neighborhood. This alternative ultimately relies on the ongoing NA of the contaminants, but does not include groundwater monitoring to determine if the plume is stable (vertically or horizontally) or confirm the rate of natural degradation. This alternative would also not include the implementation of groundwater use restrictions to eliminate the consumption of contaminated groundwater and installation of additional wells until the cleanup goal for benzene has been achieved.

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Table ES-1
Screening of Remedial Technologies for Groundwater

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Representative Technology	Effectiveness	Implementability	Cost	Recommendation
No Action				
No action	Relies on natural attenuation without monitoring to confirm reduction in toxicity and volume of contaminants.	Readily implemented.	Low	Retained
In Situ Treatment				
Air Sparging with Vapor Collection	Proven effective to remove VOCs. Site lithology and depth of contamination may limit effectiveness. Capture of generated vapors required. Injection of air at low flow rate (Biosparging) to enhance biodegradation rate; proven effective for benzene.	Depth of contamination greatly complicates system installation. Large plume will require excessive number of air sparging points and large soil vapor extraction system. Biosparging easily implemented, but requires large number of injection points. Also concerned with bio fouling.	High	Eliminated
Natural Attenuation	Natural biodegradation of benzene has been observed at the site.	Requires long term system monitoring.	Low	Retained
Enhanced Bioremediation	Site data suggest biodegradation occurring. Anaerobic conditions could be enhanced to expedite degradation rates.	Oxygen release compound readily available and easily installed inside groundwater wells or injected using direct push technology.	Medium	Retained
Permeable Reactive Wall	Patented technology. Proven in laboratory tests with only limited full-scale field experience. Questionable effectiveness on benzene.	Requires fate, transport and hydraulic modeling. Large plume will require extensive length and depth of reactive wall. Requires bench-scale column tests for optimum design. Soil excavated to construct wall may require separate management. Precipitates may form on reactive materials, limiting hydraulic lifetime of wall and requiring flushing of wall.	High	Eliminated

See notes at end of table.

Table ES-1 (Continued)
Screening of Remedial Technologies for Groundwater

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Representative Technology	Effectiveness	Implementability	Cost	Recommendation
Permeable Reactive Wall (Continued)		Integrity of permeable reactive wall and hydraulic barrier must be evaluated periodically to maintain optimum groundwater treatment.		
Ex Situ Treatment				
Air Stripping	Proven technology to remove VOCs.	May require off-gas treatment and monitoring.	High	Eliminated*
Organic Adsorption (granular activated carbon)	Proven technology to remove VOCs.	Spent carbon must be regenerated or disposed of.	High	Eliminated
Excavation of Drainage Ditch with Surface Water Aeration	Aeration effective on benzene. Limited effectiveness on containing contaminant plume.	Extensive excavation of drainage ditch (> 1,000 linear feet of ditch). Construction would temporarily impact stormwater management collection/discharge into Lake Barton. Dewatering of construction area difficult.	High	Eliminated

* Eliminated as stand-alone remedial technology, but retained when used in combination with enhanced bioremediation.

Notes: VOCs = volatile organic compounds.

The NA remedial alternative (No. 2) provides a passive, in-situ remedial alternative to reduce the benzene concentrations to the state MCL. The site screening data indicates that natural biodegradation is occurring on a limited basis as the plume moves towards Lake Barton. This alternative would also include the monitoring of the natural degradation processes to ensure the complete degradation of the groundwater plume to the MCL and to monitor the migration of the residual plume until it reaches this goal. Due to the treatment duration required to achieve the MCL for benzene, groundwater use restrictions/advisories would be implemented on Herndon Annex and within the affected areas of Azalea Park.

Enhanced biodegradation of groundwater is a process that would increase the rate of natural bacterial degradation of organic contaminants using an oxygen release compound (ORC). Remedial alternative No. 3 would rely on the injection of an ORC slurry mix by direct push technology (DPT) to maximize the amount of dissolved oxygen entering the groundwater plume during a single injection event. A total of 83 DPT probes would be installed throughout Herndon Annex and the Azalea Park Neighborhood to address the benzene contamination exceeding 10 ug/L. NA would be required to reduce the residual contamination below 10 ug/L as it is too low a concentration for ORC to be effective. This remedial alternative would require groundwater monitoring to support the evaluation of enhanced bioremediation, including the effectiveness of the ORC slurry, location of injection points and rate of degradation to achieve the state MCL of 1 ug/L.

The last remedial alternative (No. 4) involves the combination of enhanced bioremediaton with ex-situ air stripping as an aggressive response to reduce the duration required to meet the cleanup goal for benzene while providing hydraulic containment of the groundwater plume. The process flow for this alternative would include groundwater extraction, treatment via a shallow-tray air stripper, and reinjection into wells containing solid ORC. The hydraulic containment of the benzene plume would also eliminate the discharge of contaminated groundwater into the drainage ditch, subsequently discharging into Lake Barton.

Evaluation and Comparison of Remedial Alternatives: The evaluation and comparison of remedial alternatives was performed to provide the OPT with sufficient information to select the appropriate remedial alternative and has been conducted in accordance with Comprehensive Environmental Response, Compensation, and Liabilities Act (CERCLA) Section 121, the NCP (NCP, 1990) and USEPA Remedial Investigation/Feasibility Study (RI/FS) guidance (USEPA, 1988). This detailed evaluation of the remedial alternatives includes an analysis of the alternatives against three primary CERCLA criteria: effectiveness, implementability and cost and is summarized in Table ES-2.

The effectiveness criteria involve the magnitude of residual risk following remediation and the adequacy and reliability of system controls. Implementability includes the ability to construct the remedial alternative, reliability of the technology, ease of implementing the alternative and coordination with regulatory agencies. The last evaluation criteria, cost, includes capital and O&M costs, and the total present worth of the remedial alternative. These cost estimates have been prepared based on previous feasibility studies and remedial actions, and vendor information, and should be accurate within +50 percent to –30 percent, in accordance with USEPA guidance (USEPA, 1988).

As presented in Chapter 3.0 of this FFS, remedial alternatives were developed to accomplish the remedial goal of 1 ug/L for the benzene-contaminated groundwater beneath both Herndon Annex and the adjacent Azalea Park neighborhood. In addition, these remedial alternatives focused on the elimination or reduction of exposure by humans to the contaminated groundwater, and emphasized the use of treatment technologies to reduce the toxicity, mobility or volume of constituents rather than technologies that solely prevent exposure.

Remedial alternatives evaluated for their effectiveness, implementability and cost include:

- Alternative No. 1 - No action
- Alternative No. 2 - Natural attenuation (NA)
- Alternative No. 3 - Enhanced Bioremediation (ORC slurry injection) and,
- Alternative No. 4 - Enhanced bioremediation (solid phase ORC) with ex-situ air stripping

Table ES-2
Summary of Comparative Analysis for Remedial Alternatives

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Alternative:	No. 1 No Action	No. 2 Natural Attenuation	No. 3 Enhanced Bioremediation	No. 4 Enhanced Bioremediation with Ex-situ Air Stripping
Groundwater Remediation				
Groundwater extracted?	No	No	No	Yes
Organics reduced?	Unknown	Yes	Yes	Yes
Estimated time to achieve drinking water standards (years):	Indefinite	30	5[1]	5[1]
Plume contained?	No	No	No	Yes
Remedy permanent?	Unknown	Yes	Yes	Yes
MCL attained?	Unknown	Yes	Yes	Yes
Reliability to achieve MCL?	Low	Medium	Medium	High
Residuals produced?	No	No	No	No[2]
Operation and Maintenance				
Treatment O&M Duration (yrs)	+30	30	4[1]	7[1]
Utilities Maintenance	No	No	No	Yes
Groundwater Monitoring	No	Yes	Yes	Yes
Total Cost				
Present Worth	$52,800	$460,200	$399,500	$1,612,200
Capital	$0	$16,500	$189,700	$780,300

[1] Plume >10 ug/L treated to MCL within 4 years while fringe area to achieve MCL in 5 years.
[2] Estimated air emissions meet FDEP air regulations without further treatment (Appendix C).

Notes: MCL = maximum contaminant level.
O&M = operation and maintenance.

Following the detailed evaluation of the individual remedial alternatives, a comparison of the remedial alternatives was conducted to provide technical information for the selection of the preferred alternative. Table ES-2 summarizes the evaluations for the effectiveness, implementability and cost criteria.

Effectiveness: The No Action alternative would not provide any additional treatment of the benzene, or prevent possible human exposure or consumption of contaminated groundwater. Therefore, a significant residual risk would continue at the site. The No Action approach would ultimately rely on NA (without monitoring) to address the benzene contamination and protect the public from adverse contact with the contaminated groundwater. The reliability of unmonitored NA would be low.

Alternative No. 2, monitored NA, would have greater reliability based on the monitored reduction of benzene in the groundwater plume and implementation of groundwater use restrictions until the State MCL for benzene is achieved. The observed rate of benzene reduction (Appendix A) would meet the remedial action objective while eliminating potentially adverse exposure scenarios to the public (e.g., drinking water supply).

Under Alternative No. 3, the injection of an ORC slurry into the groundwater plumes would enhance the existing NA of the benzene contamination. ORC has been found to be very effective on fuel-related compounds and the delivery method of DPT has already been successfully demonstrated to the required depths at Herndon Annex and the Azalea Park Neighborhood. This remedial alternative would require a single application of the ORC slurry in conjunction with groundwater monitoring for a period of 5 years. This would expedite the natural degradation of benzene and achieve the cleanup goal of 1 ug/L in the shortest period of time. Continued groundwater monitoring and a five-year site review would ensure that this remedial approach would achieve the cleanup goal. Groundwater use restrictions would be used to protect the public from any adverse exposure to the contaminated groundwater until it was remediated to the MCL.

Under Alternative No. 4, the use of ORC (solid phase) and ex-situ air stripping to individually treat benzene-contaminated groundwater is well proven. Based on the estimated groundwater extraction rates and the low concentration of benzene detected in the groundwater, a shallow-tray air stripper would readily transfer the benzene contamination from the dissolved phase into the air stream. The benzene concentrations within the air stream were calculated to be less than 0.5 pounds per day (Appendix C), such that off-gas treatment would not be required. The associated increase in dissolved oxygen from the ORC can increase the rate of benzene biodegradation by one to two orders of magnitude further reducing the duration to meet the cleanup goal for the site. This remedial alternative would reduce the toxicity, mobility and volume of benzene contamination detected in the groundwater. Continued groundwater monitoring and a five-year site review would ensure that this remedial approach would prevent human exposure or consumption of contaminated groundwater. Groundwater use restrictions would also be used to protect the public from any adverse exposure to the contaminated groundwater until it met the MCL.

Alternative No. 4 is the only remedial alternative that would provide hydraulic containment of the groundwater plumes during remediation and has the same estimated duration to achieve the MCL as Alternative No. 3 (5 years). However, this alternative provides a greater reliability than Alternative No. 3, Enhanced Bioremediation, due to the ex-situ treatment of contaminated groundwater and amendment of treated groundwater within a hydraulically contained treatment area.

Implementability: Under the first alternative, No Action, the implementation of five-year site reviews could readily be implemented at Herndon Annex and the Azalea Park Neighborhood. However, there would be no assurance that human exposure to the contaminated groundwater would be eliminated. This alternative would solely rely on the monitoring of Study Area 2 every five years to identify any potential change in site conditions and new exposure pathways. Remedial Alternative No. 2, NA, would include the monitoring of the groundwater quality and benzene degradation to achieve the MCL, and the implementation of groundwater use restrictions/advisories to protect the public from adverse exposure scenarios. Both the groundwater monitoring and groundwater use restrictions could be readily implemented at the site.

A full-scale enhanced bioremediation response action (Remedial Alternative No. 3) could readily be implemented at both the Herndon Annex and Azalea Park Neighborhood using a DPT delivery system for the ORC slurry. The DPT delivery of the ORC slurry has been successfully implemented at sites throughout the country. DPT has also been successfully demonstrated at Herndon Annex during the site investigation of the groundwater plume. The use of

DPT would eliminate the need to install and abandon a large number of injection wells throughout the Annex and adjacent residential area. Groundwater monitoring and a five-year site review would support a single ORC injection event to ensure that the groundwater quality ultimately met the MCL for benzene.

Remedial Alternative No. 4 could readily be constructed at both Herndon Annex and the Azalea Park Neighborhood. The necessary utilities and site access are available on Herndon Annex where the bulk of the system would be constructed. The extraction/reinjection well configurations would address both the southern and northern groundwater plumes.. The air strippers would be located on Herndon Annex to avoid any potential adverse impacts to the Azalea Park area from low level emissions and O&M of the groundwater treatment systems. In addition, air strippers have been widely used for the treatment of VOCs, and enhanced bioremediation is a reliable supplement to expedite the degradation of the groundwater plume

Although this alternative would be the most reliable (ex-situ treatment, amendment of treated groundwater and hydraulic containment of the groundwater plume), it would also be the most difficult to permit and construct. This is due to the permitting for the reinjection of treated groundwater, and the installation of an extensive network of piping from the seven groundwater extraction wells and the return pipes for the reinjection of treated groundwater into the eight reinjection wells containing ORC.

Cost: The last evaluation criteria, cost, includes capital and O&M costs and the total present worth of the remedial alternative. Present worth costs have been calculated using an interest rate of 6% and include a 10% contingency due to remaining design and regulatory details to be determined.

The present worth for Remedial Alternative No. 1, No Action, is estimated to be $52,800. There are no capital costs associated with this alternative, only five-year site reviews with an assumed duration of 30 years. The capital cost for the second remedial alternative, NA, is approximately $16,500 and has a total present worth of $460,200. The capital costs are limited to the preparation of groundwater use restrictions, while the O&M costs include the implementation of the groundwater monitoring plan, and five-year site reviews. HLA estimated that the NA process would also require approximately 30 years to achieve the state MCL for benzene in groundwater.

The capital cost for Remedial Alternative No. 3 is approximately $189,700 and has a total present worth of $399,500. HLA estimated that this enhancement of natural attenuation to remediate the benzene-contaminated groundwater would achieve the MCL for benzene in approximately 5 years.

The capital cost for Remedial Alternative No. 4 is approximately $780,300 and has a total present worth of $1,612,200. This is the most costly of the four remedial alternatives, but the most reliable and aggressive in achieving the cleanup goal for the site while providing hydraulic containment of the benzene-contaminated groundwater. The MCL would be achieved in approximately 5 years, similar to Alternative No. 3. Capital costs include the design, permitting and construction of the air strippers and enhanced bioremediation systems. O&M costs are also significant due to the monitoring requirements of the ex-situ treatment system and the reinjection of groundwater to provide enhanced bioremediation, along with hydraulic containment of the groundwater plume. The treatment system would be operated for 4 years to address the plume exceeding 10 ug/L of benzene and one additional year of monitored NA to address the fringe area of the benzene plume (< 10 ug/L).

Summary of Remedial Alternative Evaluation: Table ES-2 summarizes the evaluation conclusions for convenient comparison between the different alternatives. The No Action alternative was retained in accordance with the NCP, while the NA alternative (Remedial Alternative No. 2) offers a passive and low cost alternative to remediate the benzene plume, but with less assurance of achieving the MCL and has a long estimated duration of 30 years. Remedial Alternative No. 3, Enhanced Bioremediation, would expedite the natural degradation of the benzene plumes to achieve the MCL in the shortest time frame (5 years) and with a relatively small present worth cost. The last remedial alternative, Enhanced Bioremediation with Ex-situ Air Stripping, would satisfy all of the evaluation criteria, and an estimated short treatment duration (5 years) while providing hydraulic containment of the benzene plumes. However, this last remedial alternative also has the highest estimated cost.

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LIST OF ACRONYMS

ABB-ES	ABB Environmental Services, Inc.
AS/SVE	Air Sparging and Soil Vapor Extraction
AST	aboveground storage tank
bls	below land surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CPT	cone penetrometer testing
DPT	direct push technology
FDEP	Florida Department of Environmental Protection
FFS	Focused Feasibility Study
GAC	granular activated carbon
gpm	gallons per minute
HLA	Harding Lawson Associates
MCL	maximum contaminant level
ug/L	micrograms per liter
NA	natural attenuation
NCP	National Contingency Plan
NTC	Naval Training Center
O&M	operation and maintenance
OPT	Orlando Partnering Team
ORC	oxygen release compound
PCE	tetrachloroethene
PVC	polyvinyl chloride
RI/FS	remedial investigation/feasibility study
TCE	tetrachloroethene
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound

1.0 INTRODUCTION

This Focused Feasibility Study (FFS) addresses benzene-contaminated groundwater detected beneath the Herndon Annex and the adjacent Azalea Park Neighborhood at the Naval Training Center (NTC), Orlando, Florida (Figures 1-1 and 1-2). This report was prepared under the Comprehensive Long-Term Environmental Action, Navy Contract No. N62467-89-D-0317, Contract Task Order No. 107.

1.1 ENVIRONMENTAL SITE SCREENING.

Harding Lawson Associates (HLA, formerly ABB Environmental Services, Inc. [ABB-ES]), conducted a site screening study at the Herndon Annex between 1994 and 1997. This investigation was conducted in four distinct phases, with the intent of locating and identifying any compounds that may be present at concentrations in excess of environmental screening criteria (e.g., drinking water standards). The Phase I field investigation found no contamination exceeding screening criteria in either soil or groundwater; however, geophysical investigations identified potential past landfilling activities onsite indicating the need for additional investigation.

The Phase II investigation discovered the presence of benzene in exceedance of state and federal maximum contaminant levels (MCLs) 1 microgram per liter (ug/L) and 5 ug/L, respectively. Other chlorinated compounds were detected in the groundwater, but their occurrences were less consistent than the benzene and their concentrations did not indicate wide spread contamination. A supplemental Phase II investigation was then conducted to identify the source of benzene contamination. This investigation indicated that an upgradient source may have existed, including a potential fuel and/or chlorinated solvent source at a former firefighter training area that allegedly operated from 1947 to 1962, but no specific source of benzene contamination was found. Additional releases from Herndon Annex could not be discounted.

Subsequently, HLA conducted a Phase III investigation to better define the location and depth of benzene contamination in the groundwater. In addition to benzene, volatile organic compounds (VOCs) were detected in the site groundwater, but all were below their MCL and the Florida Department of Environmental Protection (FDEP) groundwater cleanup target levels (Chapter 62-777 FAC). Benzene continued to be the dominant compound detected in the groundwater, particularly along the eastern boundary of Herndon Annex. The low number of positive detections at depths less than 40 feet below land surface (bls) would seem to limit the likelihood of a surface release on Herndon Annex. Two potential sources on the base were both removed prior to these investigations, including an aboveground storage tank (AST) at Building 602 and an underground storage tank (UST) at Building 607 in 1995. The AST was approved for clean closure and did not require any soil remediation, while the UST did require a limited removal of contaminated soil (ABB-ES, 1995 and 1996). However, groundwater contamination found in these areas was limited to depths greater than 40 feet bls, indicating that these sites were not a likely source.

Due to the presence of benzene above the state MCL along the eastern property boundary of Herndon Annex, a Phase IV investigation was conducted. This last investigation focused on additional mapping of the benzene plume in the deep surficial aquifer, including the extension of the groundwater investigation into Azalea Park, east of Herndon Annex. This included the sampling of surface water in Lake Barton, installation of new piezometers, groundwater sampling of new and existing wells and a natural attenuation (NA) evaluation of the benzene. The results of this investigation, along with the three previous groundwater investigations, are presented in the Base Realignment and Closure Environmental Site Screening Report (HLA, 1999b) and are summarized below.

These four site investigations confirmed that a benzene plume was present under Herndon Annex with concentrations as high as 200 micrograms per liter (ug/L), and under the Azalea Park Neighborhood with a maximum concentration of 110 ug/L. These benzene concentrations were based on cone penetrometer testing (CPT) methods. Based on the installation of groundwater monitoring wells to confirm these benzene detections, the maximum concentration detected was actually 83 ug/L on Herndon Annex and 53.5 ug/L in the Azalea Park Neighborhood. Figures 1-3 through 1-6 present the isoconcentration contours for benzene and individual contaminant detections at each of the wells based on the CPT data. The footprint of the plume at depths greater than 50 feet bls is more than 50 acres. Most of the groundwater plume exceeding the benzene MCL on Herndon Annex

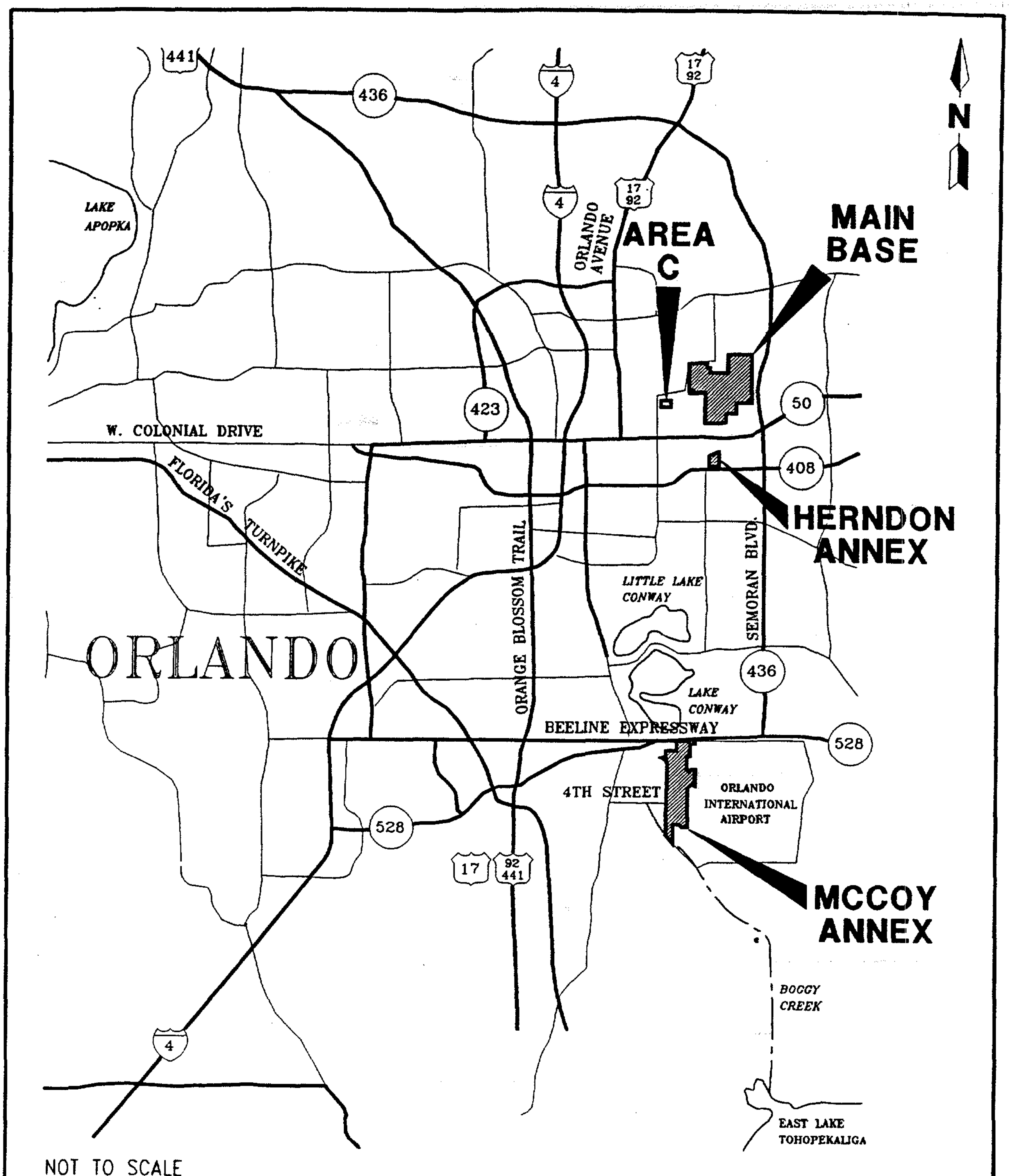

FIGURE 1-1
LOCATION OF NAVAL TRAINING CENTER, ORLANDO, FLORIDA

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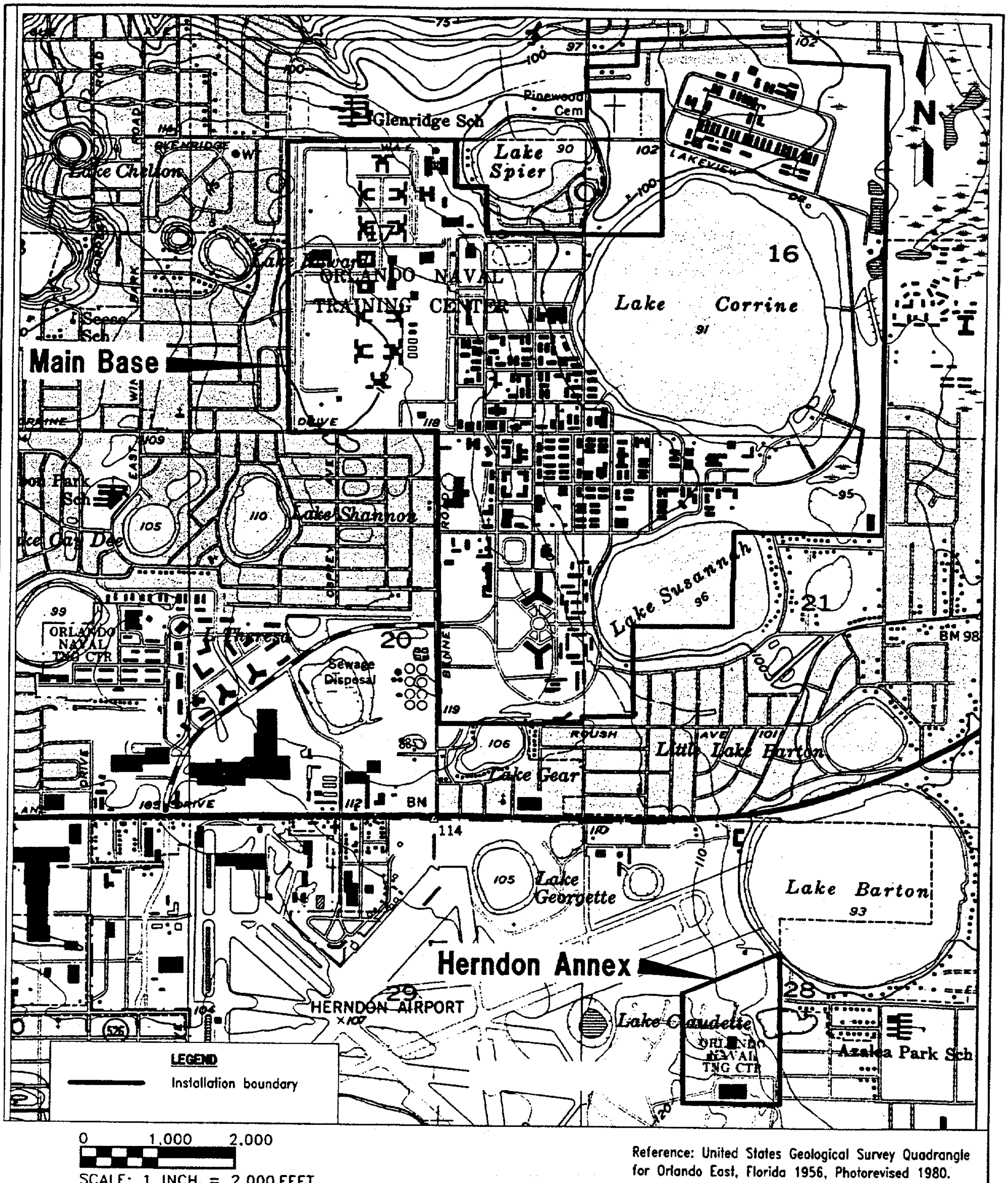
BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA



Reference: United States Geological Survey Quadrangle for Orlando East, Florida 1956, Photorevised 1980.

FIGURE 1-2
SITE LOCATION MAP
MAIN BASE AND HERNDON ANNEX

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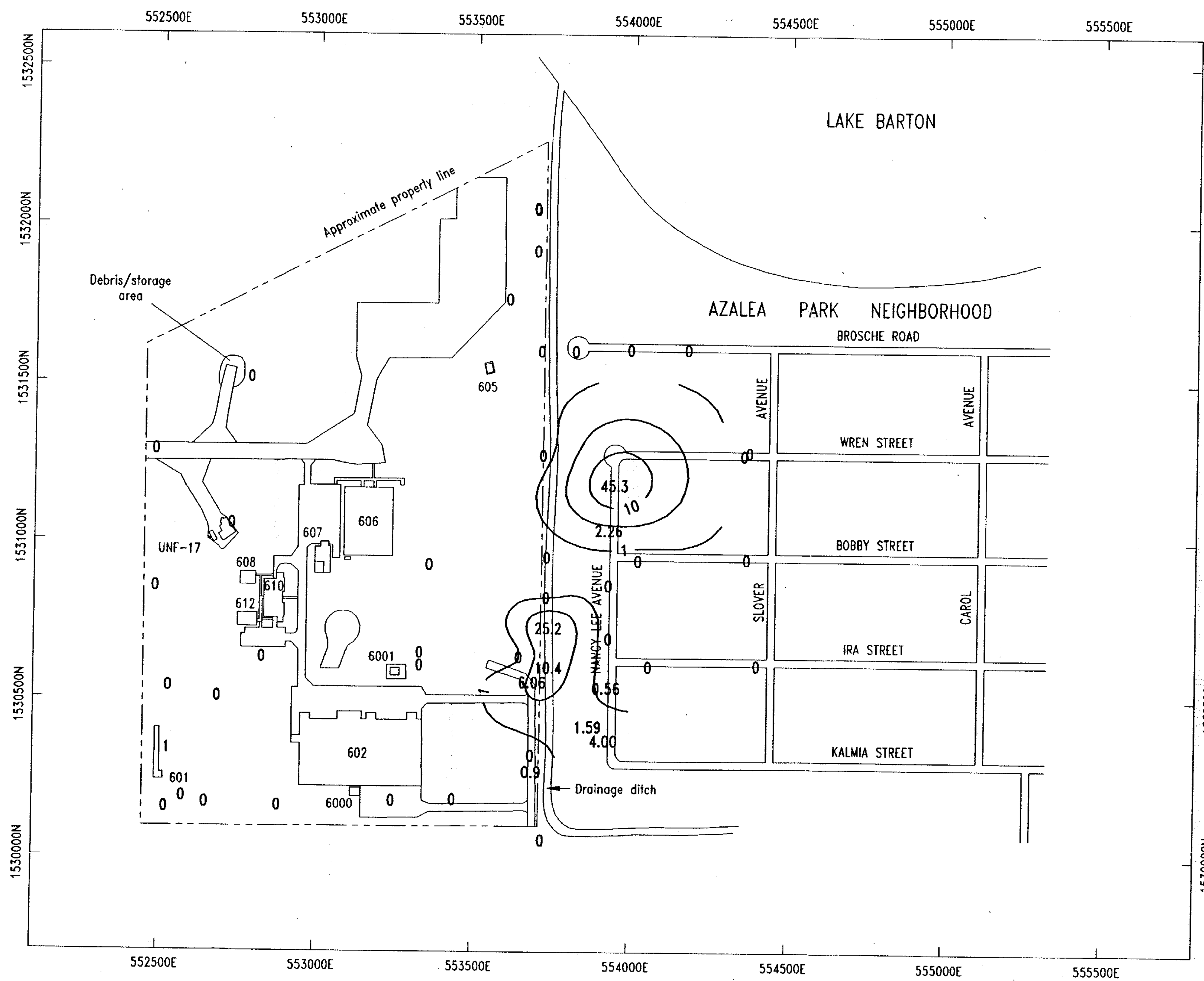
BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA



LEGEND

10	Benzene concentration contour
45.3	Benzene concentration from direct-push technology
DPT	Direct-push technology
NAD	North American Datum
MCL	Maximum contaminant level

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

Concentrations are in micrograms per liter (parts per billion).

Contours shown are two per decade (i.e., 1, 3.16, 10, 31.6, 100).

FIGURE 1-3
BENZENE MCL EXCEEDANCES IN GROUNDWATER IN THE DEPTH RANGE 0 TO 30 FEET BELOW LAND SURFACE, DPT SCREENING

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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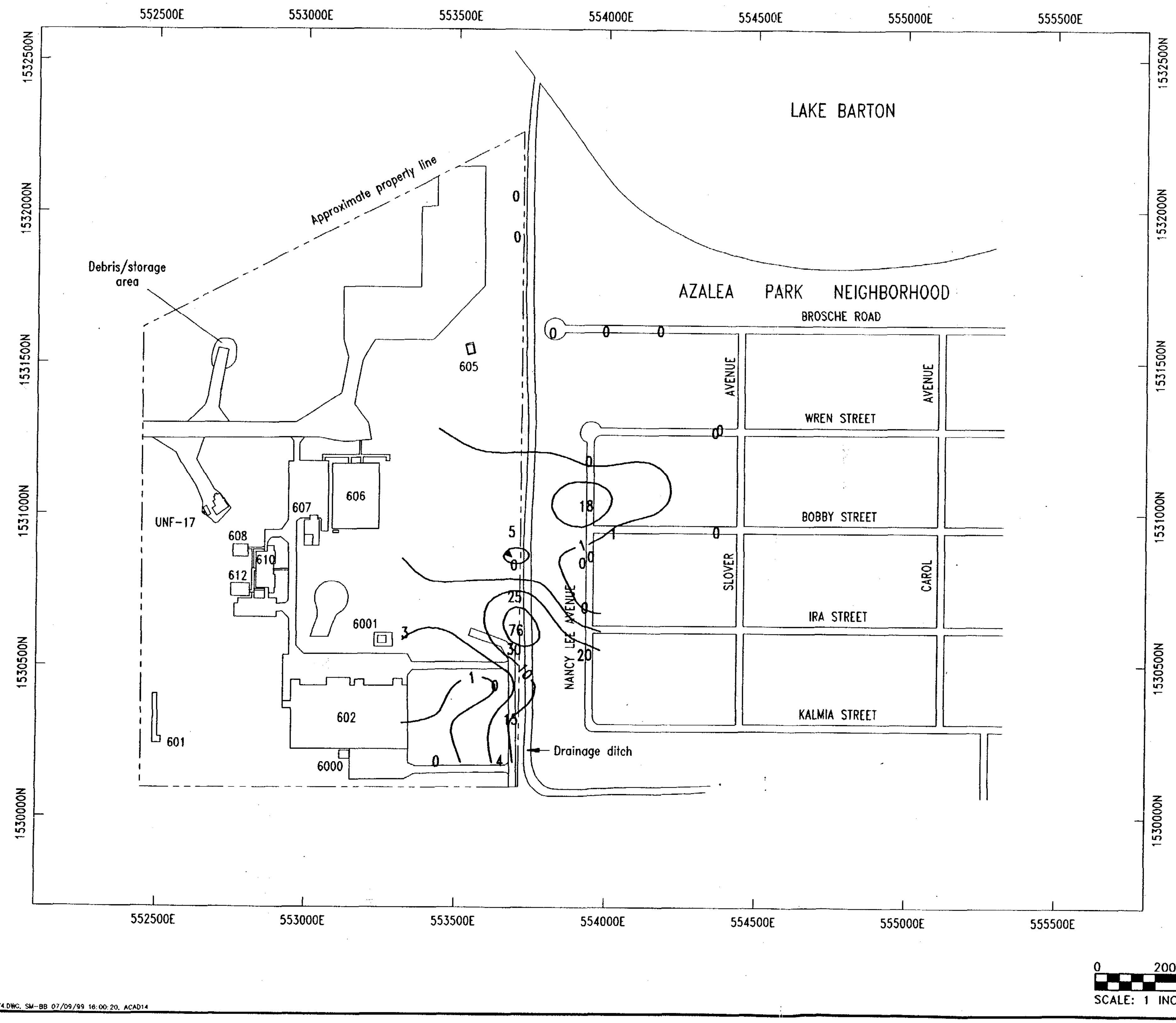

LEGEND

10 (contour line)	Benzene concentration contour
20	Benzene concentration from direct-push technology
DPT	Direct-push technology
NAD	North American Datum
MCL	Maximum contaminant level

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

Concentrations are in micrograms per liter (parts per billion).

Contours shown are two per decade (i.e., 1, 3.16, 10, 31.6, 100).

FIGURE 1-4
BENZENE MCL EXCEEDANCES IN GROUNDWATER IN THE DEPTH RANGE 30 TO 40 FEET BELOW LAND SURFACE, DPT SCREENING

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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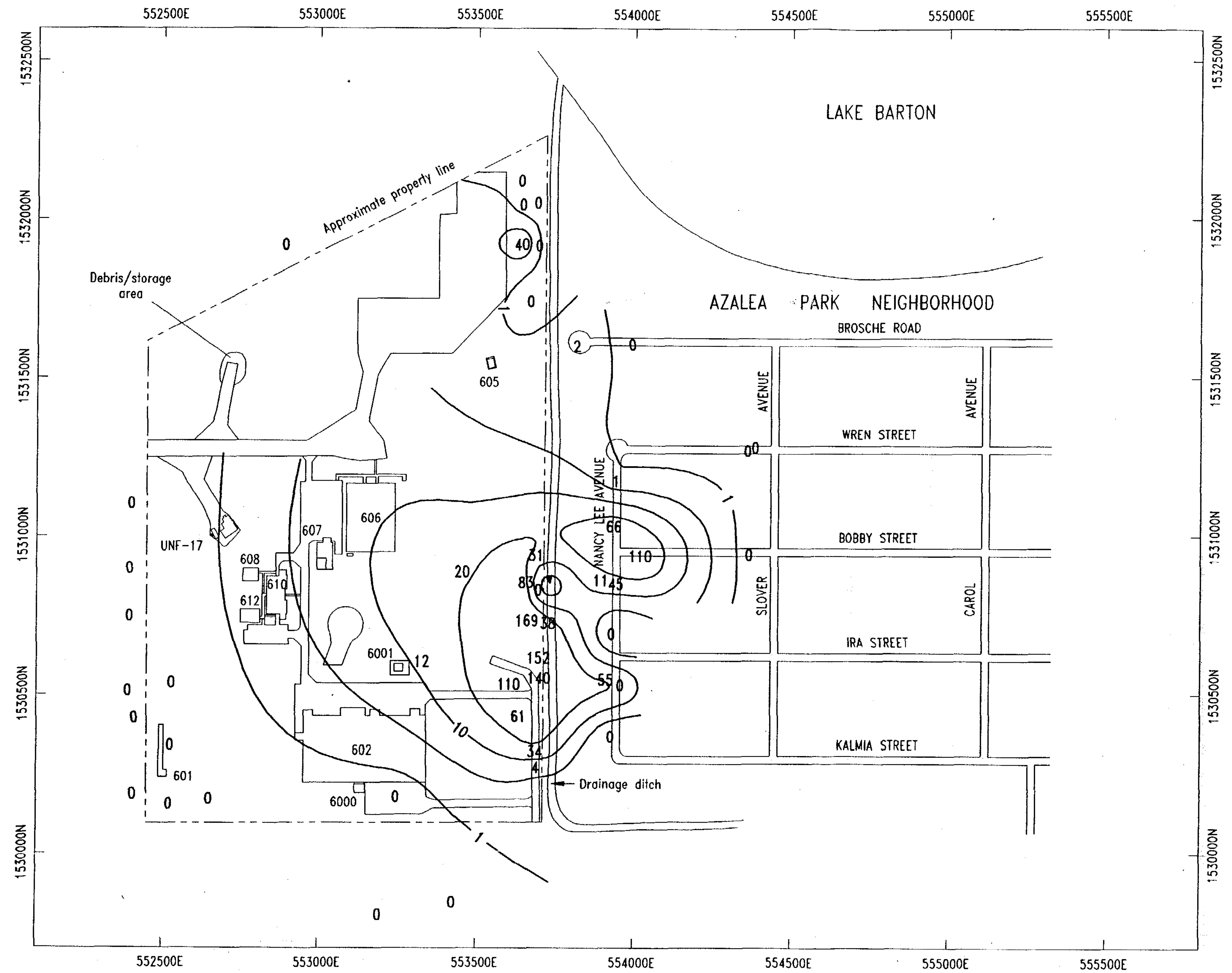

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SCALE: 1 INCH = 400 FEET

N

LEGEND

10 (contour line)	Benzene concentration contour
169	Benzene concentration from direct-push technology
DPT	Direct-push technology
NAD	North American Datum
MCL	Maximum contaminant level

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

Concentrations are in micrograms per liter (parts per billion).

Contours shown are two per decade (i.e., 1, 3.16, 10, 31.6, 100).

FIGURE 1-5
BENZENE MCL EXCEEDANCES IN GROUNDWATER IN THE DEPTH RANGE 40 TO 50 FEET BELOW LAND SURFACE, DPT SCREENING

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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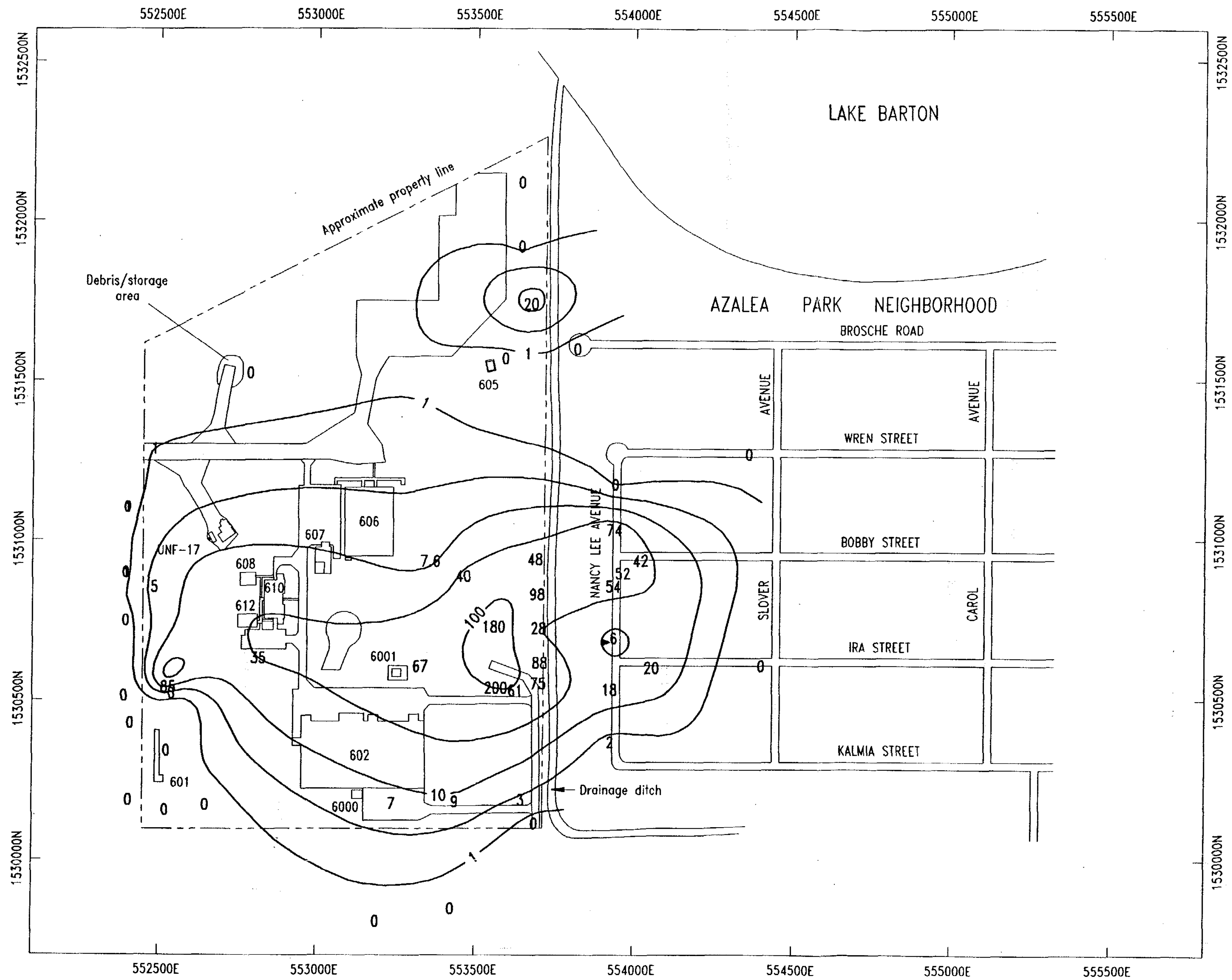

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SCALE: 1 INCH = 400 FEET

LEGEND

10	Benzene concentration contour
180	Benzene concentration from direct-push technology
DPT	Direct-push technology
NAD	North American Datum
MCL	Maximum contaminant level

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

Concentrations are in micrograms per liter (parts per billion).

Contours shown are two per decade (i.e., 1, 3.16, 10, 31.6, 100).

FIGURE 1-6
BENZENE MCL EXCEEDANCES IN GROUNDWATER IN THE DEPTH RANGE GREATER THAN 50 FEET BELOW LAND SURFACE, DPT SCREENING

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

K:\02530\02530-11\FSY\02530876.DWG, SM-BB 07/09/99 16:04:08, ACAD14 is located in the southeastern portion of the site and in the western portion of Azalea Park Neighborhood near the drainage ditch. However, a small groundwater plume was detected in the northeast corner of Herndon Annex near the intersection of the drainage ditch and Lake Barton. Figure 1-7 shows the locations of all sample points and the location of a geological-benzene contamination cross section (Figure 1-8).

The cross-section of the southern contaminant plume is presented in Figure 1-8. This figure shows that most of the benzene plume is found at depths greater than 40 feet bls, indicating the possibility that the benzene source is from further upgradient than the southern Herndon Annex property line. The screening data do not exhibit any evidence of contamination flowing downward from the shallow portion of the surficial aquifer, indicating that the plume likely has migrated under Herndon Annex from off-site. The absence of benzene detections in the shallow portions of the surficial aquifer and the decrease in benzene concentrations to the south and west is consistent with a benzene plume that has migrated onto Herndon Annex from an off-site source, and whose source is depleted. The upward vertical gradient in the area along the eastern boundary of Herndon Annex and beneath the drainage ditch brings the benzene upward from the lower zone of contamination, subsequently discharging to the surface water at the base of the ditch. This drainage ditch discharges into Lake Barton.

A total of 6 VOCs (other than benzene) were also detected in permanent groundwater monitoring wells at Study Area 2. These analytes include chloromethane, methylene chloride, cis 1,2-dichloroethene, ethylbenzene, trichloroethene (TCE), and xylene. All of the detected concentrations were well below the FDEP groundwater cleanup target levels (Chapter 62-777 FAC) and therefore have not been addressed within this FFS.

A total of three surface water samples were collected from Lake Barton, parallel to the shoreline near the drainage ditch discharge point (see Figure 1-7). Only two of the samples were found to contain any contamination, which consisted of tetrachloroethene (PCE) and TCE. The concentrations detected were all well below Florida surface water standards.

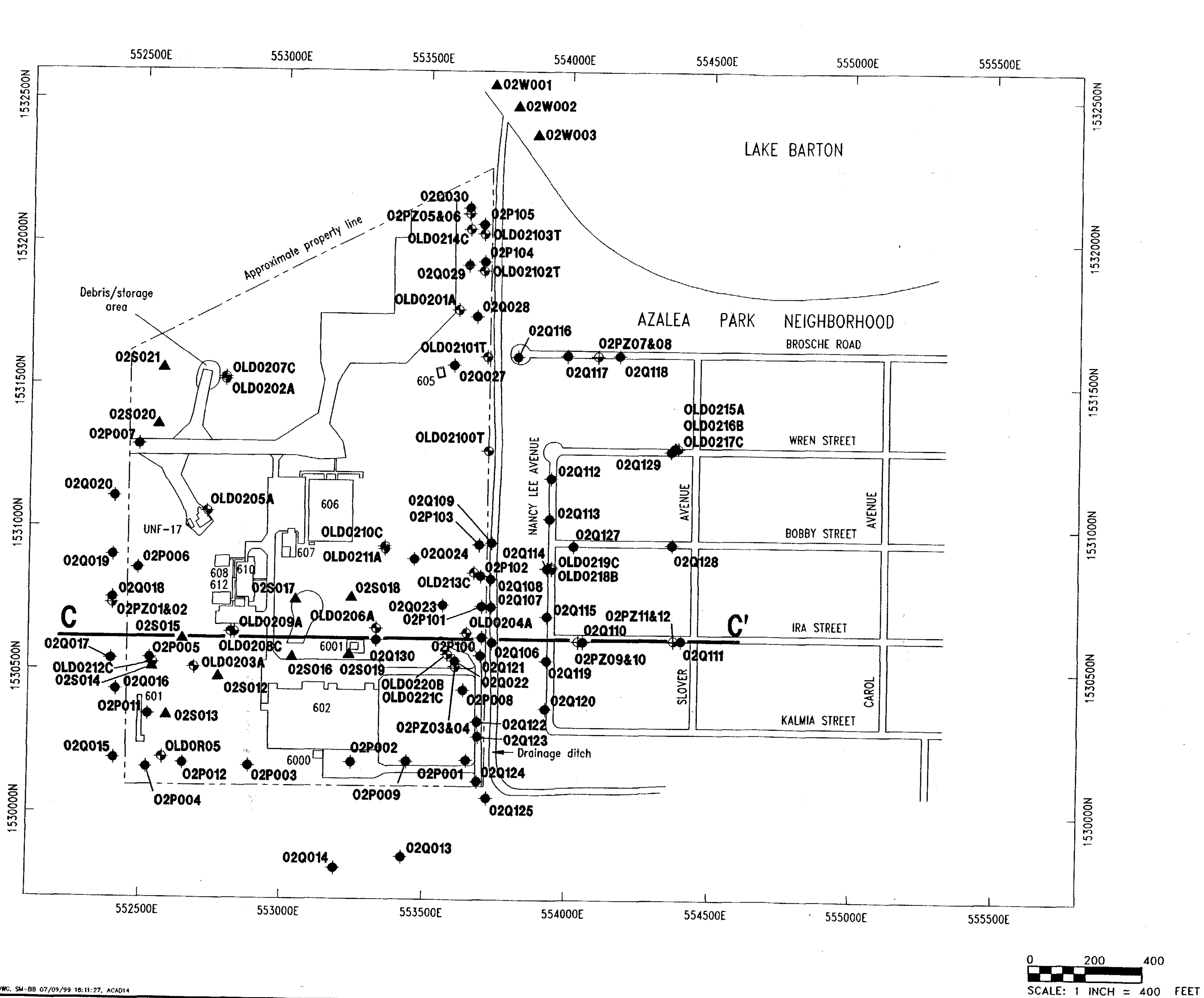
No PCE was detected in the groundwater monitoring wells on Study Area 2 indicating that this is not the source of the PCE in the lake and that there should be no future exceedances of the surface water standards derived from Study Area 2. In addition, the maximum concentration of TCE detected in the groundwater monitoring wells was 1.6 ug/L, well below the FDEP surface water standard of 80.7 ug/L. This would also indicate that there would not be any future exceedances for TCE in the lake derived from Study Area 2.

Although the source of the groundwater plume was not identified, the historical, geological, and chemical data collected during the site screening investigations indicated the strong likelihood that the contamination was due to past site activities. Based on the detection of benzene exceeding the state and federal MCLs, HLA prepared a brief memorandum identifying potential remedial technologies to address the benzene plume located beneath Herndon Annex and the Azalea Park Neighborhood (HLA, 1999a). A summary of the contents of that memo is presented in subsection 1.3 below.

1.2 NATURAL ATTENUATION EVALUATION AND MONITORING PLAN

Natural attenuation (NA) has been identified as a potential remedy for groundwater at Study Area 2. Subsequently, HLA prepared a Natural Attenuation Monitoring Work Plan (Appendix A) to estimate the rate of natural degradation of benzene at the site.

In general, the Phase IV data support a conclusion of anaerobic biodegradation of the benzene in groundwater at Study Area 2. Based on the observed decreasing trends of the benzene plume and the presence of biological activity in the subsurface, it is likely that biodegradation is responsible for attenuation of the benzene plume. However, since the predominant conditions appear to be anaerobic, specifically sulfate reducing and methanogenic, rates of benzene biodegradation would be relatively slow compared to rates that would be expected under aerobic conditions. In order for NA to be considered at Study Area 2, it was necessary to evaluate the subsurface conditions to understand which microbial processes are most active. Benzene biodegrades most rapidly under aerobic conditions, but may degrade under anaerobic conditions, although more slowly. Oxidation/reduction (Redox) parameters were measured and electron acceptor analysis was conducted during the Phase IV investigations to determine if conditions were anaerobic or aerobic and which electron acceptors were available. Other parameters



LEGEND

OLD0202A	Soil boring and monitoring well location and designation
02P001	Phase II direct-push technology exploration/sampling location and designation
02Q116	Phase III and IV direct-push technology exploration/sampling location and designation
02S012	Surface soil sampling location and designation
02PZ01	Piezometer location and designation
02W001	Surface water sampling location and designation
NAD	North American Datum

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

See Figure 1-8 for geologic cross section.

FIGURE 1-7
LOCATION PLAN FOR GEOLOGIC PROFILE C-C'
HERNDON ANNEX

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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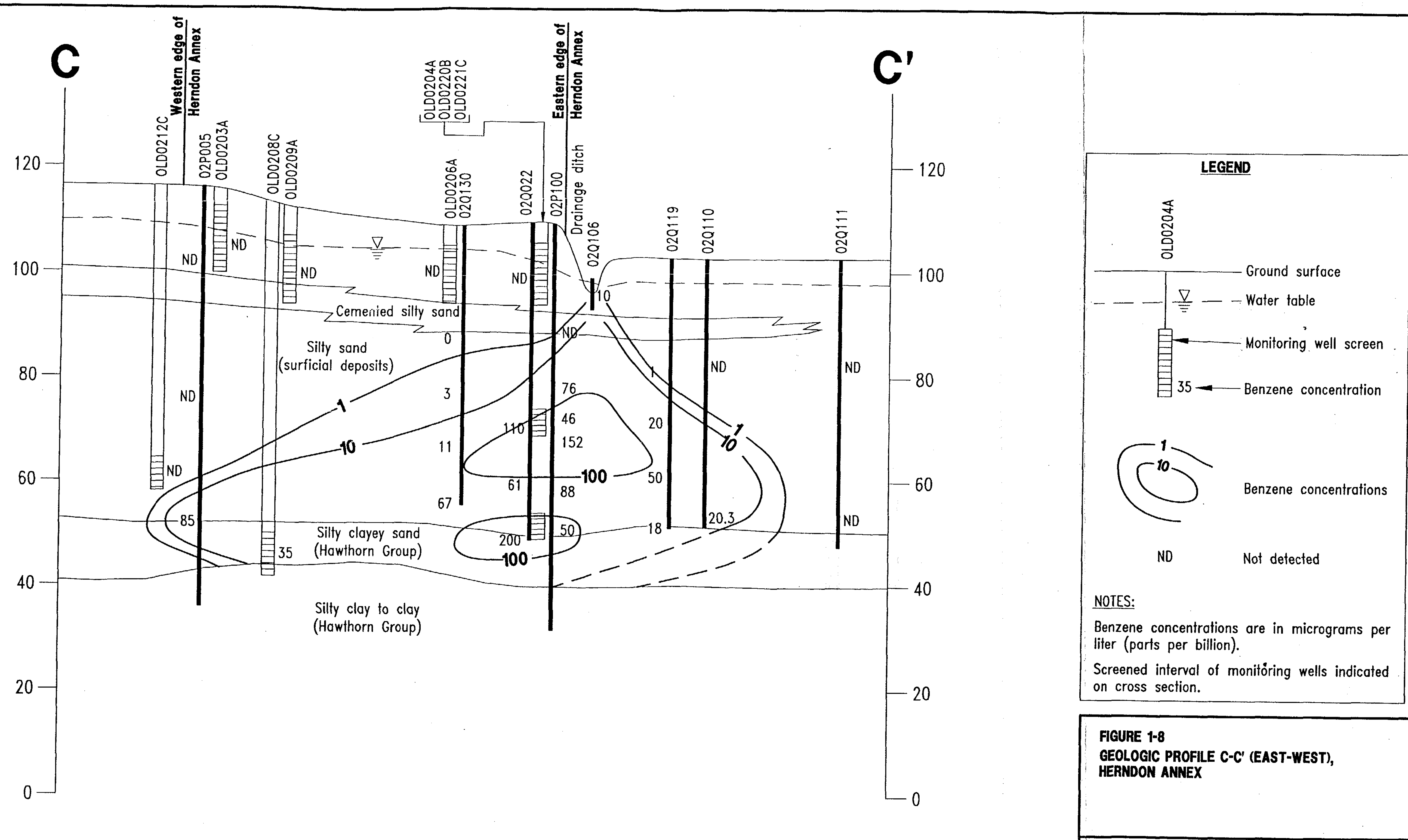


HORIZONTAL SCALE: 1 INCH = 300 FEET
VERTICAL SCALE: 1 INCH = 20 FEET

FIGURE 1-8
GEOLOGIC PROFILE C-C' (EAST-WEST), HERNDON ANNEX

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

K:\02530\02530-11\FSY\02530878.DWG, VC-VC 07/26/99 09:03:30, ACAD14 measured included alkalinity, dissolved oxygen, nitrate, sulfate/sulfide and methane. In general, the data support a conclusion of anaerobic biodegradation of the benzene in groundwater at Study Area 2. Based on the observed decreasing trends of the benzene plume and the presence of biological activity in the subsurface, it is likely that biodegradation is responsible for attenuation of the benzene plume. However, since the predominant conditions appear to be anaerobic, specifically sulfate reducing and methanogenic, rates of benzene biodegradation would be relatively slow compared to rates that would be expected under aerobic conditions.

Based on a review of the Phase IV NA data trends, the benzene concentrations are stable in one well (OLD0208C) and decreasing in the other three wells for which there is history (OLD0210C, OLD0213C, and OLD0219C). The well locations are identified in Figure 1-7. However, additional data are needed to confirm these apparent trends. Overall, benzene levels appear to be either stable or decreasing and there is no evidence to suggest the plume will expand beyond current boundaries.

The results from the NA analysis (Appendix A) also indicate approximately 30 years are required to achieve the MCL for benzene across the entire site. This assumes the benzene reaction follows first order kinetics rather than the "instantaneous reaction". Instantaneous reaction assumes biodegradation is immediate when there are available electron acceptors. Based on the concentration(s) of electron acceptor(s), benzene should be completely degraded if the instantaneous reaction is applied. However, since conditions are anaerobic and biodegradation is slower, first order kinetics would be more appropriate. When site data are plotted next to the first order model (Appendix A), a good comparison indicates that first order kinetics is appropriate. The first order rate constant was estimated from data obtained from monitoring well OLD0210, which has been sampled three times since 1995. Data used to calculate the rate constant are presented in Figure A-2 of Appendix A.

These data are considered an estimate and should be verified as more data are collected. The NA monitoring work plan presented in Appendix A describes the proposed sampling and analysis program for groundwater at Study Area 2 to support an ongoing evaluation. This work plan is consistent with the FAC 62-785.690 (Natural Attenuation Monitoring Criteria) for a minimum monitoring period of one year.

1.3 SUMMARY OF HERNDON ANNEX REMEDIAL TECHNOLOGY IDENTIFICATION.

HLA prepared a preliminary identification of remedial technologies that could be used to treat the benzene-contaminated groundwater beneath Herndon Annex and the Azalea Park Neighborhood (HLA, 1999a), which was presented to the Orlando Partnering Team (OPT) in February 1999.

The preliminary identification of treatment technologies included:

- No Action
- Natural Attenuation (NA)
- Hydraulic Containment
- Permeable Reactive Wall
- Enhanced Bioremediation
- Air Sparging and Soil Vapor Extraction (AS/SVE)
- Pump and Treat, and
- Excavation/Clearing of Drainage Ditch with Aeration

Based on discussions during this February 1999 OPT meeting, the initial preference was to consider NA as the long-term treatment process. This initial decision was based on preliminary NA data collected during Phase IV of the site screening study at Herndon Annex. As discussed in Section 1.2, HLA prepared a monitored natural attenuation work plan (Appendix A) to evaluate the NA data in accordance with NA guidance documents. This included the recommendation for additional sampling and analyses to determine the role of biological degradation and its ability to achieve the state MCL of 1 ug/L.

To support the further evaluation of this initial selection, HLA has prepared this FFS to screen the preliminary list of treatment technologies, develop a short list of remedial alternatives and evaluate these alternatives in accordance with U.S. Environmental Protection Agency (USEPA) guidance (USEPA, 1988).

The FDEP MCL of 1 ug/L for benzene will be used for the evaluation of all the remedial alternatives within this FFS.

2.0 PRELIMINARY SCREENING OF REMEDIAL TECHNOLOGIES AND DEVELOPMENT OF REMEDIAL ALTERNATIVES

The primary goal for remediating the site groundwater is to restore the aquifer to beneficial use by reducing the toxicity, mobility and/or volume of benzene contamination. HLA conducted a limited screening of remedial technologies to be used for the development of remedial alternatives that can accomplish this goal. In accordance with the National Contingency Plan (NCP, 1990), a range of remedial alternatives were considered, including the No Action alternative.

Using the preliminary list of remedial technologies presented to the OPT in February 1999, HLA conducted a limited screening using effectiveness, implementability and cost criteria for comparison and selection of remedial technologies. Two of the treatment technologies, containment and pump and treat are general such that specific technologies needed to be identified prior to the preliminary screening step. Based on site conditions and a potentially large radius of influence, hydraulic containment could readily be achieved using vertical groundwater extraction wells. However, the extracted groundwater would require treatment prior to discharge (e.g., surface water or reinjection) equating to the pump and treat alternative. This treatment would be achieved using an ex-situ treatment technology such as air stripping or liquid-phase granular activated carbon (GAC). Therefore, the evaluation of both containment and pump and treat has been combined under ex-situ treatment technologies of air stripping and GAC.

Table 2-1 presents this preliminary screening which resulted in the elimination of AS/SVE, permeable reactive wall, ex-situ organic adsorption using GAC (pump and treat) and expansion/clearing of the drainage ditch with aeration of surface water. The preliminary screening rationale is discussed in the following subsections.

2.1 AIR SPARGING/SOIL VAPOR EXTRACTION.

AS/SVE was eliminated due to the extensive size of the treatment system to remediate the groundwater plume beneath both Herndon Annex and the Azalea Park Neighborhood (approximately 50 acres in size). An inordinate number of sparging points and vapor collection points would be required to address the large surface area of the benzene plume. Air sparging would also require the transfer of contamination from the lower zone (50 to 60 feet bls) through the shallow aquifer (30 to 50 feet bls). This would potentially contaminate clean groundwater (no benzene contamination detected) within the shallow aquifer.

Biosparging was also considered and involves the injection of air into the contaminated groundwater plume at low air flow rates. This injection would transfer the zone immediately around the injection well from anaerobic to an aerobic zone supporting an increased rate of biodegradation. This remedial technology was eliminated due to the large number of biosparge points required because of the large plume and the vertical contamination transfer discussed above.

2.2 NATURAL ATTENUATION

Natural attenuation (NA) is defined by the USEPA as naturally occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume or concentration of contamination within those media (USEPA, 1997). Natural attenuation works through nondestructive mechanisms such as dispersion, adsorption, dilution, volatilization and/or chemical and biological stabilization of contaminants and destruction mechanisms such as biodegradation. NA is recognized as a legitimate and responsible solution for contaminated aquifers, and has been shown to be a technical and cost effective remedial approach for benzene-contaminated groundwater. NA was retained for the development of remedial alternatives based on the results of the NA evaluation summarized in subsection 1.2 and the monitoring work plan presented in Appendix A of this FFS.

Table 2-1
Screening of Remedial Technologies for Groundwater

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Representative Technology	Effectiveness	Implementability	Cost	Recommendation
No Action				
No action	Relies on natural attenuation without monitoring to confirm reduction in toxicity and volume of contaminants.	Readily implemented.	Low	Retained
In Situ Treatment				
Air Sparging with Vapor Collection	Proven effective to remove VOCs. Site lithology and depth of contamination may limit effectiveness. Capture of generated vapors required. Injection of air at low flow rate (Biosparging) to enhance biodegradation rate; proven effective for benzene.	Depth of contamination greatly complicates system installation. Large plume will require excessive number of air sparging points and large soil vapor extraction system. Biosparging easily implemented, but requires large number of injection points. Also concerned with bio fouling.	High	Eliminated
Natural Attenuation	Natural biodegradation of benzene has been observed at the site.	Requires long term system monitoring.	Low	Retained
Enhanced Bioremediation	Site data suggest biodegradation occurring. Anaerobic conditions could be enhanced to expedite degradation rates.	Oxygen release compound readily available and easily installed inside groundwater wells or injected using direct push technology.	Medium	Retained
Permeable Reactive Wall	Patented technology. Proven in laboratory tests with only limited full-scale field experience. Questionable effectiveness on benzene.	Requires fate, transport and hydraulic modeling. Large plume will require extensive length and depth of reactive wall. Requires bench-scale column tests for optimum design. Soil excavated to construct wall may require separate management. Precipitates may form on reactive materials, limiting hydraulic lifetime of wall and requiring flushing of wall.	High	Eliminated

See notes at end of table.

Table 2-1 (Continued)
Screening of Remedial Technologies for Groundwater

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Representative Technology	Effectiveness	Implementability	Cost	Recommendation
Permeable Reactive Wall (Continued)		Integrity of permeable reactive wall and hydraulic barrier must be evaluated periodically to maintain optimum groundwater treatment.		
Ex Situ Treatment				
Air Stripping	Proven technology to remove VOCs.	May require off-gas treatment and monitoring.	High	Eliminated*
Organic Adsorption (granular activated carbon)	Proven technology to remove VOCs.	Spent carbon must be regenerated or disposed of.	High	Eliminated
Excavation of Drainage Ditch with Surface Water Aeration	Aeration effective on benzene.	Extensive excavation of drainage ditch (> 1,000 linear feet of ditch).	High	Eliminated
	Limited effectiveness on containing contaminant plume.	Construction would temporarily impact stormwater management collection/discharge into Lake Barton.		
		Dewatering of construction area difficult.		

* Eliminated as stand-alone remedial technology, but retained when used in combination with enhanced bioremediation.

Notes: VOCs = volatile organic compounds.

2.3 ENHANCED BIOREMEDIATION.

Enhanced bioremediation could be accomplished through the passive contact of contaminated groundwater with an oxygen release compound (ORC, solid-phase), injection of an ORC slurry or by the extraction and reinjection of groundwater into a well containing the solid ORC. The ORC is a patented time-release formulation of magnesium peroxide, which releases oxygen slowly when it contacts water. The associated increase in dissolved oxygen can increase the rate of benzene biodegradation by one to two orders of magnitude. Enhanced bioremediation was retained for its use as a stand-alone remedial alternative as a slurry injection and in combination with pump and treat (solid-phase inside a reinjection well).

The passive approach could be accomplished by the installation of retrievable ORC filter socks into groundwater wells screened through the depth of contamination. Due to the passive nature of this process by which contaminated groundwater must come in contact with the ORC, an extensive network of wells throughout the groundwater plume, approximately on a 10 foot by 10 foot grid, would be required. Alternatively, the pressurized injection of a slurry mix throughout the plume would require fewer application points than the solid ORC. Application of the slurry would be done with a single injection event, either by a direct push technology (DPT) or permanent wells. Subsequently, the ORC slurry injection via DPT delivery was retained for the development of remedial alternatives. This was due to the increased radius of influence on the groundwater plume (approximately 20 foot diameter), a single injection event eliminating the periodic changeout of solid-phase ORC and the elimination of a large number of permanent well points throughout the entire benzene plume.

The active approach is through the extraction of groundwater and reinjection into wells containing the solid ORC to induce a continuous flushing of the dissolved ORC through the plume. Due to the reinjection of groundwater, an FDEP underground injection control permit would likely require treatment of the extracted groundwater prior to reinjection. The combination of enhanced bioremediation (using ORC socks within an injection well) along with pump and treat was retained for remedial alternative development below.

2.4 PERMEABLE REACTIVE WALL.

Permeable reactive walls have been found to be effective in passively reducing the concentration of organic contaminants as the groundwater plume passes through the wall. A permeable reactive wall would be required along the Herndon Annex side of the drainage channel (approximately 1300 linear feet) to address the upgradient groundwater contamination. NA would address the residual contamination beneath Azalea Park due to the groundwater flow towards Lake Barton. This reactive wall would need to be installed to a minimum depth of 60 feet bls in order to contact and remediate the benzene-contaminated groundwater exceeding the MCL beneath the Herndon Annex.

Although this technology has been demonstrated to be effective on chlorinated compounds, it is unclear if this technology is effective on benzene. Site conditions would also limit the effectiveness of this remedial technology such that the area immediately beneath the drainage ditch would not be addressed and would likely discharge into Lake Barton. Due to the extensive size of the permeable reactive wall (more than 1300 linear feet long and +60 feet deep) and the questionable effectiveness on benzene, this technology was eliminated from any further evaluation.

2.5 AIR STRIPPING AND LIQUID-PHASE GAC.

A pump and treat remedial technology was considered for evaluation in this FFS to provide hydraulic containment of the groundwater plume while reducing the concentration of benzene to the MCL of 1 ug/L. The ex-situ treatment of benzene-contaminated groundwater can be performed either by air stripping to transfer the contaminants to the air phase or by adsorption onto liquid-phase GAC. It was determined to only retain one pump and treat technology within this FFS, and subsequently, the use of liquid-phase GAC was eliminated due to the anticipation of excessive operational costs. Ex-situ air stripping was also eliminated as a stand-alone remedial technology as the anticipated treatment duration of a pump and treat remedial technology would be approximately 20 years (six to nine pore volumes) before achieving the MCL for benzene. In order to reduce the treatment duration, ex-situ air stripping was retained in combination with enhanced bioremediation (solid-phase ORC) to provide an aggressive remedial alternative.

2.6 EXCAVATION/CLEARING OF DRAINAGE DITCH AND AERATION.

The hydrogeological data for Herndon Annex indicates that the shallow aquifer has an upward vertical gradient as it approaches the drainage ditch located between Herndon Annex and the Azalea Park Neighborhood. This upward vertical gradient results in the discharge of groundwater from beneath Herndon Annex to the bottom of the drainage ditch. This installation and operation of an effective aeration system would require that the drainage ditch be cleared of all vegetation and excavated to increase the discharge of contaminated groundwater into the ditch.

The excavation of the ditch would have a limited effect on the inflow of contaminated groundwater into the drainage ditch. The contaminated groundwater from Herndon Annex would continue to migrate into the Azalea Park Neighborhood. Aeration units, similar to those used in the wastewater industry, would be installed into the ditch to transfer the benzene from the dissolved phase into the vapor phase for release to the atmosphere.

Use of the drainage ditch to accelerate the discharge of groundwater into the ditch followed by the aeration of the surface water was not retained for further evaluation due to its limited effectiveness in containing the contaminated groundwater plume.

2.7 DEVELOPMENT OF REMEDIAL ALTERNATIVES

Based on the preliminary screening presented in Table 2-1, No Action, NA, enhanced bioremediation and ex-situ air stripping were retained for the development of remedial alternatives and further evaluation. The No Action, NA and enhanced bioremediation technologies were retained as stand-alone remedial alternatives, while ex-situ air stripping was retained in combination with enhanced bioremediation, as follows:

- Alternative No. 1 - No action
- Alternative No. 2 - Natural attenuation (NA)
- Alternative No. 3 – Enhanced Bioremediation (ORC slurry injection) and,
- Alternative No. 4 - Enhanced bioremediation (solid phase ORC) with ex-situ air stripping

The No Action alternative was retained in accordance with the NCP to provide a baseline comparison to the three remaining remedial alternatives. Under the No Action alternative, no remedial action would be conducted at either Herndon Annex or the Azalea Park Neighborhood. The NA remedial alternative would provide a passive, in-situ remedial alternative, while the enhanced bioremediation would provide oxygen to the groundwater plume to expedite the natural degradation of the benzene contamination. Finally, the enhanced bioremediation with groundwater extraction, ex-situ air stripping and reinjection offers the most aggressive approach to achieve the remedial goals and would utilize a well proven ex-situ treatment technology to remove benzene from the groundwater.

3.0 DESCRIPTION AND SCHEMATIC DESIGN OF REMEDIAL ALTERNATIVES

Remedial alternatives were developed to meet the primary goal of remediating the site groundwater for beneficial use by reducing the toxicity, mobility and/or volume of benzene contamination. The following text describes the components and operation of the four remedial alternatives and will be used to support their evaluation against Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria and their ability to meet this primary goal (Chapter 4.0).

3.1 ALTERNATIVE NO. 1 – NO ACTION.

This remedial alternative was retained in accordance with the NCP for comparison to the other alternatives that reduce the toxicity, mobility and/or volume of benzene contamination. This alternative assumes that no action would be taken to either monitor or treat the benzene contamination detected in the groundwater beneath Herndon Annex and Azalea Park. This alternative ultimately relies on the ongoing NA of the contaminants (HLA, 1999b and Appendix A), but does not include groundwater monitoring to ensure that the plume is stable (vertically or horizontally) or confirm the rate of natural degradation. Without any actual groundwater monitoring data to support the on going evaluation of NA, it was assumed that the duration for the No Action alternative to achieve the MCL for benzene would be 30 years (USEPA, 1988).

If selected, five-year site reviews would be conducted to re-evaluate the appropriateness of this remedial alternative. This re-evaluation would include the identification of new site conditions (visual inspection), potentially new exposure scenarios, and treatment technologies. The appropriateness of this alternative would be compared to other remedial alternatives to confirm that this was still the most appropriate selection for Herndon Annex and Azalea Park. The site reviews would occur until the groundwater quality met the 1 ug/L MCL for benzene.

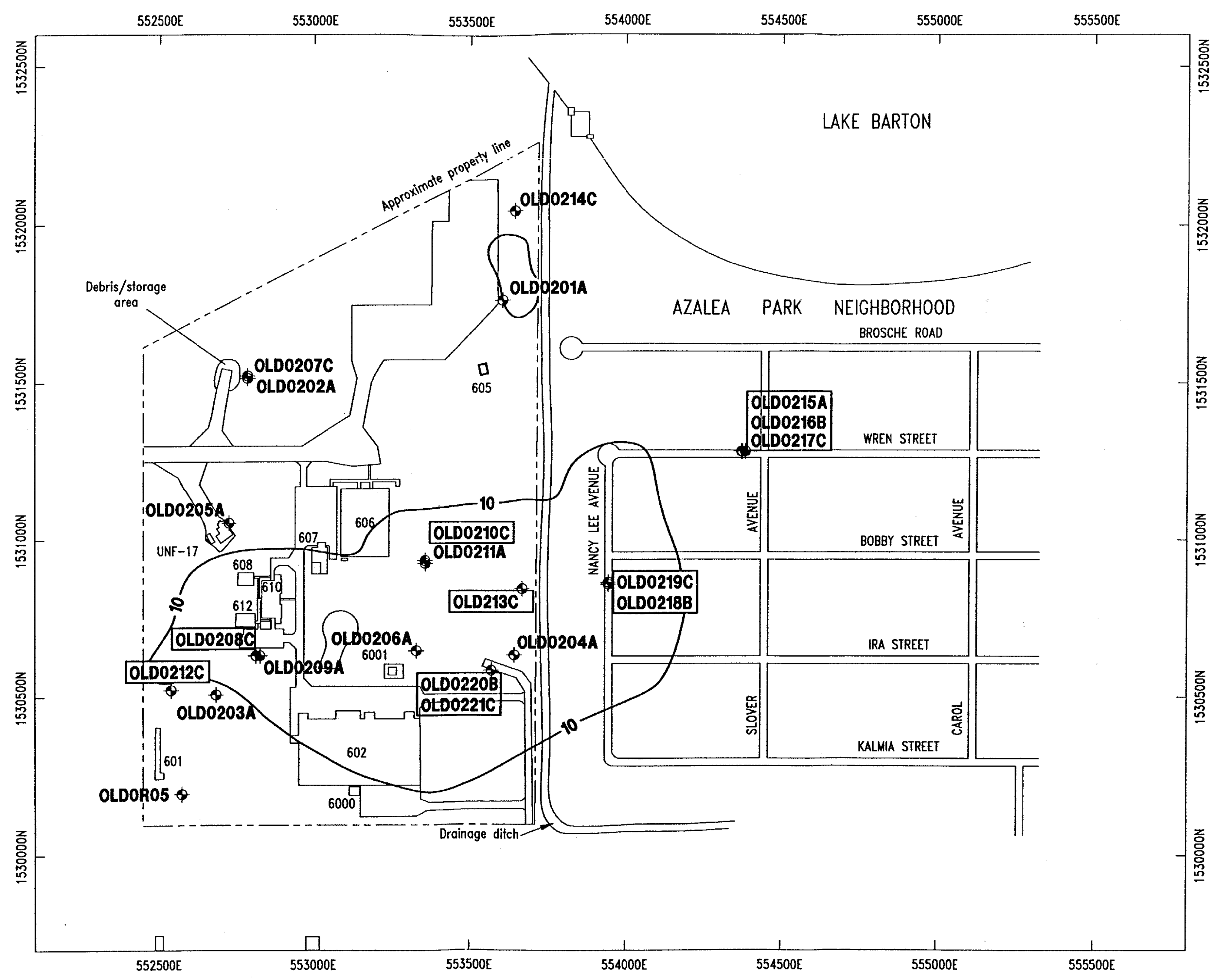
3.2 ALTERNATIVE NO. 2 – NATURAL ATTENUATION (NA).

NA is applicable to Herndon Annex and Azalea Park based on the presence of benzene and its ability to biodegrade aerobically. The site screening data indicates that natural biodegradation is occurring on a limited basis as the plume moves towards Lake Barton (HLA, 1999b). Based on the evaluation of natural attenuation data and "Bioscreen" modeling (Appendix A), HLA estimated the duration to achieve the MCL for benzene within the entire groundwater plume is approximately 30 years. The lower benzene concentrations on the outside perimeter of the plume would be reduced to 1 ug/L relatively quickly, while the elevated concentrations in the southeastern corner of Herndon Annex would require up to 30 years to achieve the MCL.

Due to the treatment duration required to achieve the MCL for benzene, groundwater use restrictions/advisories would be implemented on Herndon Annex and within the affected areas of Azalea Park. These groundwater use restrictions would address the consumption of contaminated groundwater and installation of additional wells to completely eliminate exposure pathways until the cleanup goal was achieved. Existing irrigation wells within the Azalea Park Neighborhood may require periodic sampling.

The difference between NA and No Action is that monitoring of the natural degradation processes would be conducted to ensure the complete degradation of the groundwater plume to the MCL and to monitor the migration of the residual plume until it reaches this goal. The NA groundwater monitoring plan presented in Appendix A can be referred to for more detailed information on this remedial alternative. Figure 3-1 identifies the location of existing groundwater wells to be monitored under this NA Work Plan and Table 3-1 identifies the screened interval within the plume and reasons for recommending the well for NA monitoring. As part of the monitoring, the biodegradation component of NA would be quantified and measured on a regularly scheduled basis. The groundwater monitoring program would include VOCs and the NA parameters listed below:

- oxygen
- nitrate
- nitrite



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0 200 400

SCALE: 1 INCH = 400 FEET

LEGEND

OLD0208C	Monitoring well location and designation
OLD0208C (boxed)	Long–term monitoring well for natural attenuation
10	Benzene groundwater plume >10 micrograms per liter (composite of Figures 1–3 through 1–6)
NAD	North American Datum

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983–98.

FIGURE 3-1
PROPOSED LONG-TERM MONITORING WELLS
REMEDIAL ALTERNATIVE NO. 2
NATURAL ATTENUATION

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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Table 3-1
Proposed Long-Term Monitoring Wells for Natural Attenuation

Base Realignment And Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Well Number	Screened Interval (ft bls)	Reason for Selection
OLD0215A	5-15	Shallow well edge of plume
OLD0216B	28.5 – 33.5	Intermediate well, edge of plume
OLD0217C	45.5 – 50.5	Deep well, edge of plume
OLD0218B	29.5 – 34.5	Deep well, edge of plume
OLD0219C	49 – 54	Intermediate well, edge of plume
OLD0220B	36 – 51	Intermediate well, near drainage ditch
OLD0221C	56 – 61	Deep well, near drainage ditch
OLD0210C	52 – 57	Deep well, mid-plume
OLD0213C	44 – 49	Deep well, mid-plume
OLD0208C	60 – 65	Deep well, near upgradient edge of plume
OLD0212C	57 – 62	Background well

ft bls = feet below land surface

- ferrous iron
- sulfate
- sulfide
- methane
- oxidation-reduction potential
- pH
- temperature
- carbon dioxide
- alkalinity, and
- chloride

Five-year site reviews would be conducted to re-evaluate the appropriateness of this remedial alternative. This would include the identification of potential new site conditions and exposure scenarios that could adversely alter the effectiveness of this remedial alternative. This would also include an evaluation of the groundwater monitoring data to evaluate the rate of benzene degradation, estimated duration to achieve the MCL and the overall effectiveness of the remedial alternative. This alternative would be compared to other remedial alternatives to confirm that this was still the most appropriate selection for Herndon Annex and Azalea Park. Data from the groundwater monitoring program would be included within this five-year evaluation. When the cleanup goal for benzene was achieved, the groundwater use restrictions would be eliminated.

3.3 ALTERNATIVE NO. 3 – ENHANCED BIOREMEDIATION (ORC SLURRY INJECTION)

Enhanced biodegradation of groundwater is a process that would increase the rate of natural bacterial degradation of organic contaminants. This would be accomplished by introducing ORC into the groundwater plume to stimulate bacterial growth and the speed of aerobic biodegradation of the benzene. As discussed in the remedial technology screening process, this remedial alternative would rely on the injection of an ORC slurry mix by DPT to maximize the amount of dissolved oxygen entering the groundwater plume during a single injection event. A total of 83 DPT probes would be installed throughout Herndon Annex and the Azalea Park Neighborhood (Figure 3-2) to address the benzene contamination exceeding 10 ug/L. NA would be required to reduce the residual contamination below 10 ug/L as it is too low a concentration for ORC to be effective. The ORC application would occur at the site-specific depths of contamination identified during the site investigation and as specified on Figure 3-2. HLA estimated that the single ORC injection would address most of the groundwater plume and achieve the MCL within the benzene plume >10 ug/L in approximately 4 years (Appendix B). HLA also estimated that the fringe contamination (<10 ug/L) not addressed by the ORC injection would naturally attenuate to the MCL in a period of five years.

This remedial alternative would also follow the prescribed NA groundwater monitoring and five-year site reviews discussed in Alternative No. 2. The groundwater monitoring would support the evaluation of enhanced bioremediation, including the effectiveness of the ORC slurry, location of injection points, and rate of degradation to achieve the MCL. The monitoring of ORC injection and benzene biodegradation would be conducted on 11 existing monitoring wells (Figure 3-1) over a period of 5 years. The short duration of this remedial alternative to achieve the MCL for benzene results in a single five-year site review prior to site closeout.

3.4 ALTERNATIVE NO. 4 – ENHANCED BIOREMEDIATON WITH EX-SITU AIR STRIPPING.

The combination of enhanced bioremediaton with ex-situ air stripping (Figure 3-3) is an aggressive remedial response to attempt to reduce the duration required to meet the cleanup goal for benzene while providing hydraulic containment of the groundwater plume (Figure 3-4). This alternative would expedite the ongoing natural attenuation of the groundwater plume by the addition of ORC into a recirculating groundwater system. The process flow for this alternative would include groundwater extraction, treatment, and reinjection/amendment. This is the only remedial alternative that would provide hydraulic containment of the groundwater plume while reducing the concentration of benzene in the groundwater beneath Herndon Annex and Azalea Park. This hydraulic containment would also eliminate the discharge of contaminated groundwater into the drainage ditch, subsequently discharging into Lake Barton.

554000E 554500E 555000E 555500E

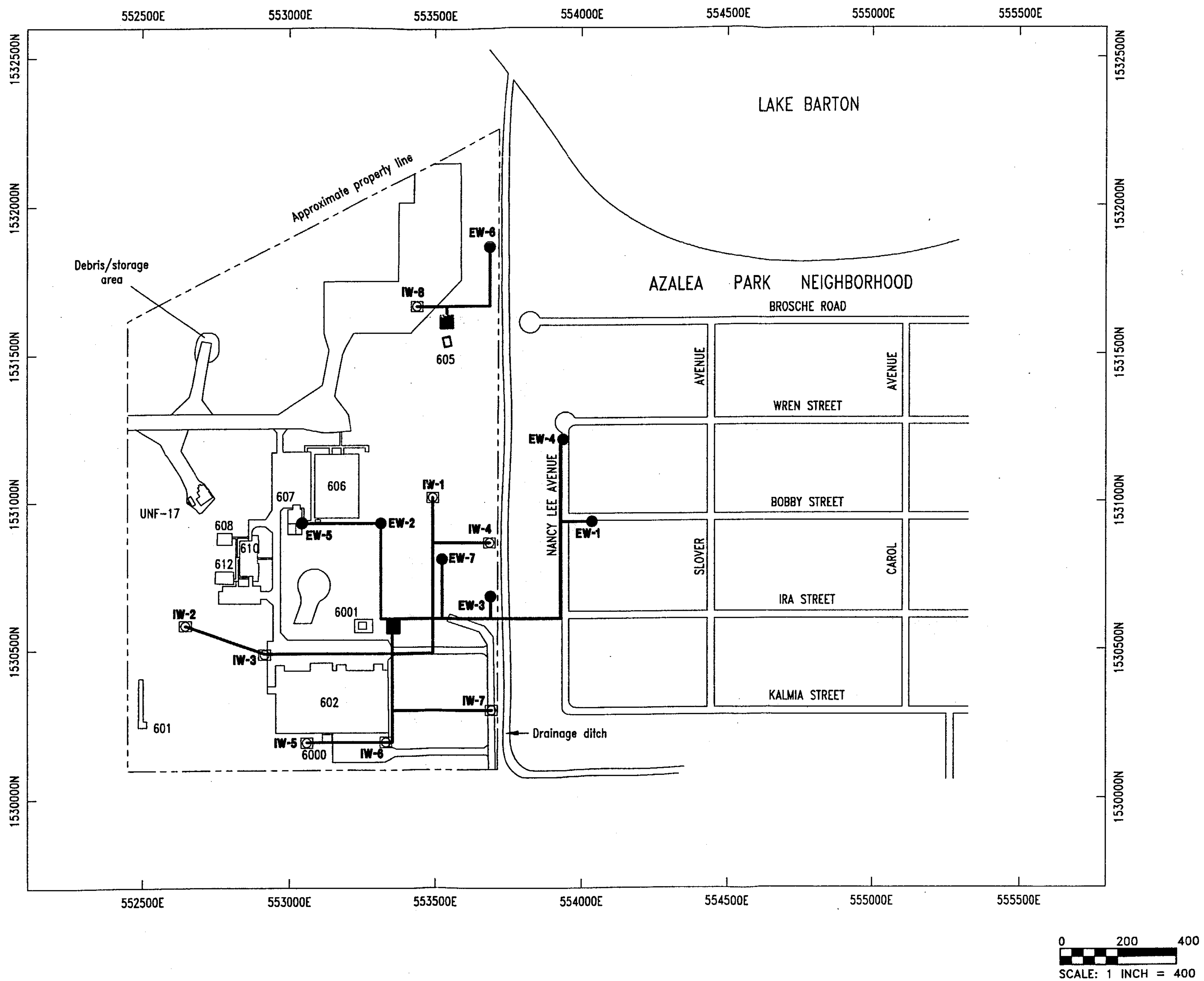
DPT INJECTION POINT DETAIL

N

0 50 100

SCALE: 1 INCH = 100 FEET

FIGURE 3-2 PROPOSED ORC INJECTION POINTS REMEDIAL ALTERNATIVE NO. 3 ENHANCED BIOREMEDIATION	BASE REALIGNMENT AND CLOSURE FOCUSED FEASIBILITY STUDY STUDY AREA 2 HERNDON ANNEX NAVAL TRAINING CENTER ORLANDO, FLORIDA



LEGEND

EW-3 ●	Proposed groundwater extraction well with designation
IW-4 ⊡	Proposed reinjection well with designation containing ORC
———	Underground piping
■	Ex-situ air stripper treatment system/building
NAD	North American Datum
ORC	Oxygen release compound

NOTE:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

FIGURE 3-3
SCHEMATIC LAYOUT
REMEDIAL ALTERNATIVE NO. 4
ENHANCED BIOREMEDIATION WITH EX-SITU AIR STRIPPING

BASE REALIGNMENT AND CLOSURE
FOCUSED FEASIBILITY STUDY
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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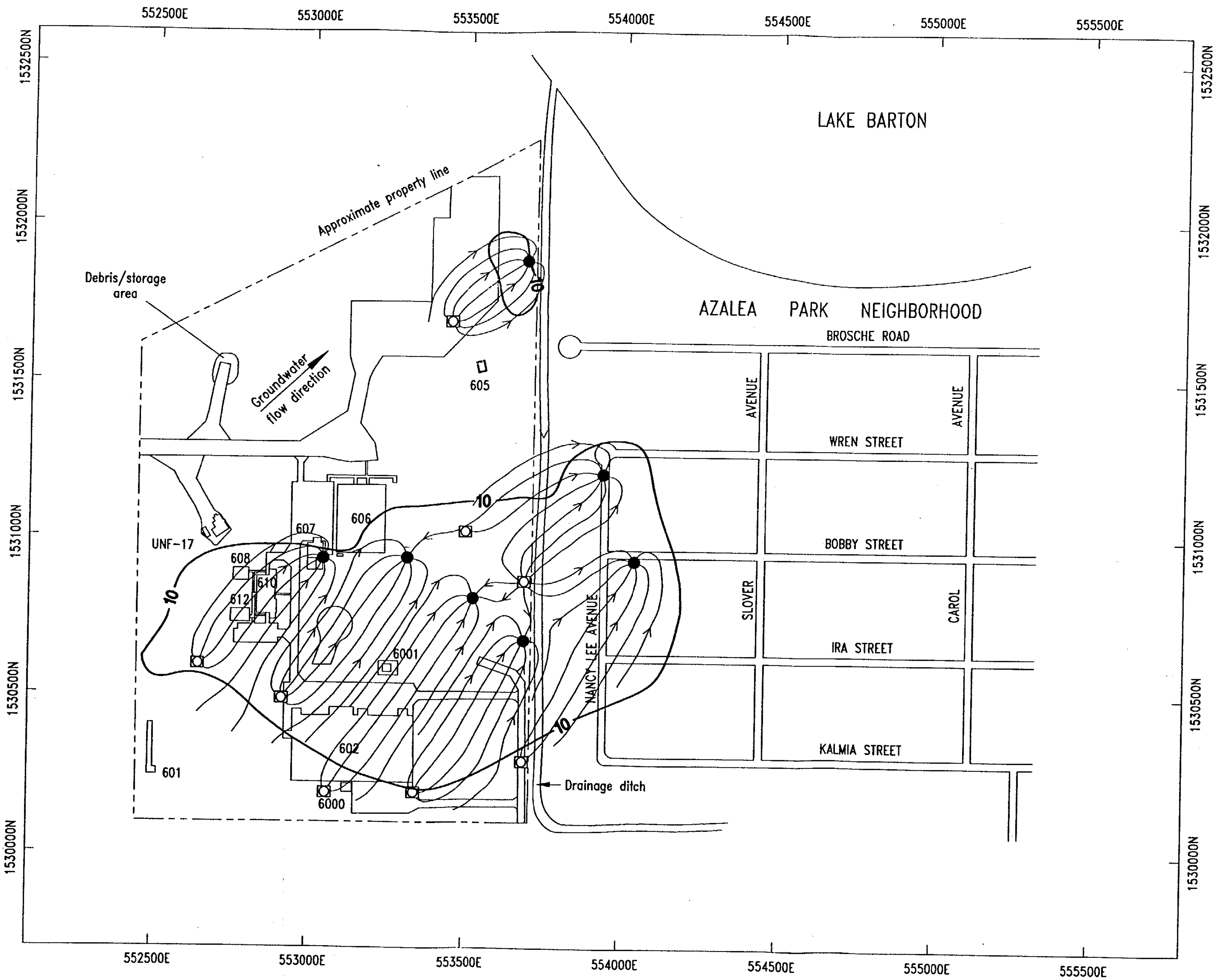

LEGEND

- ● Proposed extraction well
- ◘ Proposed reinjection well
- → Groundwater flow direction constant extraction/reinjection
- 10 Benzene groundwater plume >10 micrograms per liter (composite of Figures 1-3 through 1-6)
- NAD North American Datum

NOTE:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

0 200 400

SCALE: 1 INCH = 400 FEET

FIGURE 3-4
GROUNDWATER FLOW USING EXTRACTION / REINJECTION WELLS REMEDIAL ALTERNATIVE NO. 4 ENHANCED BIOREMEDIATION AND EX-SITU AIR STRIPPING

BASE REALIGNMENT AND CLOSURE FOCUSED FEASIBILITY STUDY STUDY AREA 2 HERNDON ANNEX NAVAL TRAINING CENTER ORLANDO, FLORIDA

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Enhanced biodegradation of groundwater would increase the rate of natural bacterial degradation of organic contaminants by the placement of solid-phase ORC in the reinjection wells. This approach would maximize the amount of dissolved oxygen entering the groundwater plume and would require a smaller number of injection points than Alternative No. 3 (8 versus 83) as shown in Figure 3-3. HLA estimated a duration of 5 years to achieve the MCL for the entire benzene plume (Appendix C). The plume with benzene concentrations >10 ug/L was estimated to achieve the MCL in 4 years, while the fringe contamination (<10 UG/L) would require an additional year. The groundwater would be reinjected/amended following the extraction and treatment by air stripping. Ex-situ air stripping would also increase the volume of dissolved oxygen in the treated groundwater prior to reinjection further supporting the enhanced bioremediation process.

Modeling of ORC usage indicates that the ORC "socks" would have to be replaced approximately every three months throughout the system operation until the MCL for benzene (1 ug/L) was achieved. This rate of replacement is mostly due to the continued injection of treated groundwater into the well containing the ORC and not due to the concentration of benzene contamination. ORC usage was estimated using proprietary software provided by the ORC vendor, and a maximum concentration of benzene at 83 ug/L as confirmed in the groundwater monitoring wells (Appendix C).

Ex-situ air stripping would be used to remove benzene dissolved in the groundwater prior to it being reinjected into the recirculating cell. The air stripper would transfer the dissolved benzene into the vapor phase by contacting the extracted groundwater with a continuous supply of clean air. Although many vendor-specific air stripping units exist, they generally fall into the one of the four categories: packed towers, diffused aeration, cascade towers and trays. Due to low concentrations of benzene detected in the groundwater, preference for small, unobtrusive treatment units and ease of equipment maintenance, shallow tray air strippers were selected for this evaluation. Shallow tray air strippers consist of a series of stacked trays to maximize the air-water interface. Water flows over a flat tray, discharges into a lower tray and continues to pass over the required number of trays to achieve the desired cleanup goal. These trays consist of porous bottoms allowing air to be forced up through the tray as the extracted groundwater passes over the trays, increasing turbulence and aeration. Trays may be added or subtracted based on the quality of the extracted groundwater. Shallow tray air strippers are readily available, easy to modify by the addition/removal of a stacked tray and easy to maintain. Alternative air stripping technologies may be evaluated if this remedial alternative is selected for implementation.

Based on the low concentration of benzene detected in the groundwater, HLA determined that the benzene transferred from the dissolved phase to the air phase and released to the atmosphere would be less than the FDEP threshold of 13.7 pounds per day of total VOCs (Appendix C). Therefore, off-gas treatment would not be required. The air strippers would also be located on Herndon Annex well away from the residential area of Azalea Park. Off-gas treatment using vapor-phase GAC would only be used if the emissions were later found to exceed the FDEP standard.

The major components of the full-scale remedial alternative would consist of:

- seven groundwater extraction wells within the highest contaminant concentrations on Herndon Annex and within the Azalea Park Neighborhood; 4-inch polyvinyl chloride (PVC) wells generally screened from 30 to 60 feet bls
- ex-situ treatment by a shallow tray air stripper transferring the benzene contamination in the extracted groundwater from the dissolved-phase into the air phase
- one centralized air stripper to address the southern plume, and a smaller air stripper to address the northeastern groundwater plume
- reinjection of treated groundwater via eight 4-inch injection wells containing solid-phase ORC, and
- a network of 11 existing wells for monitoring contaminant reduction and hydraulic containment.

A schematic of the treatment system is presented in Figure 3-3 showing the location of the extraction wells, central treatment facilities and reinjection/ORC wells. Figure 3-4 identifies the benzene plume that exceeds 10 ug/L (composite of less than 30 feet bls through greater than 50 feet bls) and the groundwater flow lines developed by the operation of several recirculation cells on Herndon Annex and in Azalea Park.

Five of the groundwater extraction wells would be located on Herndon Annex (four in southern plume and one in northern plume) and two would be located across the drainage ditch in Azalea Park (Figure 3-3). All eight reinjection wells containing ORC would be installed on Herndon Annex upgradient of the extraction wells as depicted on Figure 3-3. The extraction and reinjection wells would be operated at a design flow rate of:

Extraction Wells	Reinjection Wells
EW-1 = 25 gpm	IW-1 = 20 gpm
EW-2 = 25 gpm	IW-2 = 19 gpm
EW-3 = 25 gpm	IW-3 = 19 gpm
EW-4 = 25 gpm	IW-4 = 35 gpm
EW-5 = 25 gpm	IW-5 = 19 gpm
EW-6 = 20 gpm	IW-6 = 19 gpm
EW-7 = 25 gpm	IW-7 = 19 gpm
	IW-8 = 20 gpm

The air stripper for the southern plume would have a design flow rate of 150 gallons per minute (gpm) and the northern air stripper would have a design flow rate of 20 gpm. Maintenance of the air stripper system and groundwater extraction and reinjection wells would be required on an annual basis to eliminate any potential fouling of the well screens.

One pore volume turnover would be achieved approximately every 800 days of operation (Figure 3-4). Using the combination of enhanced bioremediation with ex-situ air stripping to treat the benzene-contaminated groundwater (area >10 ug/L), approximately 2 pore volumes would be required to achieve the MCL for benzene. This would result in an estimated treatment duration of approximately 4 years. However, NA of the fringe contamination (<10 ug/L) would require an additional year for a total duration of 5 years.

Existing groundwater monitoring wells would be used to monitor the hydraulic containment of the recirculation system, potential migration of the groundwater plume and reduction of benzene contamination within the cell. These wells are identified in Figure 3-1. In addition to these 11 existing monitoring wells, the groundwater extraction and reinjection wells would be used to monitor the performance of the remedial alternative in achieving the cleanup goal for benzene. Monitoring of the treatment system influent and effluent and groundwater plume would be done to ensure that the ex-situ air stripper met the reinjection permit requirements, and to monitor the rate of enhanced biodegradation and hydraulic containment of the groundwater plume. Following the selection of this remedial alternative, a monitoring plan would be prepared detailing sampling frequency and the analytical program for regulatory approval prior to implementation.

Based on the estimated duration, one five-year site review would also be conducted to re-evaluate the appropriateness of this remedial alternative for Herndon Annex and Azalea Park and to confirm that it achieved the state MCL for benzene. This alternative would be compared to other remedial alternatives to confirm that this was still the most appropriate selection. Data from the groundwater monitoring program would be included within this five-year evaluation.

4.0 EVALUATION OF REMEDIAL ALTERNATIVES

This Chapter presents a detailed evaluation of the four remedial alternatives described in Chapter 3.0 that could address the benzene-contaminated groundwater at Herndon Annex and Azalea Park. This evaluation was performed to provide the decision makers with sufficient information to select the appropriate remedial alternative and has been conducted in accordance with CERCLA Section 121, the NCP (NCP, 1990) and USEPA Remedial Investigation/Feasibility Study (RI/FS) guidance (USEPA, 1988). This detailed evaluation of the remedial alternatives includes an analysis of the alternatives against three primary CERCLA criteria: effectiveness, implementability and cost.

The effectiveness criteria involves the magnitude of residual risk following remediation and the adequacy and reliability of system controls. Implementability includes the ability to construct the remedial alternative, reliability of the technology, ease of implementing the alternative and coordination with regulatory agencies. The last evaluation criteria, cost, includes capital and O&M costs and the total present worth of the remedial alternative. Present worth costs have been calculated using an interest rate of 6% and include a 10% contingency due to remaining design and regulatory details to be determined (Appendix D). These cost estimates have been prepared based on previous feasibility studies, remedial actions and vendor information, and should be accurate within +50 percent to –30 percent, in accordance with USEPA guidance (USEPA, 1988).

4.1 ALTERNATIVE NO. 1 – NO ACTION.

The No Action alternative implies that no action will be taken to either treat or monitor the benzene concentrations detected in the groundwater beneath Herndon Annex and the Azalea Park Neighborhood. This alternative ultimately relies on the natural attenuation of the benzene (without groundwater monitoring) and five-year site reviews.

Effectiveness. This administrative action would not provide any treatment of the benzene, or prevent possible human exposure or consumption of contaminated groundwater.

Implementability. The implementation of five-year site reviews could readily be implemented at Herndon Annex and the Azalea Park Neighborhood.

Cost. The present worth for this remedial alternative is estimated to be $52,800. A breakdown of the No Action costs is presented in Table 4-1, with an assumed duration of 30 years, as suggested by the USEPA guidance (USEPA, 1988). This estimate shows that all costs are associated with the five-year site review process; more detailed cost estimate information is presented in Table D-1 of Appendix D.

4.2 ALTERNATIVE NO. 2 – NATURAL ATTENUATION (NA).

Effectiveness. Limited NA has been confirmed to be ongoing at Herndon Annex (HLA, 1999b and Appendix A). NA can be a reliable and cost effective solution for contaminated aquifers, and has been shown to be particularly effective for benzene-contaminated groundwater under anaerobic conditions. The existing site conditions support the use of this technology as the remedial alternative for the entire groundwater plume beneath both Herndon Annex and the Azalea Park Neighborhood. It appears that the ongoing NA is occurring under an anaerobic condition (without oxygen), which is a much slower process for benzene than under aerobic conditions (with oxygen). The slower rate of reduction associated with the anaerobic conditions of the site is acceptable as long as there continue to be no adverse exposure scenarios to the public (e.g., drinking water supply). To ensure that this does not occur during the NA of the benzene plume, groundwater use restrictions would be implemented to eliminate the potential exposure pathways for all of the existing and future industrial/residential receptors.

This remedial alternative would reduce the toxicity, mobility and volume of benzene contamination detected in the groundwater using natural processes. Continued groundwater monitoring, implementation of groundwater use restrictions and five-year site reviews would ensure that this remedial approach would prevent possible human

Table 4-1
Cost Summary for Alternative No. 1: No Action

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
	$0
Total Direct Cost	$0
INDIRECT COSTS	
	$0
Total Indirect Cost	$0
Total Capital Cost (Direct + Indirect)	$0
OPERATION AND MAINTENANCE (O&M) COSTS	
Five-Year Site Reviews (once every 5 years for 30 years)	
Present Worth - Five-Year Site Reviews (6%, 30 years)	$47,959
Total O&M Cost (present worth)	$47,959
Total Capital and O&M Cost	$47,959
Contingency (10%)	$4,796
Total Cost of Alternative No. 1: No Action	$52,755

Notes: % = percent.
O&M = operation and maintenance.

exposure or consumption of contaminated groundwater. These monitoring activities and groundwater use restrictions would be eliminated once the benzene-contaminated groundwater was reduced to its MCL of 1 ug/L. HLA estimated the duration of this remedial alternative to be approximately 30 years.

Implementability. The implementation of NA, groundwater monitoring and five-year site reviews could readily be implemented at Herndon Annex and Azalea Park. Land use plans (e.g., zoning regulations) for affected land within Herndon Annex and Azalea Park would be annotated to indicate that groundwater extraction for potable use in this area may pose an unacceptable health risk if consumed without treatment. This annotation would also include restrictions and/or advisories associated with groundwater extraction for non-potable uses that might adversely expose the public to benzene-contaminated groundwater (e.g., lawn sprinklers, gardens, etc.). A groundwater monitoring plan to confirm the natural degradation of benzene has been prepared and can readily be implemented (Appendix A).

Cost. The capital cost for this alternative is approximately $16,500 and has a total present worth of $460,200. A breakdown of the costs associated with the preparation of groundwater use restrictions, implementation of the groundwater monitoring plan, and five-year site reviews is presented in Table 4-2. Detailed cost estimates for this remedial alternative are presented in Table D-2 of Appendix D. This estimate has assumed that the NA process will require approximately 30 years to achieve the MCL for benzene in groundwater.

The groundwater monitoring plan requires that 11 existing monitoring wells be sampled on a regularly scheduled basis to confirm the natural degradation of benzene contamination. The proposed schedule consists of sampling quarterly for the first 2 years, biannually for the next 3 years and annually for the remaining 25 years. The analytical parameters would include VOCs and NA parameters (listed in subsection 3.2).

4.3 ALTERNATIVE NO. 3 – ENHANCED BIOREMEDIATION

Effectiveness. The use of an ORC slurry injection to biodegrade the benzene-contaminated groundwater is well proven for fuel-related compounds. The grid of slurry injection points throughout the two groundwater plumes was designed to expedite the natural degradation of benzene to nontoxic compounds. The use of ORC would however, cause a slight increase of inorganic precipitate within the aquifer. This should be at a low concentration and should not adversely affect the water quality of the shallow aquifer.

Based on the site hydrogeological characteristics, the low concentrations of benzene detected in the groundwater, and injection of ORC throughout the groundwater plumes (northern and southern), the benzene-contaminated groundwater could quickly achieve the MCL of 1 ug/L. This would be achieved through a single application of the ORC slurry. It has been estimated that the cleanup goal for benzene could be achieved within 4 years in areas where benzene contamination exceeds 10 ug/L. Those fringe areas with benzene concentrations below 10 ug/L would likely achieve the MCL over a period of 5 years through monitored natural attenuation. This would be a significant reduction in treatment time in comparison to the estimated 30 years for monitored natural attenuation alone to completely remediate the plumes.

This remedial alternative would reduce the toxicity, mobility and volume of benzene contamination detected in the groundwater. Groundwater monitoring over a period of 5 years and one five-year site review would ensure that this remedial approach would prevent possible human exposure or consumption of contaminated groundwater. The groundwater use restrictions would be eliminated once the benzene-contaminated groundwater was reduced to its MCL of 1 ug/L.

Implementability. A full-scale enhanced bioremediation response could readily be implemented at both the Herndon Annex and Azalea Park Neighborhood using a direct push delivery system for the ORC slurry. Figure 3-2 identifies the proposed locations of slurry injection to address both the northern and southern groundwater plumes. The use of a DPT delivery of ORC has been successfully implemented at sites throughout the country. DPT was also used successfully at Herndon Annex during the site investigation of the groundwater plume. The use of DPT would also eliminate the need to install and abandon a large number of injection wells throughout the Annex and adjacent residential area. A small support system would be required on Herndon Annex for the implementation of this technology, along with groundwater monitoring before, during and after the single ORC slurry injection event.

Table 4-2
Cost Summary for Alternative No. 2: Natural Attenuation

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Cost Item		Cost
DIRECT COSTS		
Groundwater Use Restrictions		$10,000
	Total Direct Cost	$10,000
INDIRECT COSTS		
Health and Safety		$500
Administration and Permitting		$1,000
Engineering and Design		$4,000
Construction Support Services		$1,000
	Total Indirect Cost	$6,500
	Total Capital Cost (Direct + Indirect)	$16,500
OPERATION AND MAINTENANCE (O&M) COSTS		
Natural Attenuation Monitoring (30-year period)		
	Present Worth - Entire Benzene Plume (6%, 30 years)	$353,863
Five-Year Site Reviews (once every 5 years for 30 years)		
	Present Worth - Five-Year Site Reviews (6%, 30 years)	$47,959
	Total O&M Cost (present worth)	$401,822
	Total Capital and O&M Cost	$418,322
	Contingency (10%)	$41,832
	Total Cost of Alternative No. 2: Natural Attenuation	$460,154

Notes: % = percent.
O&M = operation and maintenance.

Cost. The capital cost for this alternative is approximately $189,700, with a total present worth of $399,500. A breakdown of the costs associated with the delivery of ORC, groundwater monitoring of the in-situ enhanced bioremediation process, and five-year site review is presented in Table 4-3. A detailed cost estimate for this remedial alternative is presented in Table D-3 of Appendix D. HLA estimated that this enhancement of natural attenuation to remediate the benzene-contaminated groundwater would achieve the MCL in approximately 5 years.

A groundwater monitoring plan would be prepared as part of the response action, and will likely include the monitoring of 11 existing wells located throughout the benzene plume. The proposed monitoring schedule consists of quarterly sampling of the monitoring wells for the first two years and then annual monitoring of the groundwater quality for the remaining 3 years. The analytical parameters would include VOCs and NA parameters. One five-year site review will be conducted as discussed in section 4.2.

4.4 ALTERNATIVE NO. 4 – ENHANCED BIOREMEDIATION WITH EX-SITU AIR STRIPPING.

Effectiveness. The use of ORC and ex-situ air stripping to individually treat benzene-contaminated groundwater is well proven. Based on the estimated groundwater extraction rates and the low concentration of benzene detected in the groundwater, a shallow-tray air stripper would readily transfer the benzene contamination from the dissolved phase into the air stream. The concentrations within the air stream were calculated to be below the 13.7 pounds per day FDEP limit, such that off-gas treatment would not be required (Appendix C). If actual emissions were found to exceed the FDEP criteria, then vapor-phase GAC could be used to remove the benzene vapors from the effluent air stream prior to being emitted into the atmosphere. The extraction/reinjection well configuration presented in Figure 3-4 would also result in the only remedial alternative to provide hydraulic containment of the benzene plume within this FFS. The recirculation cell for the northern plume would operate at an estimated flow rate of 20 gpm while the southern plume system would operate at an estimated flow rate of 150 gpm. To further ensure the protection of the public health during the remediation of the benzene plume, groundwater use restrictions would be implemented to eliminate the potential exposure pathways for all of the existing and future industrial/residential receptors. These groundwater use restrictions would be eliminated when the groundwater plume meets the MCL for benzene.

This remedial alternative would reduce the toxicity, mobility and volume of benzene contamination detected in the groundwater. Groundwater use restrictions, continued groundwater monitoring and five-year site reviews would ensure that this remedial approach would prevent possible human exposure or consumption of contaminated groundwater. The groundwater use restrictions and monitoring activities would be eliminated when the benzene-contaminated groundwater was reduced to its MCL of 1 ug/L.

Implementability. A full-scale enhanced bioremediation system can be constructed on Herndon Annex and support the degradation of benzene-contaminated groundwater beneath both Herndon Annex and the Azalea Park Neighborhood. The existing site conditions would support the use of this remedial alternative for the entire groundwater plume beneath both Herndon Annex and the Azalea Park Neighborhood. All but two of the groundwater extraction wells and all of the reinjection wells would be located on the Herndon Annex (Figure 3-3). Two groundwater extraction wells would be located along the residential streets (Nancy Lee Avenue and Bobby Street). The air strippers would also be located on Herndon Annex such that the O&M of the groundwater treatment system would not disturb the residents of Azalea Park. All of the piping would be installed underground and the groundwater extraction and reinjection wells would be located inside locking underground vaults.

Shallow tray air strippers are readily available and can be sized for the specific groundwater flow rates, influent concentrations of benzene (conservatively estimated to be 50 to 100 ug/L) and an effluent goal of 1 ug/L. Due to the potential for low level benzene vapors to be released from the air stripper, the systems would be constructed outside existing buildings 6001 and 605, taking advantage of available electrical power and a source of potable water. A small emissions stack would be constructed adjacent to each treatment system to ensure proper dispersion of the system off-gas. Piping and electrical lines from the extraction/injection wells would be buried in a shallow trench along the side of existing roadways with clear marking of its location. The extraction pump controls and sampling locations for each extraction/injection well would be centrally located at the treatment systems.

Table 4-3
Cost Summary for Alternative No. 3: Enhanced Bioremediation

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater Use Restrictions	$10,000
Site Preparation and Mobilization	$24,400
ORC Injection and Support System	$120,315
Total Direct Cost	$154,715
INDIRECT COSTS	
Health and Safety	$5,000
Administration and Permitting	$5,000
Engineering and Design	$15,000
Construction Support Services	$10,000
Total Indirect Cost	$35,000
Total Capital Cost (Direct + Indirect)	$189,715
OPERATION AND MAINTENANCE (O&M) COSTS	
ORC/NA Groundwater Monitoring (4 years)	
Present Worth - System Operation (6%, 5 years)	$158,775
Five-Year Site Reviews (once after 5 years)	
Present Worth - Five-Year Site Reviews (6%, 5 years)	$14,677
Total O&M Cost (present worth)	$173,452
Total Capital and O&M Cost	$363,167
Contingency (10%)	$36,317
Total Cost of Alternative No. 3: Enhanced Bioremediation	$399,484

Notes: % = percent.
O&M = operation and maintenance.

Cost. The capital cost for this alternative is approximately $78,300 and has a total present worth of $1,612,200. A breakdown of the costs associated with the design, construction and O&M of the air strippers and enhanced bioremediation systems, and five-year site review is presented in Table 4-4. A detailed cost estimate for this remedial alternative is presented in Table D-4 of Appendix D. HLA estimated that this aggressive approach to remediating the benzene-contaminated groundwater would achieve the MCL in 5 years.

A groundwater monitoring plan would be prepared as part of the system design, but has been assumed to include the monitoring of the 7 extraction wells, the treated groundwater from each of the air strippers (prior to reinjection) and 11 existing monitoring wells located throughout the benzene plume. The proposed schedule consists of monthly sampling of the extraction wells and treated groundwater, and biannual sampling of the monitoring wells for enhanced bioremediation evaluations. The analytical parameters would include VOCs and NA parameters. One five-year site review would also be conducted as discussed in section 4.2.

Table 4-4
Cost Summary for Alternative No. 4: Enhanced Bioremediation with Ex-situ Air Stripping

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater Use Restrictions	$10,000
Site Preparation and Mobilization	$95,900
Groundwater Extraction System	$470,908
Shallow-Tray Air Strippers	$52,500
Enhanced Bioremediation (ORC)	$36,000
Total Direct Cost	$665,308
INDIRECT COSTS	
Health and Safety	$20,000
Administration and Permitting	$15,000
Engineering and Design	$40,000
Construction Support Services	$40,000
Total Indirect Cost	$115,000
Total Capital Cost (Direct + Indirect)	$780,308
OPERATION AND MAINTENANCE (O&M) COSTS	
Air Strippers (4 years)	
Present Worth - System Operation (6%, 4 years)	$385,031
Enhanced Bioremediation (4 years)	
Present Worth - System Operation (6%, 4 years)	$124,740
Present Worth - Groundwater Monitoring (6%, 4 years)	$160,898
Five-Year Site Reviews (once after 5 years)	
Present Worth - Five-Year Site Reviews (6%, 5 years)	$14,677
Total O&M Cost (present worth)	$685,346
Total Capital and O&M Cost	$1,465,654
Contingency (10%)	$146,565
Total Cost of Alternative No. 4: Enhanced Bioremediation with Ex-situ Air Stripping	$1,612,219

Notes: % = percent.
O&M = operation and maintenance.

5.0 COMPARISON OF REMEDIAL ALTERNATIVES EVALUATED

Remedial alternatives for Herndon Annex and the Azalea Park Neighborhood were developed (Chapter 3.0) and individually evaluated (Chapter 4.0) using three of the seven technical criteria recommended in the NCP, effectiveness, implementability and cost. This chapter presents a comparison of remedial alternatives with respect to these criteria. This comparison is intended to provide technical information for the selection of a preferred alternative. Table 5-1 has also been prepared to summarize the evaluations for the effectiveness, implementability and cost criteria, as well as responses clarifying if the remedial technologies are in-situ or ex-situ, VOCs are reduced, time to achieve the MCL, hydraulic containment achieved and if residuals are produced.

As presented in Chapter 3.0, remedial alternatives were developed to accomplish the remedial goal (MCL of 1 ug/L) for the benzene-contaminated groundwater located beneath both Herndon Annex and the adjacent Azalea Park neighborhood. In addition, these remedial alternatives focused on the elimination or reduction of exposure by humans to the contaminated groundwater, and emphasized the use of treatment technologies to reduce the toxicity, mobility or volume of constituents rather than technologies that solely prevent exposure.

Alternatives evaluated within this FFS included: No Action, NA, Enhanced Bioremediation (ORC slurry injection) and Enhanced Bioremediation (solid-phase ORC) with ex-situ Air Stripping.

5.1 EFFECTIVENESS.

The effectiveness includes the magnitude of residual risk following remediation and the adequacy and reliability of system controls. The No Action alternative would not provide any treatment of the benzene, or prevent possible human exposure or consumption of contaminated groundwater, such that a significant residual risk would continue at the site. The No Action approach would ultimately rely on NA (without monitoring) to address the benzene contamination and protect the public from adverse contact with the contaminated groundwater. The reliability of unmonitored NA would be low.

The effectiveness of monitored NA (Remedial Alternative No. 2) would have greater reliability than the No Action alternative. This increased reliability is based on the monitored reduction of benzene in the groundwater plume and implementation of groundwater use restrictions until the MCL for benzene was achieved. The observed rate of contaminant reduction is likely due to the anaerobic conditions of the aquifer. This rate of benzene reduction would meet the remedial action objective while eliminating potentially adverse exposure scenarios to the public (e.g., drinking water supply).

The injection of an ORC slurry (Remedial Alternative No. 3) into the groundwater plumes would enhance the existing natural attenuation of the benzene contamination. ORC has been found to be very effective on fuel-related compounds and the delivery method of DPT has already been successfully demonstrated to the required depths at Herndon Annex and the Azalea Park Neighborhood. This remedial alternative would require a single application of the ORC slurry followed by groundwater monitoring for a period of 4 years. This would expedite the natural degradation of benzene and achieve the cleanup goal of 1 ug/L in a shortest period of time. Continued groundwater monitoring (total of 5 years) and a five-year site review would ensure that this remedial approach would achieve the cleanup goal for the entire benzene plume. Groundwater use restrictions would be used to protect the public from any adverse exposure to the contaminated groundwater until it could be remediated to the MCL.

The use of ORC (solid phase) and ex-situ air stripping to individually treat benzene-contaminated groundwater is well proven. Based on the estimated groundwater extraction rates and the low concentration of benzene detected in the groundwater, a shallow-tray air stripper would readily transfer the benzene contamination from the dissolved phase into the air stream. The benzene concentrations within the air stream were calculated to be less than 0.5 pounds per day, such that off-gas treatment would not be required (Appendix C). This remedial alternative would reduce the toxicity, mobility and volume of benzene contamination detected in the groundwater. Continued groundwater monitoring and five-year site reviews would ensure that this remedial approach would prevent human exposure or consumption of contaminated groundwater. This is the only remedial alternative that provides hydraulic containment of the groundwater plumes during remediation and has the same estimated duration to achieve the MCL

Table 5-1
Summary of Comparative Analysis for Remedial Alternatives

Base Realignment and Closure
Focused Feasibility Study
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Alternative:	No. 1 No Action	No. 2 Natural Attenuation	No. 3 Enhanced Bioremediation	No. 4 Enhanced Bioremediation with Ex-situ Air Stripping
Groundwater Remediation				
Groundwater extracted?	No	No	No	Yes
Organics reduced?	Unknown	Yes	Yes	Yes
Estimated time to achieve drinking water standards (years):	Indefinite	30	5[1]	5[1]
Plume contained?	No	No	No	Yes
Remedy permanent?	Unknown	Yes	Yes	Yes
MCL attained?	Unknown	Yes	Yes	Yes
Reliability to achieve MCL?	Low	Medium	Medium	High
Residuals produced?	No	No	No	No[2]
Operation and Maintenance				
Treatment O&M Duration (yrs)	+30	30	4[1]	7[1]
Utilities Maintenance	No	No	No	Yes
Groundwater Monitoring	No	Yes	Yes	Yes
Total Cost				
Present Worth	$52,800	$460,200	$399,500	$1,612,200
Capital	$0	$16,500	$189,700	$780,300

[1] Plume >10 ug/L treated to MCL within 4 years while fringe area to achieve MCL in 5 years.
[2] Estimated air emissions meet FDEP air regulations without further treatment (Appendix C).

Notes: MCL = maximum contaminant level.
O&M = operation and maintenance.

as Alternative No. 3 (5 years). This alternative also provides a greater reliability than Alternative No. 3, Enhanced Bioremediation, due to the ex-situ treatment of contaminated groundwater and amendment of treated groundwater within a hydraulically-contained plume. Groundwater use restrictions would also be used to protect the public from any adverse exposure to the contaminated groundwater until it met the MCL.

5.2 IMPLEMENTABILITY.

Implementability includes the ability to construct the remedial alternative, reliability of the technology, ease of implementing the alternative and coordination with regulatory agencies. Under the first alternative, the implementation of five-year site reviews could readily be implemented at Herndon Annex and the Azalea Park Neighborhood. However, there would be no assurance that human exposure to the contaminated groundwater would be eliminated by this No Action alternative. This alternative would solely rely on the five-year monitoring of Study Area 2 to identify any potential change in site conditions and new exposure pathways. Remedial Alternative No. 2, NA, would include the monitoring of the groundwater quality and benzene degradation to achieve the MCL and the implementation of groundwater use restrictions/advisories to protect the public from adverse exposure scenarios. Both the groundwater monitoring and implementation of groundwater use restrictions could be readily implemented at the site.

A full-scale enhanced bioremediation response action (Remedial Alternative No. 3) could readily be implemented at both the Herndon Annex and Azalea Park Neighborhood using a DPT delivery system for the ORC slurry (Figure 3-2). A DPT delivery of the ORC slurry has been successfully implemented at sites throughout the country. This technology has also been successfully demonstrated at Herndon Annex during the site investigation of the groundwater plume. The use of DPT would eliminate the need to install and abandon a large number of injection wells throughout the annex and adjacent residential area. Groundwater monitoring and a five-year site review would support a single ORC injection event to ensure that the groundwater quality ultimately met the MCL for benzene.

A full-scale enhanced bioremediation system with ex-situ treatment of extracted groundwater (Remedial Alternative No. 4) could readily be constructed at both Herndon Annex and the Azalea Park Neighborhood. The necessary utilities and site access are available on Herndon Annex where the bulk of the system would be constructed. The extraction/injection well configurations presented in Figures 3-3 and 3-4 would address both the southern and northern groundwater plumes. In addition, air strippers have been widely used for the treatment of VOCs, and enhanced bioremediation is a reliable supplement to expedite the degradation of the groundwater plume. The air strippers would also be located on Herndon Annex to avoid any potential adverse impacts to the Azalea Park area from low level emissions and O&M of the groundwater treatment systems. Although this alternative would be the most reliable of the four (ex-situ treatment, amendment of treated groundwater and hydraulic containment of the groundwater plume), it would also be the most difficult to permit and construct. This is due to the permitting for the reinjection of treated groundwater, and the installation of the two groundwater extraction wells and the associated piping along public roadways and beneath the drainage ditch.

5.3 COST.

The last evaluation criteria, cost, includes capital and O&M costs and the total present worth of the remedial alternative. Present worth costs have been calculated using an interest rate of 6% and include a 10% contingency due to remaining design and regulatory details to be determined.

The present worth for Remedial Alternative No. 1, No Action, is estimated to be $52,800. There are no capital costs associated with this alternative, only five-year site reviews. A breakdown of the costs associated with the five-year site review is presented in Table 4-1, with an assumed duration of 30 years. More detailed cost estimate information is presented in Table D-1 of Appendix D.

The capital cost for the second remedial alternative, NA, is approximately $16,500 and a total present worth of $460,200. The capital costs are limited to the preparation of groundwater use restrictions, while the O&M costs include the implementation of the groundwater monitoring plan, and five-year site reviews (Table 4-2). A detailed cost estimate for this remedial alternative is presented in Table D-2 of Appendix D. HLA estimated that the NA process would require approximately 30 years to achieve the MCL for benzene in groundwater.

The capital cost for Enhanced Bioremediation, Remedial Alternative No. 3, is approximately $189,700 and has a total present worth of $399,500. A breakdown of the costs associated with the preparation of groundwater use restrictions, delivery of the ORC slurry, groundwater monitoring of the in-situ, enhanced bioremediation process, and five-year site review is presented in Table 4-3. A detailed cost estimate for this remedial alternative is presented in Table D-3 of Appendix D. HLA estimated that this enhancement of natural attenuation to remediate the benzene-contaminated groundwater would achieve the MCL for benzene for the entire plume in approximately in 5 years.

The capital cost for Remedial Alternative No. 4, Enhanced Bioremediation with Ex-situ Air Stripping, is approximately $780,300 and has a total present worth of $1,612,200. This is the most costly of the four remedial alternatives, but the most aggressive in achieving the cleanup goal for the site while providing hydraulic containment of the benzene-contaminated groundwater. The MCL would be achieved in approximately 5 years, similar to Alternative No. 3. Capital costs include the design, permitting and construction of the air strippers and enhanced bioremediation systems. O&M costs are also significant due to the monitoring requirements of the ex-situ treatment system and the reinjection of groundwater to provide enhanced bioremediation, along with hydraulic containment of the groundwater plume. These costs are summarized in Table 4-4 and detailed costs are presented in Table D-4 of Appendix D.

5.4 SUMMARY OF REMEDIAL ALTERNATIVE EVALUATION.

Table 5-1 summarizes the evaluation conclusions for convenient comparison between the different alternatives. The No Action alternative was retained in accordance with the NCP, while the NA alternative (No. 2) offers a passive and low cost alternative to remediate the benzene plume, but with less assurance of achieving the MCL and a long duration. Remedial Alternative No. 3, enhanced bioremediation, would expedite the natural degradation of the benzene plumes to achieve the MCL in the shortest time frame and with a relatively small present worth cost. The last remedial alternative, enhanced bioremediation with ex-situ air stripping, would satisfy all of the evaluation criteria, and a similar short treatment duration while providing hydraulic containment of the benzene plumes. However, this last remedial alternative also has the highest estimated cost.

The schematic design of the remedial alternatives (Chapter 3.0 and Figures 3-2 through 3-4), and the remedial alternative evaluation (Chapters 4.0 and 5.0) should be used to evaluate the benefits of the different approaches in achieving the cleanup goal for the site. The comparison presented in Table 5-1 is further intended to provide technical information for the selection of a preferred alternative.

In accordance with the USEPA guidance (USEPA, 1988), the undersigned members of the Orlando Partnering Team have reviewed this FFS and support the evaluation results for presentation and acceptance by the community.

STUDY AREA 2, HERNDON ANNEX

U.S. Environmental Protection Agency, Region IV ____ Date ____

Florida Department of Environmental Protection ____ Date ____

U.S. Department of the Navy ____ Date ____

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APPENDIX A
NATURAL ATTENUATION MONITORING WORK PLAN

STUDY AREA 2, HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

NOVEMBER 1999

APPENDIX A
NATURAL ATTENUATION MONITORING WORK PLAN

STUDY AREA 2, HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

Unit Identification Code: N65928

Contract No. N62467-89-D-0317/107

Prepared by:

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NOVEMBER 1999

CERTIFICATION OF TECHNICAL
DATA CONFORMITY (AUGUST 1999)

The Contractor, Harding Lawson Associates, hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0317/107 are complete and accurate and comply with all requirements of this contract.

DATE: November 15, 1999

NAME AND TITLE OF CERTIFYING OFFICIAL: John Kaiser
Task Order Manager

NAME AND TITLE OF CERTIFYING OFFICIAL: Richard Allen
Project Technical Lead

The engineering evaluations and professional opinions rendered in this planning document that describes the Natural Attenuation Monitoring for Herndon Annex, Study Area 2, Naval Training Center, Orlando, Florida, were conducted or developed in accordance with commonly accepted procedures consistent with applicable standards of practice.

HARDING LAWSON ASSOCIATES
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Expires February 28, 2001

Date: November 15, 1999

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GLOSSARY

ABB-ES	ABB Environmental Services, Inc.
bls	below land surface
COC	contaminant of concern
DO	dissolved oxygen
DPT	direct-push technology
FAC	Florida Administrative Code
FFS	Focused Feasibility Study
FTA	firefighter training area
HLA	Harding Lawson Associates
MCL	maximum contaminant level
µg/L	micrograms per liter
mg/L	milligrams per liter
mv	millivolts
NA	Natural Attenuation
NTC	Naval Training Center
OPT	Orlando Partnering Team
PCE	tetrachloroethene
Redox	oxidation/reduction
SOUTHNAV-FACENGCOM	Southern Division, Naval Facilities Engineering Command
TEA	terminal electron acceptor
TCE	trichloroethene

1.0 INTRODUCTION

Natural attenuation (NA) has been identified as a potential remedy for benzene-contaminated groundwater at Study Area 2, Herndon Annex, Naval Training Center (the Site) Orlando, Florida. Under contract to the Naval Facilities Engineering Command, Southern Division (SOUTHNAVFACENGCOM), Harding Lawson Associates (HLA, formerly ABB Environmental Services, Inc. [ABB-ES]) prepared an Environmental Site Screening Report (HLA, 1999b) that confirmed the presence of benzene contamination in the groundwater beneath the Herndon Annex and adjacent Azalea Park Neighborhood. Subsequently, HLA prepared a preliminary identification of remedial technologies that could be used to treat the benzene-contaminated groundwater beneath Herndon Annex and the Azalea Park Neighborhood (HLA, 1999a), which was presented to the Orlando Partnering Team (OPT) in February 1999. This preliminary list of remedial technologies included NA. As part of a NA response action, it will be necessary to monitor groundwater conditions to confirm the trends observed at the Site and to ensure groundwater treatment objectives will be met. This groundwater monitoring plan describes the sampling and analysis program for groundwater at Study Area 2.

The monitoring plan has been prepared to satisfy the objective of protecting human health and the environment from benzene contaminated groundwater beneath Herndon Annex and the Azalea Park Neighborhood. This workplan also establishes a reasonable exit strategy that will define when a satisfactory level of cleanup has been achieved. This groundwater monitoring plan is divided into the following sections: :results from previous site investigations; objectives of the monitoring plan; specific monitoring plan components; data assessment methodology; contingency plan components; and, the exit strategy.

1.1 RESULTS FROM SITE INVESTIGATIONS. HLA prepared a Site Screening Report for Study Area 2 (HLA, 1999b), under the Comprehensive Long-Term Environmental Action, Navy Contract No. N62467-89-D-0317 as Contract Task Order No. 107. The objective of the site screening investigation was to locate and identify any compounds that may be present at concentrations in excess of screening criteria. The investigation required several phases to complete. During the Phase I field investigation completed in September 1994, no contaminants were found in excess of screening criteria in either soil or groundwater. However, geophysical surveys indicated the likelihood that landfill materials were present, and OPT concerns about leaching of landfill materials to groundwater prompted the need for a Phase II investigation. This investigation included the collection of surface soil samples within mapped landfill areas and installation of additional monitoring wells downgradient from those areas. Phase II was completed in June 1996; results included two groundwater samples from wells screened at the base of the surficial aquifer with benzene detected at concentrations exceeding State and Federal maximum contaminant levels (MCLs). Other chlorinated solvents, including tetrachloroethene (PCE) and trichloroethene (TCE), were detected during these investigations, but their occurrences were less consistent than benzene and their concentrations were not indicative of widespread chlorinated solvent contamination. These findings led the OPT to request a continuation of Phase II screening investigations to evaluate and characterize the benzene contamination in the surficial aquifer and determine whether or not the contaminant source was located under Herndon Annex. The additional Phase II screening was completed with direct-push technology (DPT), which utilized a cone penetrometer testing rig, and resulted in the conclusion that an off-site (upgradient) benzene source may exist.

In June 1996, the U.S. Army Corps of Engineers conducted an investigation on behalf of the Greater Orlando Aviation Authority to determine if groundwater upgradient (south) of Herndon Annex had benzene contamination. The study collected groundwater samples up to 40 feet below land surface (bls) and did not detect any contamination. However, this study was considered inconclusive by the OPT, as the Phase I and Phase II investigations had only detected benzene above MCLs at depths greater than 40 feet bls.

In October 1996, HLA completed Phase III site screening activities, which consisted of a second DPT survey to better define the location of benzene contamination. Phase III also included the installation of three piezometer clusters to better evaluate the direction of horizontal groundwater flow and vertical hydraulic head differences in the surficial aquifer. The benzene contamination plume, as determined in Phase III, was largely confined to the southeastern corner of Herndon Annex at depths from 40 to 62 feet bls. HLA concluded that the data could not preclude an on-site benzene source. However, the absence of benzene detections at depths shallower than 40 feet bls reduced the likelihood of an on-site release. Historical evidence suggested a potential benzene and/or chlorinated solvent source at the former firefighter training area (FTA), upgradient from Herndon Annex, that allegedly operated from 1947 to 1962. Other potential sources are the numerous World War II era aircraft parking aprons, many of which are upgradient of the Annex, and the refueling or defueling operations that undoubtedly took place there.

Due to the presence of benzene above MCLs along the eastern margin of Herndon Annex, HLA conducted a final phase of investigation, Phase IV, in 1997, to map the benzene plume in the deep surficial aquifer. Field activities included additional groundwater screening with DPT both on site (Herndon Annex) and off site (in the Azalea Park Neighborhood east of Herndon Annex). Groundwater screening was followed by the installation of eight monitoring wells screened at various depths to confirm screening results.

Based on data collected through 1997, HLA concluded that a benzene plume exists under Herndon Annex and the Azalea Park Neighborhood at concentrations of up to 83 micrograms per liter (µg/L), the highest benzene concentration measured from any monitoring well. Although the source of the plume has not been positively identified, the historical, geologic, and chemical data collected in site screening activities indicate the strong likelihood that the contamination is due to past site activities by the U.S. Army Air Corps and the U.S. Air Force.

The footprint of the plume at depths greater than 50 feet bls is more than 50 acres in size. The zone of contamination is from 10 to 30 feet thick and is largely confined to depths greater than 40 feet bls. An exception to this is the drainage ditch that forms the east boundary of Herndon Annex, where contaminants are discharging to surface water at the base of the ditch. The site screening data are consistent with a benzene plume that has migrated onto Herndon Annex and whose source is depleted. Further attempts to define the source(s) of contamination would very likely prove to be futile. Benzene appears to be the only contaminant of concern (COC).

OPT concerns during review of the draft final report for Herndon Annex included a recommendation that two additional monitoring wells be installed (intermediate and deep depth intervals) in the portion of the benzene plume with the highest contaminant concentrations (as determined from DPT). The OPT also required groundwater sampling of all the monitoring wells for volatiles and NA parameters. This was completed in the Fall of 1998. HLA concluded from these and previous data that NA is likely taking place in the four monitoring wells in which there are benzene detections (Chapter 6.2, HLA, 1999b). The groundwater data from these wells indicated an apparent decrease in benzene concentrations between August 1997 and December 1998, however additional data are required to confirm this NA trend.

<u>1.2 NATURAL ATTENUATION ASSESSMENT</u>. NA is defined as the reduction in contaminant mass that is the result of physical, chemical and biological mechanisms. Some of the key factors that are considered when evaluating NA as a remedy at a site includes source reduction, plume stability, risk to human health and the environment and potential for the groundwater contaminant to undergo biological biodegradation.

Benzene has been shown to be the primary COC at Study Area 2 and the plume in both shallow and deep aquifer is shown in Figures 1-4 through 1-7. The benzene has been detected in groundwater monitoring wells at concentrations as high as 83 µg/L. Historical groundwater data collected from monitoring wells is available from 1995, 1997 and 1998, which are presented in Table A-1 and Figure A-1, Appendix A. Data from the DPT investigations are reported in the Environmental Site Screening Report. (HLA, 1999b).

Based on a review of Table A-1, data trends suggest benzene concentrations are stable in one well (OLD0208C) and the other three wells for which there is history (OLD0210C, OLD0213C, and OLD0219C), benzene concentrations are beginning to decrease. However, additional data are needed to confirm these apparent trends. Overall, benzene levels appear to be either stable or decreasing and there is no evidence to suggest the plume will expand beyond current boundaries.

Attempts have been made in previous investigations to define the source; however, there is no evidence of free product or elevated concentrations that would suggest the presence of a continuing source. For the purposes of this document, any reference to "source" is intended to refer to the portion of the site with the highest benzene concentrations. Thus the "source" is in the vicinity of well OLD0213C.

In order for NA to be considered at Study Area 2, it is necessary to evaluate the subsurface conditions to understand which microbial processes are most active. Benzene biodegrades most rapidly under aerobic conditions, but may degrade under anaerobic conditions, although more slowly. Oxidation/reduction (Redox) parameters were measured and electron acceptor analysis was conducted to determine if conditions were anaerobic or aerobic and which electron acceptors were available. The results of this evaluation are summarized below.

<u>1.2.1 Natural Attenuation Parameter Analysis Results</u> NA parameters were analyzed during the Phase IV investigations, including redox conditions and electron acceptor concentrations. These data presented in Table A-1 of Appendix A suggest that site conditions are anaerobic; thus, benzene biodegradation may be relatively slow. The results from the analysis of the NA parameters are discussed in more detail below.

<u>Alkalinity</u>. An increase in alkalinity from upgradient to downgradient locations would indicate that aerobic degradation is occurring and has produced carbon dioxide, thereby increasing the alkalinity of the groundwater. Using OLD0212C as the upgradient point, there does not seem to be much difference in alkalinity levels based on the data in wells OLD0213C and OLD0219C, although there is a slight increase in alkalinity in well OLD 210C. Each of these latter three wells is located within the plume.

<u>Dissolved oxygen.</u> Dissolved oxygen (DO) in groundwater is a primary and preferred terminal electron acceptor (TEA) for aerobic biodegradation. The DO readings ranged from 0.9 milligrams per liter (mg/L) to 3.5 at well locations where benzene has been detected (OLD0208C, OLD0210C, OLD0213C, OLD0219C, OLD0220B, OLD0221C). The DO reading in the background well, OLD212C was 3.6 mg/L. The DO readings within the plume are somewhat contradictory with the redox readings, since redox levels were detected in a negative range more consistent with anaerobic conditions, while the DO readings of several mg/L suggest aerobic conditions. HLA concluded that although the DO levels are elevated, conditions are predominantly anaerobic based on results from other NA parameters (e.g. redox, methane). Also, since benzene levels appear to persist in groundwater, oxygen may not be readily available to microorganisms. Accurate DO readings can be problematic and are also susceptible to interference from ambient air during the analysis.

<u>Nitrate.</u> When oxygen in the groundwater is consumed, redox potentials decrease, and nitrate, if present, becomes the next TEA utilized in the biodegradation of the benzene. Nitrate was detected in several wells in the benzene plume (OLD0208C, OLD0210C, OLD0213C, and OLD0220B). It is surprising that nitrate was detected in these wells, since redox conditions were in a range that would generally support more reducing conditions, and nitrate is usually utilized once reaching those ranges. Benzene biodegradation is very slow under nitrate reducing conditions; this would not be considered an important mechanism at this site.

<u>Iron.</u> Iron is present in the aquifer as an oxide or hydroxide, and can be utilized by bacteria as a TEA when oxygen and nitrate have been depleted. The resultant ferrous iron may be determined and used as an indication of the degree of utilization in the degradation of organic compounds. Ferrous iron was detected in wells within the plume as well as in the background well OLD0212C, indicating anaerobic conditions. However, there was no apparent increase in ferrous iron in the plume as compared with the background well. Since ferrous iron concentrations did not increase in the plume, iron reduction may not be an important mechanism.

Sulfate/Sulfide. When conditions allow, sulfate reduction (to sulfide) may occur due to bacterial action. Sulfate is available as an electron acceptor and sulfide was detected, suggesting active sulfate reduction.

Methane. Methane was detected in all wells within the benzene plume suggesting that methanogenic conditions exist within the subsurface. The concentration of methane was also lower in the background well (OLD0212C) compared to levels observed within the plume. Benzene degradation may occur under methanogenic conditions, but more slowly than under aerobic conditions.

Redox. Measured redox values (-83 to –208 millivolts [mv]) correspond with the results that suggest subsurface conditions within the benzene plume appear to favor sulfate reduction and methanogenesis. Redox levels were low in the background well (-77 mv), but are even lower in the wells within the benzene plume.

Summary. In general, the data support a conclusion of anaerobic biodegradation of the benzene in groundwater at Study Area 2. Based on the observed decreasing trends of the benzene plume and the presence of biological activity in the subsurface, it is likely that biodegradation is responsible for attenuation of the benzene plume. However, since the predominant conditions appear to be anaerobic, specifically sulfate reducing and methanogenic, rates of benzene biodegradation would be relatively slow compared to rates that would be expected under aerobic conditions.

1.3 BIOSCREEN MODELING. Published literature values are available for use within the bioscreen modeling, however, it is always more valuable to utilize site data to estimate biodegradation rates. HLA understands that more data is needed to develop a reliable model and has recommended that more data be collected (Section 2.0). HLA used the data from well OLD210C to estimate the biodegradation rate to develop a preliminary model for estimating purposes as this well had the longest data history and is indicative of what may be occurring in the groundwater plume. The model was fit to benzene results that had been observed along the flowpath. HLA understands this is a starting point and will modify the model as more data becomes available.

In applying the BIOSCREEN model to the Herndon Annex plume, the following assumptions were made:

- NA in the fringe areas of the plume is occurring at a rate that indicates a half life for benzene of approximately 0.53 years. This estimate is based on historical data from monitoring well OLD0210C (Appendix A), and this half life was used within the model.
- Although there is no actual "source" of benzene, a source area is assumed to exist in the middle of the mapped plume with a total mass of about 5 kg benzene, and the BIOSCREEN software automatically calculates a source area half life of about 8 years.

These assumptions along with site-specific data allow the use of the BIOSCREEN model to estimate the time required to meet the MCL for benzene across the entire site. BIOSCREEN input data include the following:

Seepage velocity: 183 feet per year
Benzene Biodegradation Rate: 1.3 year-1
Source concentration: 83 µg/L
Source soluble mass: 5 kilograms
Plume Dimensions: 200 feet x 800 feet
Fraction of Organic Carbon (FOC): 0.001
Octanal Carbon Coefficient (KOC): 63 liters per kilogram

The results from this analysis indicate approximately 30 years are required to achieve the MCL for benzene across the entire site. This assumes the benzene reaction follows first order kinetics rather than the "instantaneous reaction". Instantaneous reaction assumes biodegradation is immediate when there are available electron acceptors. Based on the concentration(s) of electron acceptor(s), benzene should be completely degraded if the instantaneous reaction is applied. However, since conditions are anaerobic and biodegradation is slower, first order kinetics would be more appropriate. When site data are plotted next to the first order model (Appendix B), a good comparison indicates that first order kinetics is appropriate. The first order rate constant used was estimated from data obtained from monitoring well OLD0210, which has been sampled three times since 1995. Data used to calculate the rate constant are presented in Figure A-2 of Appendix A.

The modeling results were also used to estimate the future benzene concentrations at different locations across the site. These data are summarized in Table 1-1. Estimates show approximately 30 years will be required to reach the MCL for benzene across the entire site. This is an estimate and should be verified as more data are collected during the proposed groundwater monitoring program.

Since current conditions do not pose a threat to human health and the environment, a long-term remedy can be considered and NA is a viable remedial alternative for this site.

2.0 NATURAL ATTENUATION MONITORING PLAN

This NA monitoring plan describes groundwater sample collection and analysis to ensure compliance with State and Federal groundwater standards for benzene across the site, 1 ug/L and 5 ug/L, respectively. The primary purpose of this monitoring plan is to provide an assessment of overall progress being made to achieve remedial goals. This plan has been prepared to comply with Florida regulations (62-770, Florida Administrative Code [FAC]) that specifically address NA.

2.1 MONITORING PLAN OBJECTIVES. This monitoring plan will be used to ensure that the selected groundwater remedy (incorporating NA) is protective of human health and the environment from adverse effects due to benzene-contaminated groundwater. This groundwater monitoring plan satisfies the following objectives:

- assure the public and regulator community that the selected remedy is working as expected and continues to be protective of human health and the environment;
- collect sufficient groundwater quality data to conduct a reliable assessment of data trends and duration estimates to achieve the MCL for benzene;
- compare the data trends to the milestone reductions in benzene concentrations as presented in Table 1-1;
- make timely decisions for the implementation of contingent response actions as specified in 62-770.690(7)(g) of the FAC if NA is not adequately meeting the annual milestones;
- assess the progress of the cleanup towards achieving the exit strategy; and,
- achieve MCL for benzene and associated No Further Action criteria (Rule 62-770.680, FAC).

2.2 GROUNDWATER SAMPLE COLLECTION AND ANALYSIS. Groundwater samples will be collected from designated wells within the benzene plume. The groundwater sampling schedule includes quarterly groundwater monitoring during the first two years, followed by semiannual monitoring for the next two years, and annual monitoring for the remaining duration of the cleanup. The total duration to achieve the MCL for benzene is estimated to be approximately 30 years. The monitoring results will be used to assess the restoration of the aquifer at Herndon Annex Property and evaluate the potential for continued off-site migration. The goal of the program is to achieve the MCL for benzene first at the property boundary and second to achieve the MCL across the entire site. Figure 2-1 shows the location of the 11 groundwater monitoring wells where samples will be collected as part of this monitoring plan. The monitoring wells are also listed in Table 2-1 along with their depths of completion.

The well locations identified to monitor NA include wells both at locations with the highest concentration of benzene and at locations beyond the edge of the existing plume. In accordance with 62-770.690(7) of the FAC, the monitoring wells will also include a well downgradient from the well containing the highest concentration and immediately before the groundwater discharges into the drainage ditch. As part of the groundwater monitoring program, groundwater level measurements will be taken prior to the collection of the groundwater sample during each of the sampling events. This data will be used to evaluate seasonal trends in the data, and the fate and transport of the benzene plume.

Groundwater samples will be analyzed for volatile organics and the following NA parameters:

- nitrate;
- sulfide and sulfate;
- ferrous iron (filtered);
- methane, and
- DO, redox, temperature, and pH (field measurements).

HLA recommends using low flow sampling techniques to collect samples and analytical methods consistent with those specified in Natural Attenuation Guidance (Technical Protocol for Evaluation of Chlorinated Solvents in Groundwater, EPA/600/R-98/128) and in accordance with the Project Operations Plan for NTC Orlando (ABB-ES, 1997). Quality assurance and quality control samples to be taken include 10 percent duplicates, a trip blank, a matrix spike, a matrix spike duplicate, and an equipment rinsate blank for every sampling event.

3.0 DATA ASSESSMENT AND REPORTING

Reports summarizing the monitoring data and NA assessment will be prepared on a biannual basis for the first four years and annually for the remaining treatment duration. At a minimum, these reports will include the analytical results and laboratory report, chain of custody, site maps illustrating the analytical results and groundwater contour map. These monitoring reports will also include an assessment of the biodegradation rate of the benzene and the status of the plume in comparison to the estimated degradation rates presented in Table 1-1. Should groundwater monitoring results indicate that the actual rate of degradation is significantly below the estimated half-lives, an evaluation will be made to determine if a supplemental site assessment, increased groundwater monitoring or contingency remedial action is necessary (62-770.690(3), FAC).

In general, the monitoring report will be organized as follows:

- Introduction: This section should describe the field activities, including date, weather conditions, monitoring points sampled, and any unusual occurrences during the sampling episode.

- Data Presentation: This section should include physical information for each well such as total depth, depth to water, and general condition of the well. It also should include tables of all data with the current episode highlighted, and graphical representations of benzene concentrations. This section of the report will also include a summary of the NA parameters collected throughout the NA monitoring program.

- Data Assessment: This section should discuss the data and trends and what they mean in terms of NA vs. groundwater migration and projections of future concentrations

4.0 EXIT STRATEGY

The completion of the remedial action will be achieved once the benzene concentrations in the groundwater beneath Herndon Annex and the Azalea Park Neighborhood are below the MCL of 1 µg/L. According to the FAC 62-785.690 (Natural Attenuation Monitoring Criteria) the monitoring period shall be a minimum of one year; however, the estimated duration for NA to achieve the cleanup goal is 30 years. Confirmation of the site cleanup will be based on two consecutive sampling events where benzene concentrations meet the MCL.

Groundwater monitoring wells may be removed from the sampling plan if results of analysis of groundwater are below the MCL for two consecutive sampling episodes, and provided the monitoring well is not located downgradient of a plume containing concentrations above the MCL. Wells removed from the monitoring program shall be properly abandoned, by grouting, such that a seal against vertical migration of groundwater is created along the entire well borehole. For the abandonment of wells, the description and guidelines presented in Monitoring Well Design, Installation, Construction, and Development Guidelines, Interim Final (Southern Division, Naval Facilities Engineering Command, 1997) shall be followed. The well abandonment will be documented within the next groundwater monitoring report.

The groundwater monitoring program will be terminated upon reaching the MCL for benzene at all monitoring points. Subsequently, a Site Rehabilitation Completion Report will be prepared and submitted to the applicable regulatory agencies (FAC 62-770.690(8)). This report will summarize all the groundwater monitoring results for the site and a final assessment of the NA of the benzene plume. This Completion Report will be signed and sealed by a registered Professional Geologist and/or a Professional Engineer, as necessary, following regulatory concurrence with the report.

REFERENCES

ABB Environmental Services, Inc. (ABB-ES), 1997. Project Operations Plan for Site Investigations and Remedial Investigations, Naval Training Center, Orlando, Florida. Prepared for Southern Division Naval Facilities Engineering Command, North Charleston, South Carolina. August.

Florida Administrative Code (FAC). Chapter 62, Part 770.

Harding Lawson Associates (HLA), 1999a. Preliminary ID of Remedial Technologies memorandum, February

HLA, 1999b. Environmental Site Screening Report, Study Area 2, Herndon Annex, Naval Training Center, Orlando, Florida. Prepared for Southern Division Naval Facilities Engineering Command, North Charleston, South Carolina. July.

Southern Division, Naval Facilities Engineering Command. 1997. Monitoring Well Design, Installation, Construction, and Development Guidelines, Interim Final. North Charleston, South Carolina (March 27).

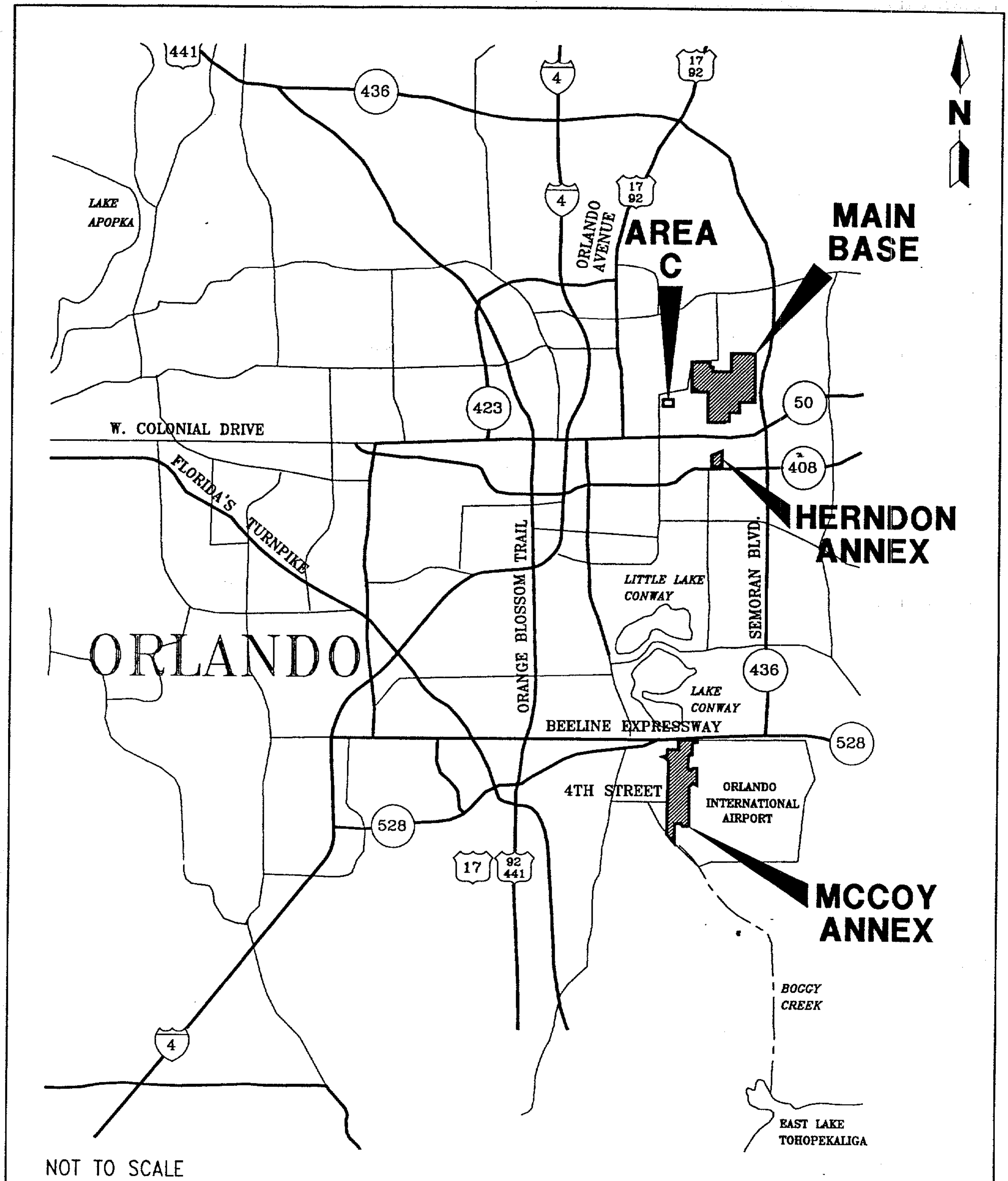

FIGURE 1-1
LOCATION OF NAVAL TRAINING CENTER, ORLANDO

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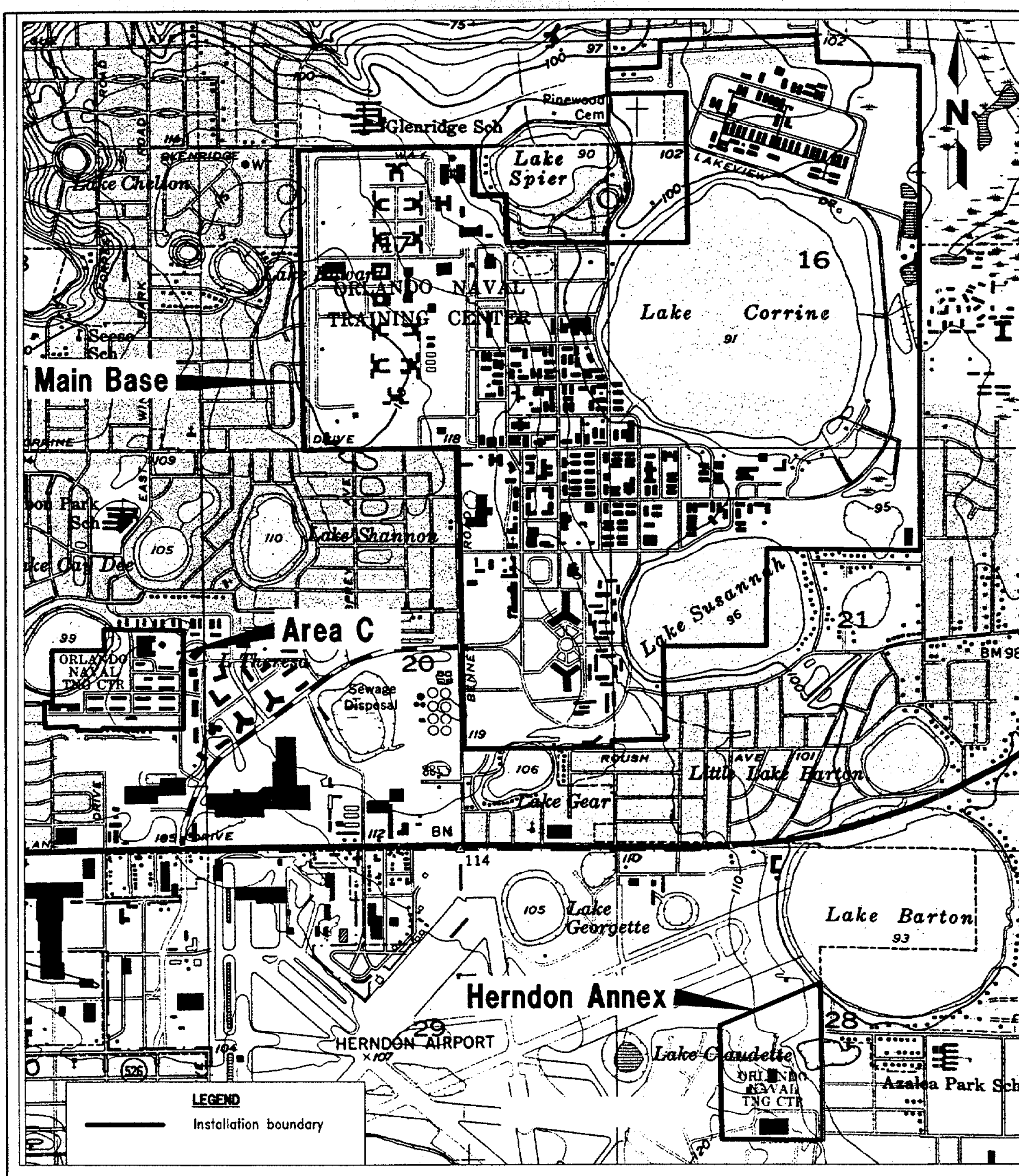
NATURAL ATTENUATION MONITORING WORK PLAN
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA



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SCALE: 1 INCH = 2,000 FEET

Reference: United States Geological Survey Quadrangle for Orlando East, Florida 1956, Photorevised 1980.

FIGURE 1-2
SITE LOCATION MAP
MAIN BASE, HERNDON ANNEX
AND AREA C

NATURAL ATTENUATION
MONITORING WORK PLAN
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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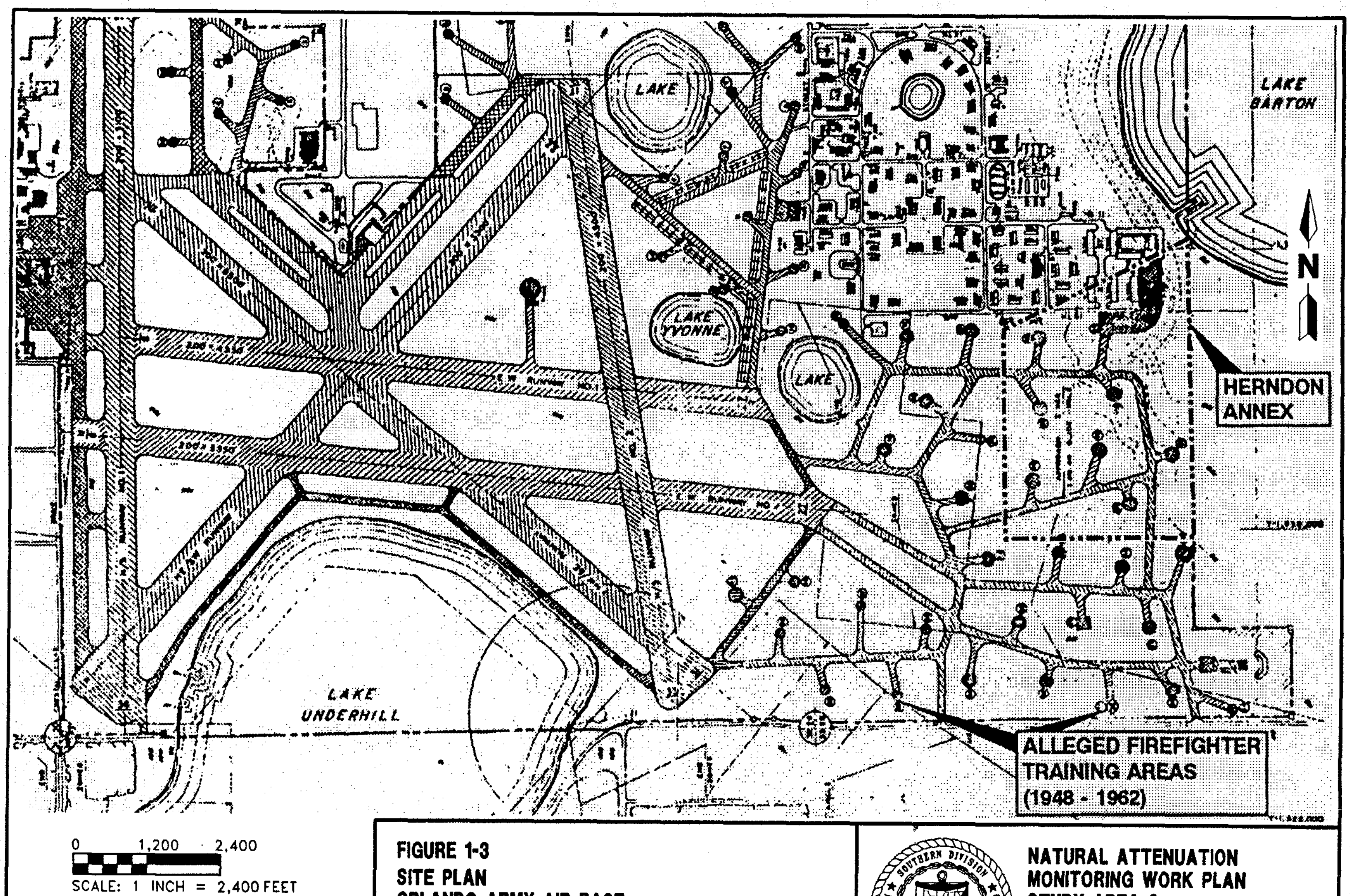

SOURCE: AARPGC & Orlando Army Air Base Layout Plan, U.S. Engineer Office, Savannah, GA., Sheet 1 of 2, June 1945

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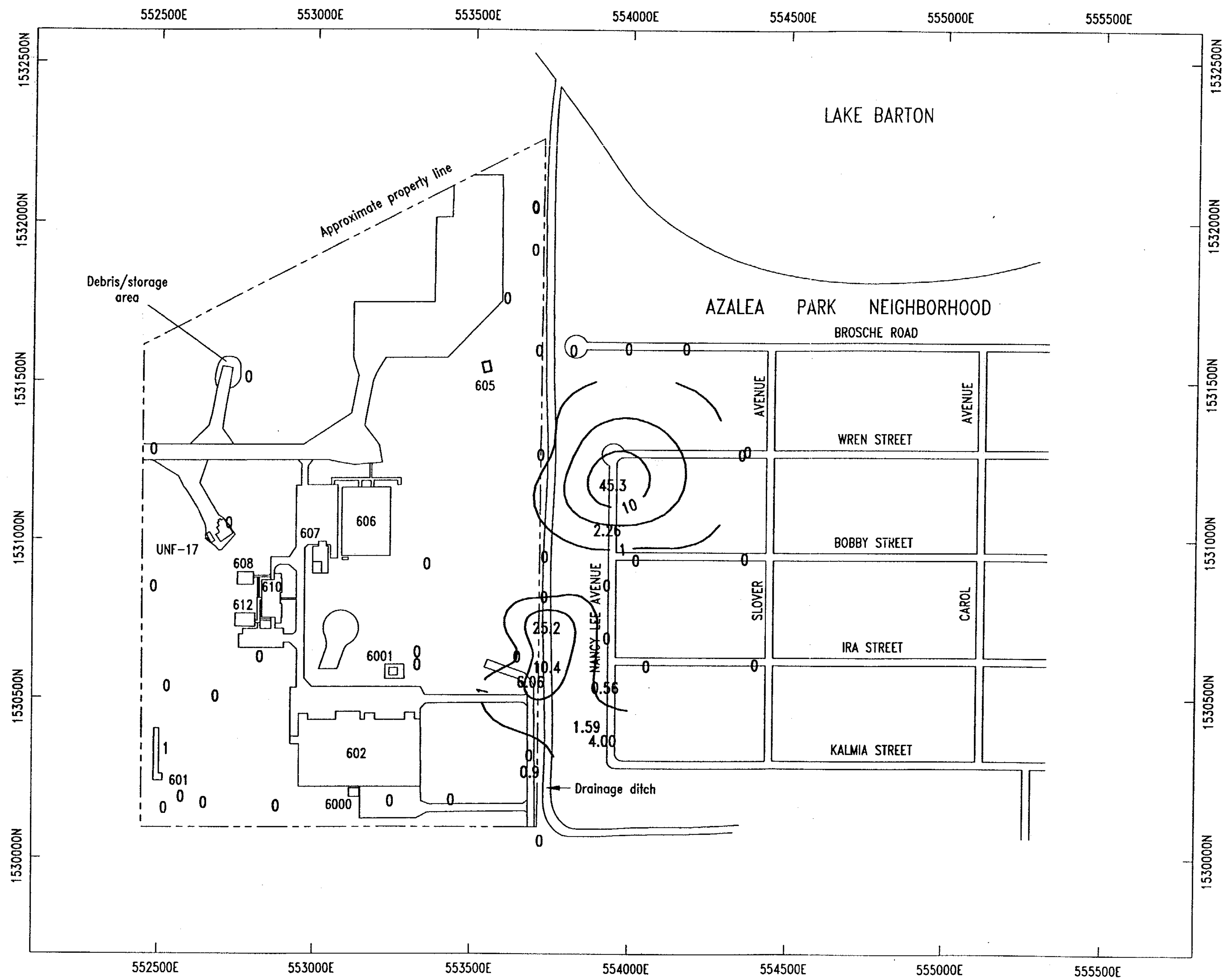
FIGURE 1-3
SITE PLAN
ORLANDO ARMY AIR BASE
JUNE 1945

NATURAL ATTENUATION MONITORING WORK PLAN
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA



N

LEGEND

10 (contour line)	Benzene concentration contour
45.3	Benzene concentration from direct-push technology
DPT	Direct-push technology
NAD	North American Datum
MCL	Maximum contaminant level

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

Concentrations are in micrograms per liter (parts per billion).

Contours shown are two per decade (i.e., 1, 3.16, 10, 31.6, 100).

0 200 400

SCALE: 1 INCH = 400 FEET

FIGURE 1-4
BENZENE MCL EXCEEDANCES IN GROUNDWATER IN THE DEPTH RANGE 0 TO 30 FEET BELOW LAND SURFACE, DPT SCREENING

NATURAL ATTENUATION MONITORING WORK PLAN
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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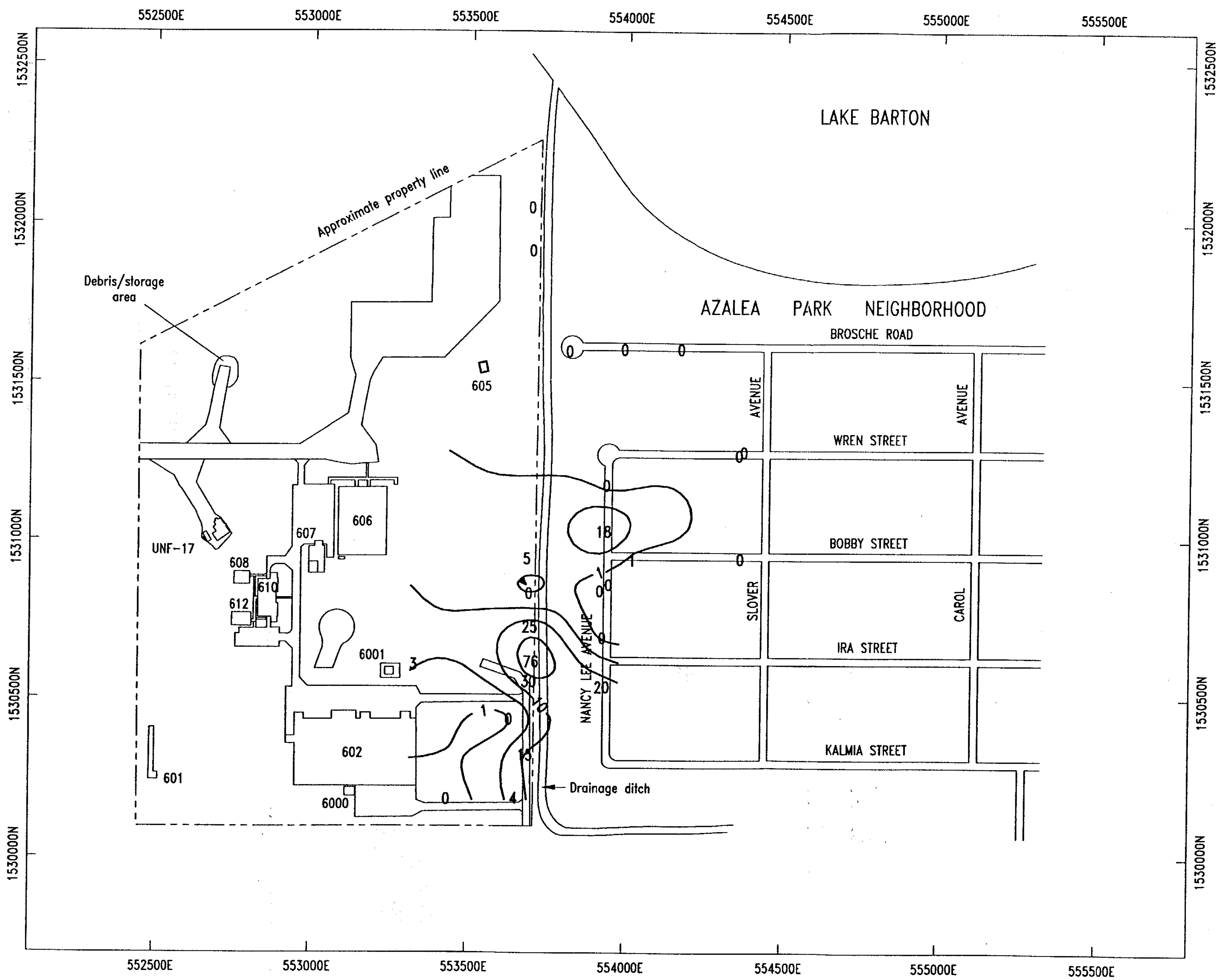

0 200 400

SCALE: 1 INCH = 400 FEET

N

LEGEND

10	Benzene concentration contour
20	Benzene concentration from direct-push technology
DPT	Direct-push technology
NAD	North American Datum
MCL	Maximum contaminant level

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

Concentrations are in micrograms per liter (parts per billion).

Contours shown are two per decade (i.e., 1, 3.16, 10, 31.6, 100).

FIGURE 1-5
BENZENE MCL EXCEEDANCES IN GROUNDWATER IN THE DEPTH RANGE 30 TO 40 FEET BELOW LAND SURFACE, DPT SCREENING

NATURAL ATTENUATION MONITORING WORK PLAN
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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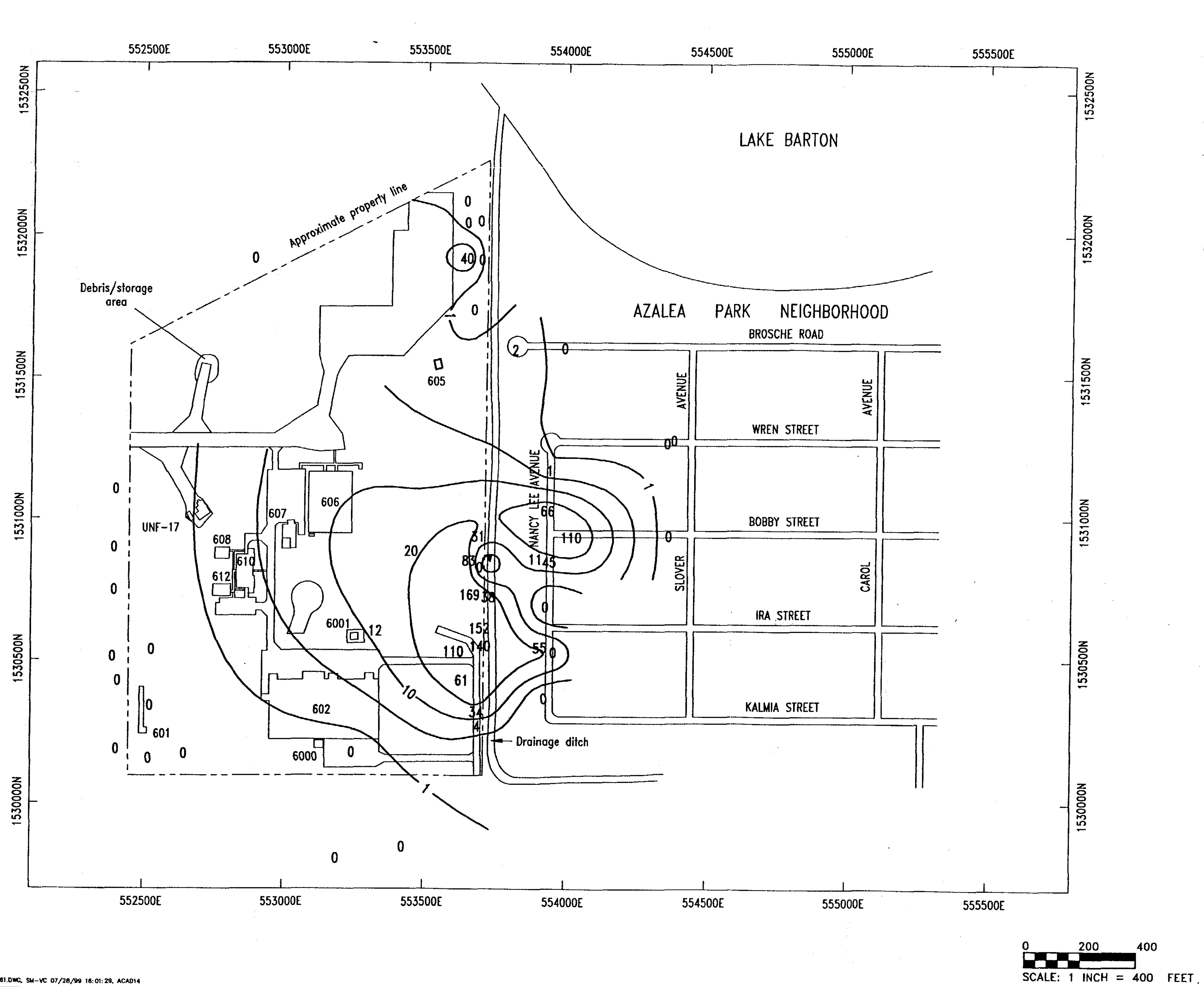

LEGEND

10	Benzene concentration contour
169	Benzene concentration from direct-push technology
DPT	Direct-push technology
NAD	North American Datum
MCL	Maximum contaminant level

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

Concentrations are in micrograms per liter (parts per billion).

Contours shown are two per decade (i.e., 1, 3.16, 10, 31.6, 100).

FIGURE 1-6
BENZENE MCL EXCEEDANCES IN GROUNDWATER IN THE DEPTH RANGE 40 TO 50 FEET BELOW LAND SURFACE, DPT SCREENING

NATURAL ATTENUATION MONITORING WORK PLAN
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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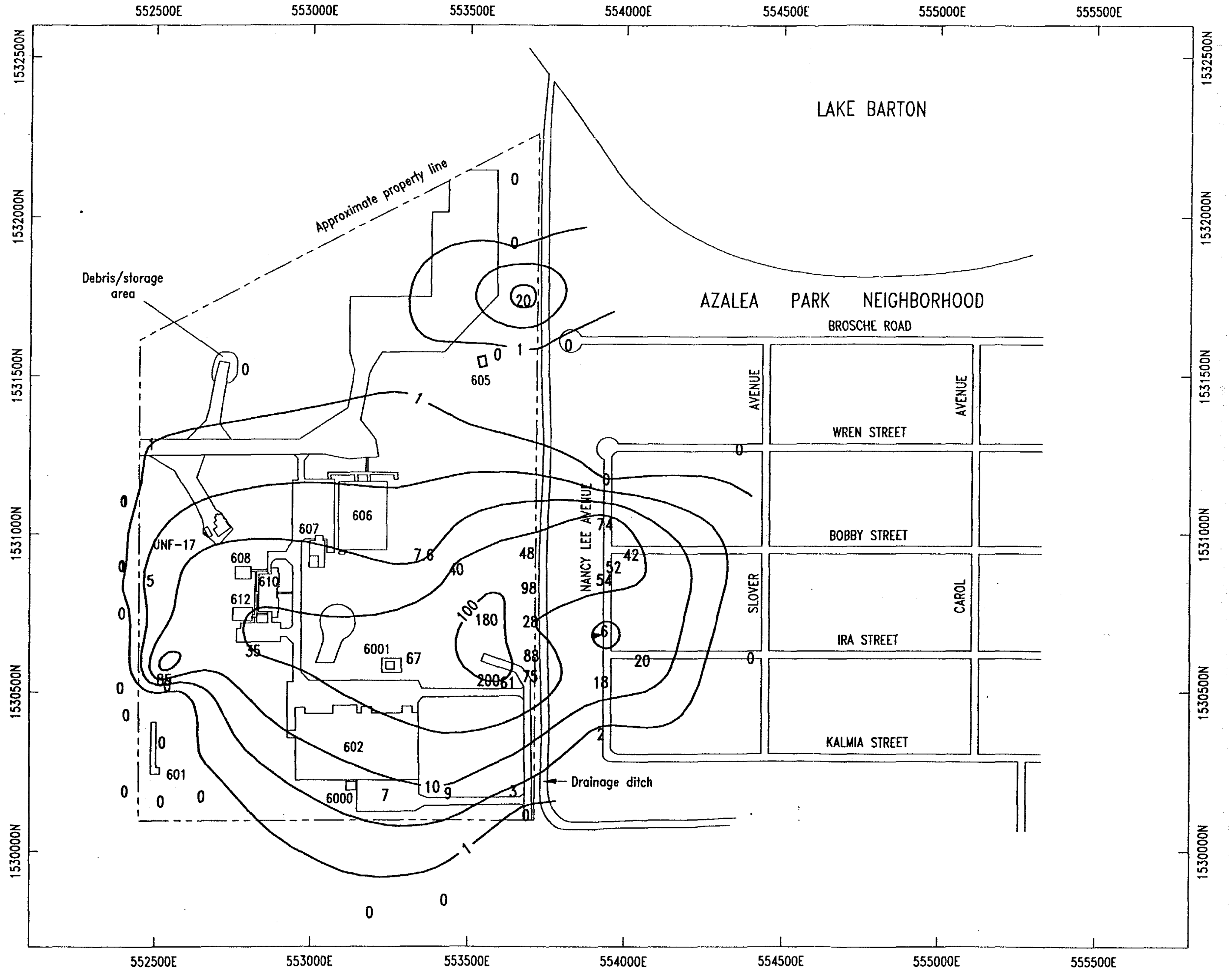

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SCALE: 1 INCH = 400 FEET

N

LEGEND

10	Benzene concentration contour
180	Benzene concentration from direct–push technology
DPT	Direct–push technology
NAD	North American Datum
MCL	Maximum contaminant level

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983–98.

Concentrations are in micrograms per liter (parts per billion).

Contours shown are two per decade (i.e., 1, 3.16, 10, 31.6, 100).

FIGURE 1-7
BENZENE MCL EXCEEDANCES IN GROUNDWATER IN THE DEPTH RANGE GREATER THAN 50 FEET BELOW LAND SURFACE, DPT SCREENING

NATURAL ATTENUATION MONITORING WORK PLAN
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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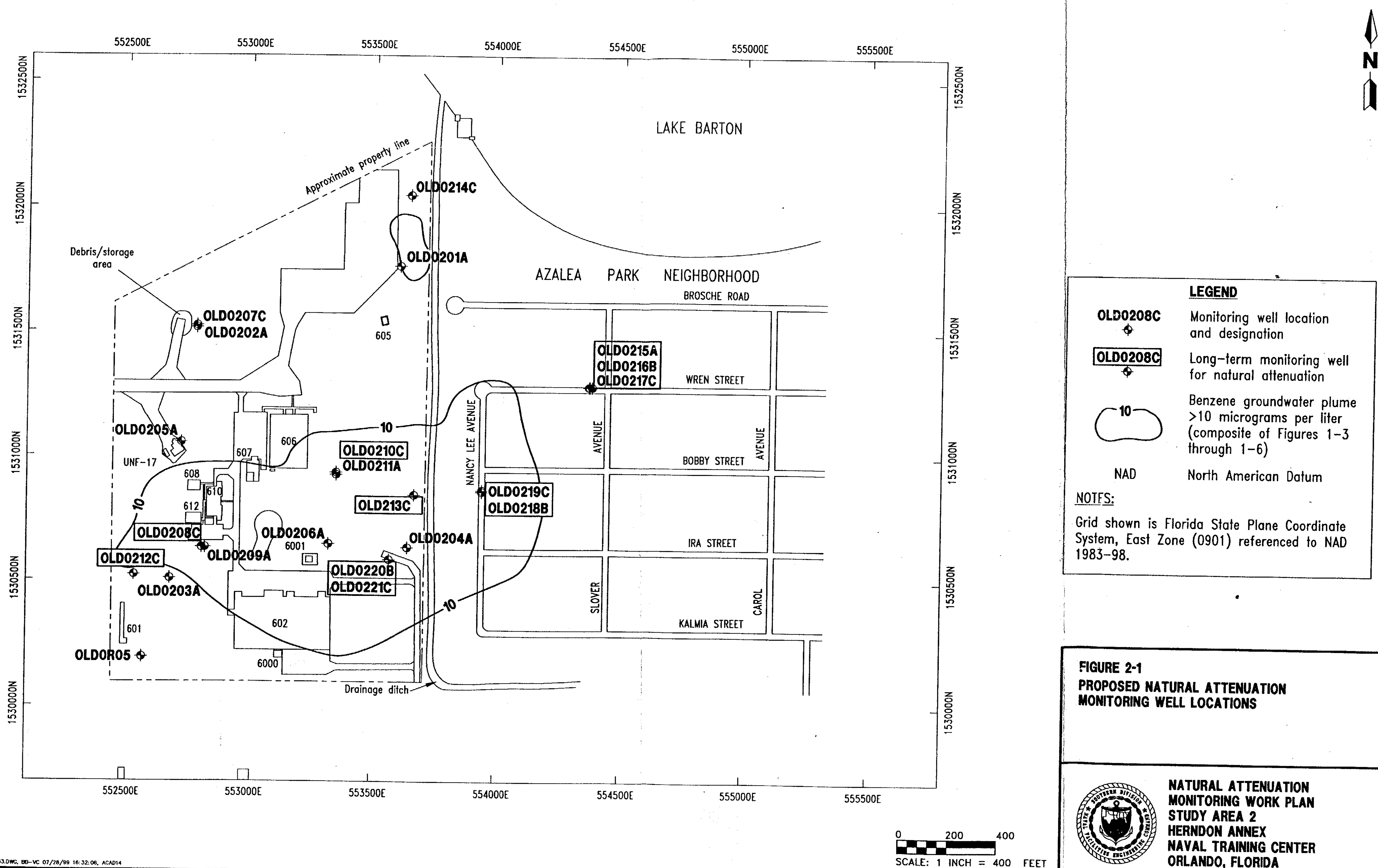

LEGEND

OLD0208C	Monitoring well location and designation
OLD0208C (boxed)	Long-term monitoring well for natural attenuation
10	Benzene groundwater plume >10 micrograms per liter (composite of Figures 1-3 through 1-6)
NAD	North American Datum

NOTES:

Grid shown is Florida State Plane Coordinate System, East Zone (0901) referenced to NAD 1983-98.

FIGURE 2-1
PROPOSED NATURAL ATTENUATION MONITORING WELL LOCATIONS

NATURAL ATTENUATION MONITORING WORK PLAN
STUDY AREA 2
HERNDON ANNEX
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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Table 1-1
Estimated Decrease in Benzene Concentrations
Using the BIOSCREEN Model

Natural Attenuation Monitoring Work Plan
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Location		Current Benzene levels (µg/L)	Estimated Benzene in 5 years (µg/L)	Estimated Benzene in 10 years (µg/L)	Estimated Benzene in 15 years (µg/L)	Estimated Benzene in 20 years (µg/L)	Estimated Benzene in 30 years (µg/L)
Source	Well	80	52	34	22	14	6
Site Boundary	100' from "source"		23	15	10	5	3
Housing, OLD0218/0219	400' from "source"	53	2	1	1	1	<1

Table 2-1
Proposed Natural Attenuation Monitoring Wells

Natural Attenuation Monitoring Work Plan
Study Area 2, Herndon Annex
Naval Training Center
Orlando, Florida

Well Number	Screened Interval (ft bls)	Well Location and Depth
OLD0215A	5'-15'	Shallow well edge of plume
OLD0216B	28.5'-33.5'	Intermediate well, edge of plume
OLD0217C	45.4'-50.5'	Deep well, edge of plume
OLD0218B	29.5'-34.5'	Deep well, edge of plume
OLD0219C	49'-54'	Intermediate well, edge of plume
OLD0220B	36'-51'	Intermediate well, near drainage ditch
OLD0221C	56'-61'	Deep well, near drainage ditch
OLD0210C	52'-57'	Deep well, mid-plume
OLD0213C	44'-49'	Deep well, mid-plume
OLD0208C	60'-65'	Deep well, near upgradient portion of plume
OLD0212C	57'-62'	Background well

Notes: ft bls = feet below land surface.

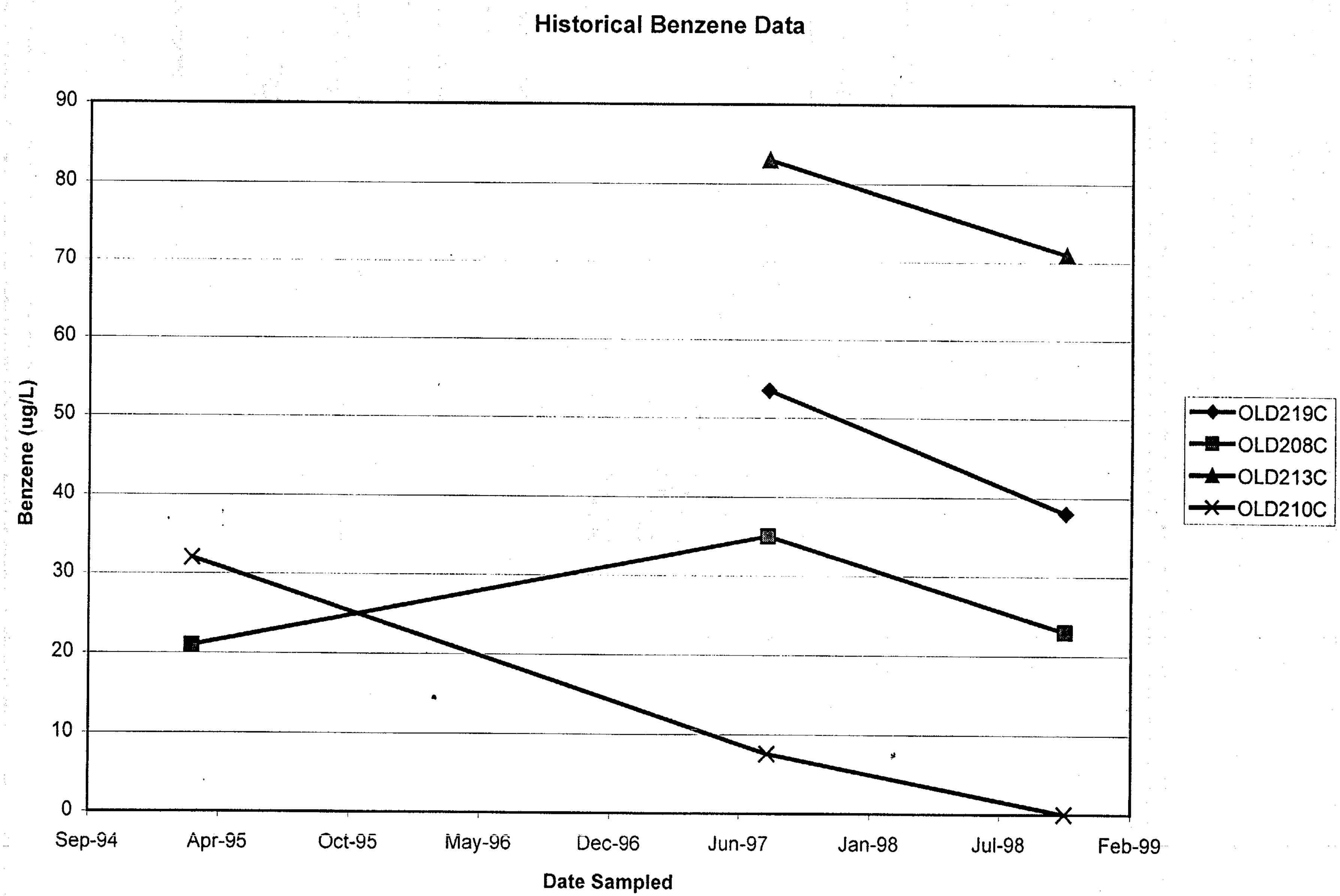
APPENDIX A

DATA TABLES AND GRAPHS

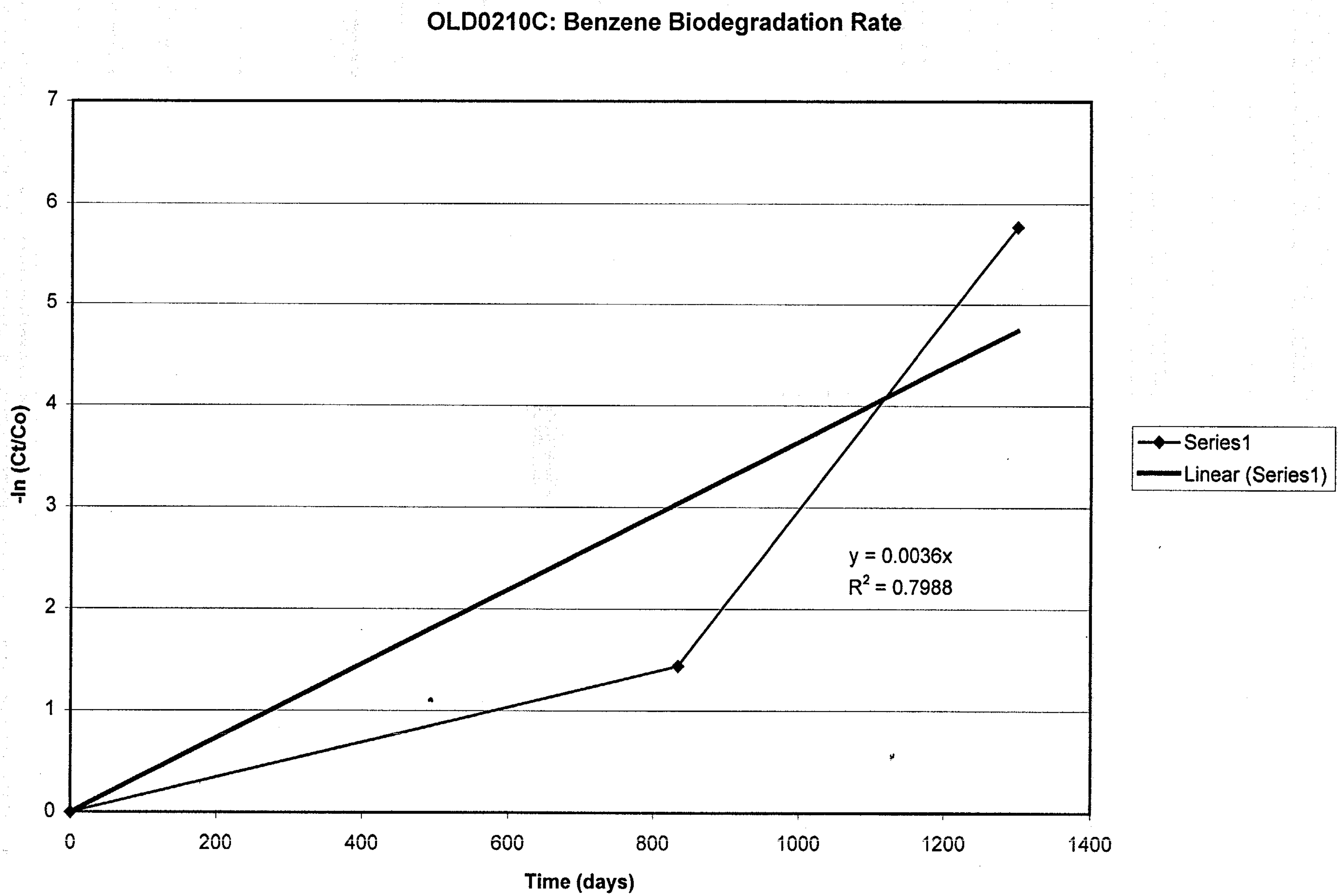
Appendix A

Table A-1
Herdon Annex
Natural Attenuation Evaluation
Intermediate and Deep Wells Only

Well ID Well Within the Plume	Dissolved Oxygen mg/L	Nitrate mg/L	Sulfate mg/L	Dissolved Iron (II) mg/L	Methane ug/L	Carbon Dioxide mg/L	Alkalinity mg/L	Ethane ug/L	Dissolved Iron (III) mg/L	ORP mv	Sulfide mg/L	pH	Mar-95 Benzene ug/L	Aug-Nov 97 Benzene ug/L	Dec-98 Benzene ug/L
OLD0208C	1.1	3.3	62	1.5	270	85	7	0.61	1.8	-205	2	5	**21**	**35**	**23**
OLD0210C	1.3	3.4	52	1.3	1.2	70	34		1.3	-158	1	5.9	**32**	**7.6**	**ND**
OLD0213C	3.5	3.1	14	0.4	770	60	6.8	1.4	0.8	-98	5	5	n/a	**83**	**71**
OLD0219C	0.9	0	5	0.4	240	50	13.6	0.74	0.75	-83	0.5	5	n/a	**53.5**	**38**
OLD0220B	1.2	5.3	15	0.2	340	67	7	0.68	0.6	-147	5	4.1	n/a	n/a	**46**
OLD0221C	2.9	0	27	0.8	680	50	27.2	1.3	0.75	-140	2	5.8	n/a	n/a	**50**
Wells outside the Plume															
OLD0207C	6.7	1.3	40	2.3	20	30	26.4		2.6	-50	2	6	ND	n/a	ND
OLD0212C	3.6	3.3	39	0.9	8	50	13.6		1.2	-77	0.1	5.1	n/a	ND	ND
OLD0214C	0.8	2.8	0	0.4	920	70	20.4		0.65	-143	2	5.1	n/a	ND	ND
OLD0215A	0.1	1.8	11	0.2	89	70	13.6		0.45	-116	0.5	4.9	n/a	ND	ND
OLD0216B	0.4	0.8	11	2.4	78	65	6		2.5	-97	2	4.9	n/a	ND	ND
OLD0217C	0.7	1.7	0	1.2	170	50	27.2		1.5	-148	0.7	5.5	n/a	ND	ND
OLD0218B	1.7	2.7	12	1.9	23	55	13.6		2.25	-112	2	5	n/a	ND	ND



Historical Benzene Data
90
80
70
60
50
40
30
20
10
0
Benzene (ug/L)
Sep-94
Apr-95
Oct-95
May-96
Dec-96
Jun-97
Jan-98
Jul-98
Feb-99
Date Sampled
OLD219C
OLD208C
OLD213C
OLD210C


OLD0210C: Benzene Biodegradation Rate
-ln (Ct/Co)
Time (days)
0
1
2
3
4
5
6
7
0
200
400
600
800
1000
1200
1400
y = 0.0036x
R^2 = 0.7988
Series1
Linear (Series1)

APPENDIX B

BIOSCREEN OUTPUT

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.4

Run Name: orlando/herndon md

Data Input Instructions:

115 — 1. Enter value directly... or
↑ or
0.02 — 2. Calculate by filling in grey cells below. (To restore formulas, hit button below)

Variable* — Data used directly in model.
20 — Value calculated by model (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	183.0	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	1.1E-02	(cm/sec)
Hydraulic Gradient	i	0.003	(ft/ft)
Porosity	n	0.3	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	50.0	(ft)
Transverse Dispersivity*	alpha y	5.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	800	(ft)

3. ADSORPTION

Retardation Factor*	R	1.4	(-)
or		↑ or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	63	(L/kg)
FractionOrganicCarbon	foc	1.0E-3	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	1.3E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	0.15	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	2.3	(mg/L)
Delta Nitrate*	NO3	0	(mg/L)
Observed Ferrous Iron*	Fe2+	0.5	(mg/L)
Delta Sulfate*	SO4	25	(mg/L)
Observed Methane*	CH4	0.762	(mg/L)

5. GENERAL

Modeled Area Length*	800	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	30	(yr)

6. SOURCE DATA

Source Thickness in Sat.Zone* 20 (ft)

Source Zones:

Width* (ft)	Conc. (mg/L)*
200	0.005
150	0.02
75	0.08
150	0.02
200	0.005

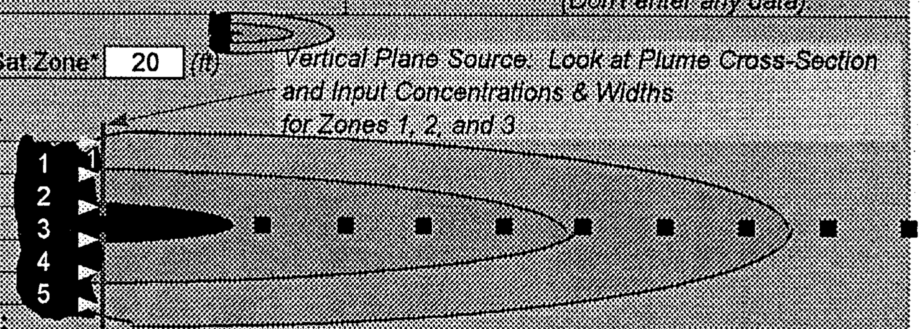
Source Halflife (see Help):

Inst. React.	1st Order
5	6

(yr)

Soluble Mass in Source NAPL, Soil: 5 (Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Concentration (mg/L)	.08					.018				.001	
Dist. from Source (ft)	0	80	160	240	320	400	480	560	640	720	800

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

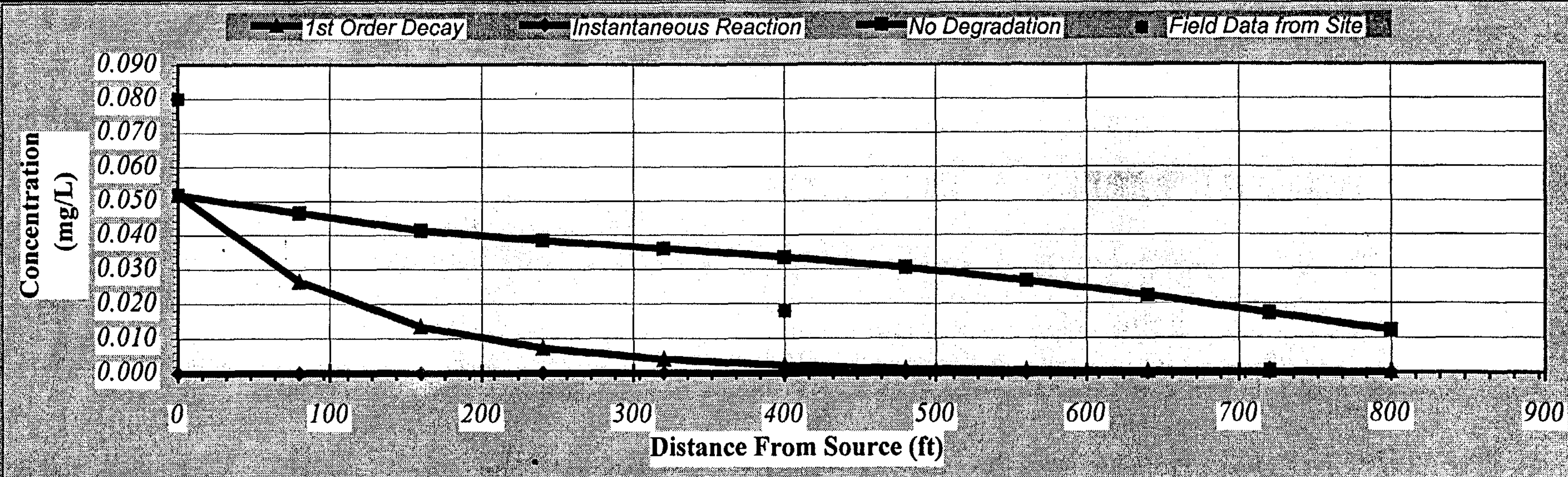
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	0	80	160	240	320	400	480	560	640	720	800
	Distance from Source (ft)										
No Degradation	0.052	0.046	0.041	0.038	0.036	0.033	0.030	0.027	0.022	0.017	0.012
1st Order Decay	0.052	0.026	0.013	0.007	0.004	0.002	0.001	0.001	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	0.080					0.018				0.001	



Calculate Animation

Time:

5 Years

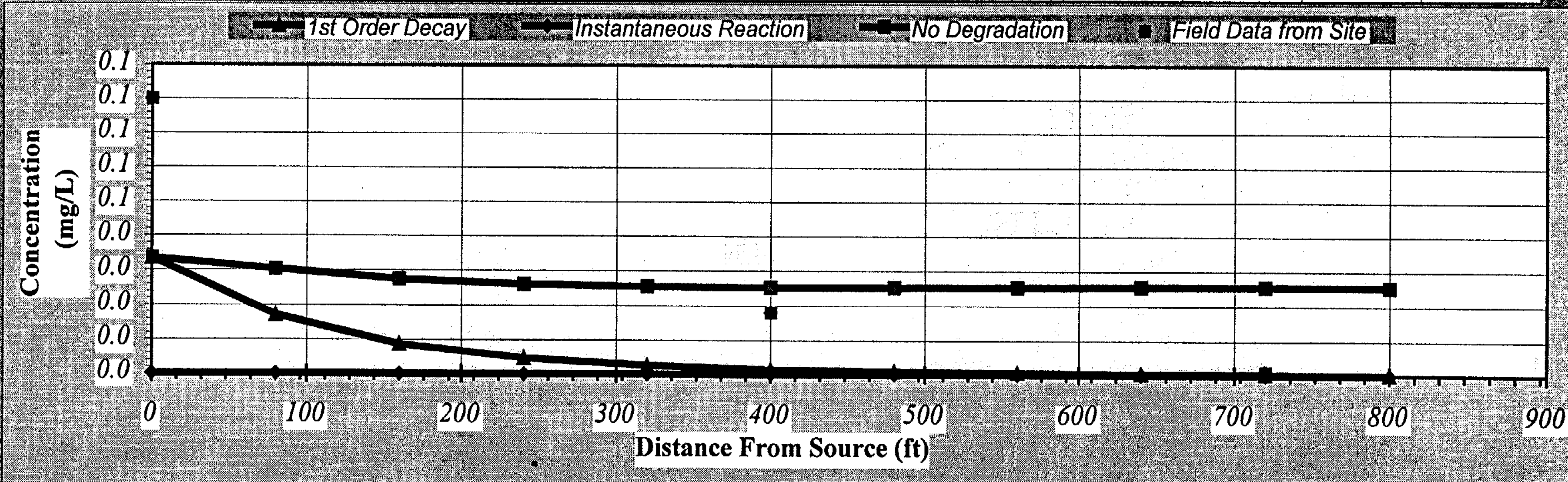
Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	80	160	240	320	400	480	560	640	720	800
No Degradation	0.034	0.030	0.027	0.026	0.025	0.025	0.025	0.025	0.025	0.026	0.025
1st Order Decay	0.034	0.017	0.009	0.005	0.003	0.001	0.001	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	0.080					0.018				0.001	



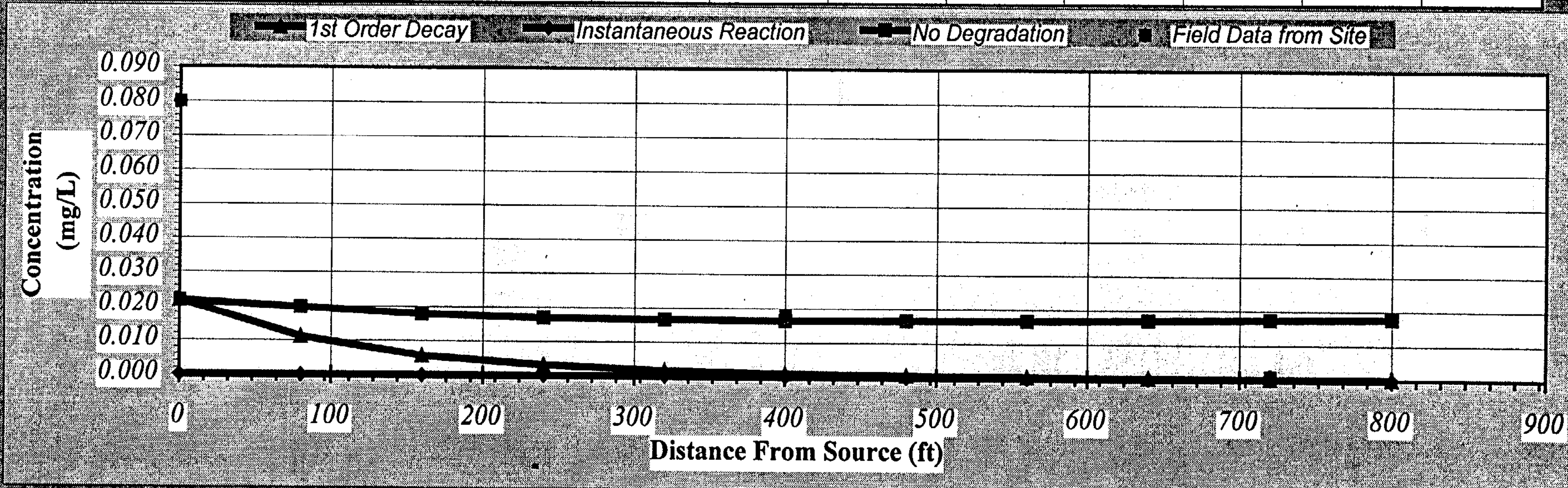
Replay Animation | Next Timestep | Prev Timestep

Time:
10 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft)										
	0	80	160	240	320	400	480	560	640	720	800
No Degradation	0.022	0.020	0.018	0.017	0.017	0.016	0.016	0.017	0.017	0.017	0.018
1st Order Decay	0.022	0.011	0.006	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	0.080					0.018				0.001	



Calculate Animation

Time:

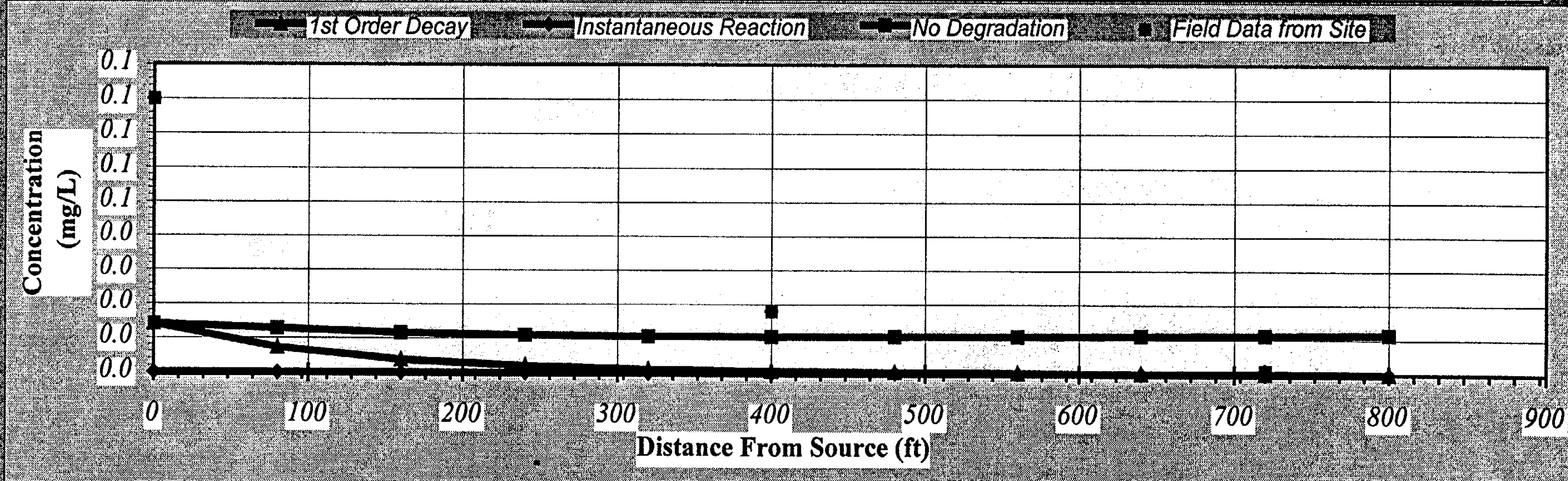
15 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	80	160	240	320	400	480	560	640	720	800
No Degradation	0.014	0.013	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
1st Order Decay	0.014	0.007	0.004	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site	0.080					0.018				0.001	



Replay Animation

Next Timestep

Prev Timestep

Time:

20 Years

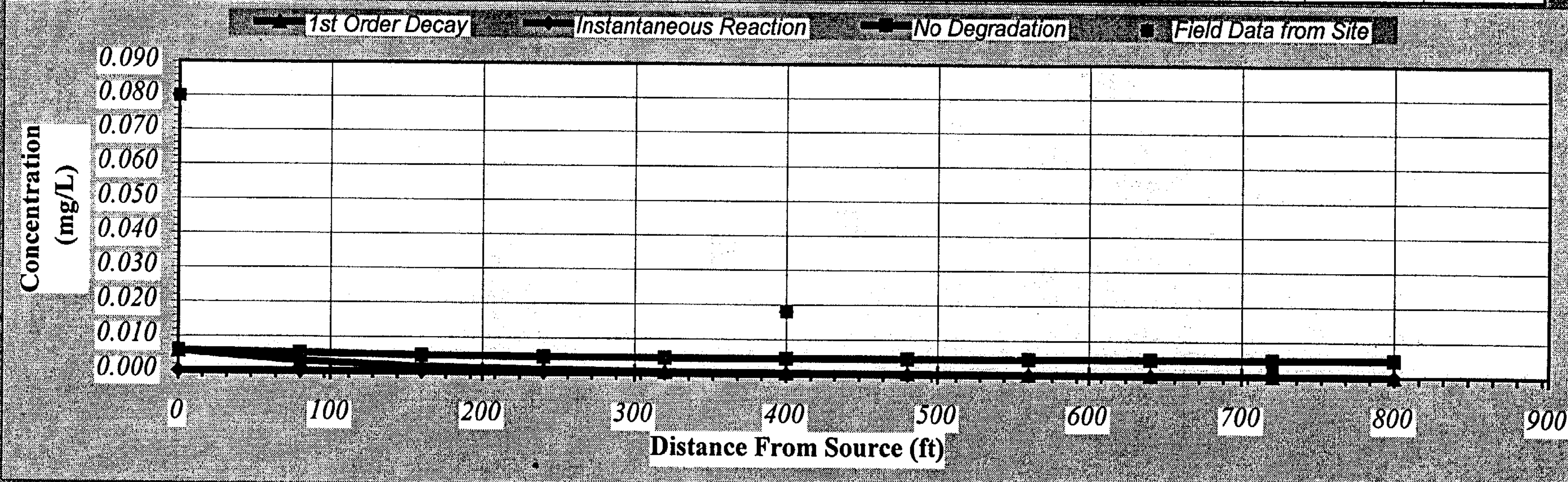
Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	80	160	240	320	400	480	560	640	720	800
No Degradation	0.006	0.005	0.005	0.005	0.004	0.004	0.004	0.005	0.005	0.005	0.005
1st Order Decay	0.006	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
Field Data from Site	0.080					0.018				0.001	



Calculate Animation

Time:

30 Years

Return to Input

Recalculate This Sheet

APPENDIX B

REMEDIAL ALTERNATIVE NO. 3
ENHANCED BIOREMEDIATION TECHNICAL APPROACH AND SCHEMATIC DESIGN

APPENDIX B

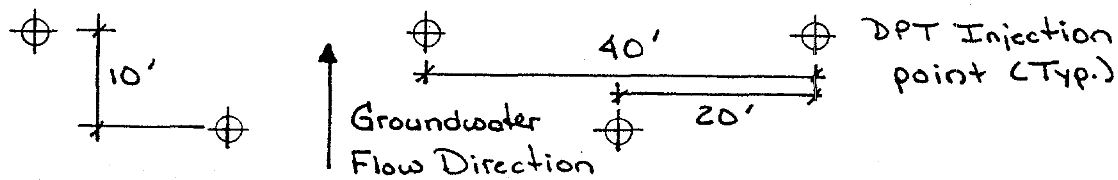
ALTERNATIVE NO. 3 – ENHANCED BIOREMEDIATION TECHNICAL APPROACH AND SCHEMATIC DESIGN

Herndon Annex and Azalea Park – Passive Treatment via DPT Injection of ORC Slurry

- Remedial goal to directly enhance the central higher concentration area of plume (>10 ug/L) and let fringe areas of plume naturally attenuate

- Hydraulic characteristics used for development of the ORC schematic design:
  Hydraulic Conductivity, k=30 feet per day (fpd)
  Hydraulic Gradient, i=0.005 in a northeasterly direction
  Transmissivity, T=1500 feet^2/day
  Porosity, n=0.30

- ORC is injected in slurry form (~1% solution) into "push-probe" holes from 40 to 60 feet below ground surface (isolated points from 40'-50' and 50'-60'). The ORC was assumed to have a radial influence of 10 feet and would be injected along two parallel lines with points at 40 ft centers, staggered, with the lines perpendicular to groundwater flow direction (see below).



- The ORC will cause benzene to instantaneously degrade on contact, since much more ORC than needed at each point will be injected; the residual ORC migrates downgradient to destroy benzene in its path.

- Groundwater migration speed is 0.5 fpd and maximum distance to be covered for the central high concentration area between rows of injection points is about 300 feet. Travel time of the groundwater plume is thus 300'/0.5 fpd = 600 days.

- Assume that due to the utilization of oxygen at the leading edge of ORC-oxygen cloud due to benzene oxidation, the oxygen will migrate at only half the speed of the groundwater. This equates to two pore volumes to achieve the MCL.

- Therefore, the total duration for the ORC-oxygen cloud to sweep the central high concentration area will be approximately 1,200 days or 4 years.

- Based on the natural attenuation calculations for the benzene plume under anaerobic conditions, the fringe areas (<10 ug/L) will naturally degrade to the MCL within approximately 5 years. This five-year duration will be used for the total estimated duration to achieve the MCL of 1 ug/L for benzene.

- Using an additional demand factor of 4, we calculate (see attached ORC spreadsheet) about 4,500 lbs. Of ORC will be required.

- Based on the configuration of injection points presented on attached Figure (and Figure 3-2), a total of 83 points would be required to address the contamination exceeding 20 ug/L. These direct push injection points would have a 10 foot radius of influence over 20 foot thickness of aquifer (estimated porosity of 30%). The estimated number of pounds ORC per injection point would be 4,500/83= approximately 55 pounds of ORC per injection point, with 14,000 gallons of water each injection.

ORC SLURRY INJECTION

Dissolved Hydrocarbon Level (ppm)	0.2
(For gasoline sites use BTEX measurements)	
Treatment Zone Width (ft)	1000
Treatment Zone Length (ft)	500
Thickness of Saturated Treatment Zone (ft)	20
Porosity	0.3
(sand = 0.3, silt = 0.35, clay = 0.4)	
Total Treatment Zone Volume (cu. ft)	10,000,000
Dissolved Phase Hydrocarbon Mass (lbs)	37.4
Additional Demand Factor	4
(REGENESIS recommends a factor of about 8)	
Loaded Hydrocarbon Mass (lbs)	149.6
Oxygen Required (lbs)	448.8
ORC Required (lbs)	4,488.0
ORC Unit Cost	$ 10.00
Total Cost of ORC	$ 44,880.00

FOR SOLUTE TRANSPORT MODEL ENTER VALUES BELOW

GW Velocity (ft / day)	0.5
Compliance Pt. (ft)	300
Ratio of O2 provided : O2 required (percent)	100%
HC Level at compliance point after selected ratio of oxygen in ppm	0.00

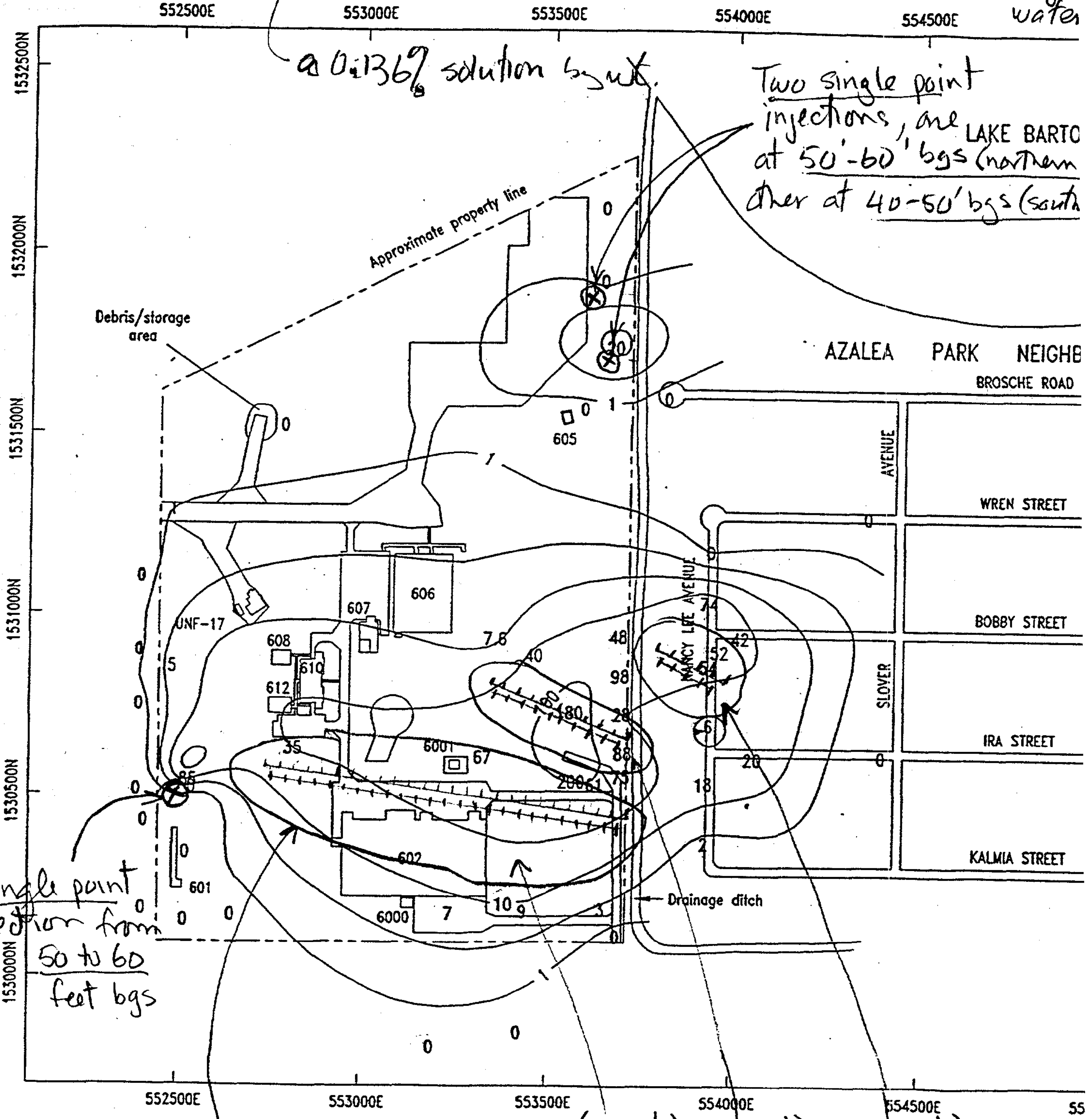
Solids Content (%)	1%
Hole Spacing (ft)	20
Number of Holes in Grid	1250
ORC per Hole (lbs)	3.6
Water needed per Hole for Slurry (gal)	42.7

APPLICATION COMMENTS

* Use more than 1 pound of ORC per linear foot by increasing hole spacing

ORC Slurry Injection Points

(slurry is injected to a 10-ft radius from each point)
(ORC powder is mixed with water at 10 lbs ORC to 883 gal water — a 0.136% solution by wt.)



Lines of injection points two rows, staggered, with points at 40-ft centers along each row, from 40 to 60 ft bgs.

KI-09\SSR\02530720.DWG DEL 4/16/98

APPENDIX C

REMEDIAL ALTERNATIVE NO. 4
ENHANCED BIOREMEDIATION WITH EX-SITU AIR STRIPPING
TECHNICAL APPROACH AND SCHEMATIC DESIGN

APPENDIX C

ALTERNATIVE NO. 4 – ENHANCED BIOREMEDIATION WITH EX-SITU AIR STRIPPING TECHNICAL APPROACH AND SCHEMATIC DESIGN

Herndon Annex and Azalea Park – Active Ex-situ/In-situ Treatment

- Remedial goal to provide hydraulic containment of the benzene plume exceeding 10 ppb, ex-situ treatment of the extracted groundwater and enhanced bioremediation of the benzene plume using solid-phase ORC in the reinjection wells.

- Hydraulic characteristics used for development of the ORC schematic design:
  Hydraulic Conductivity, k=30 feet per day (fpd)
  Hydraulic Gradient, i=0.005 in a northeasterly direction
  Transmissivity, T=1500 feet^2/day
  Porosity, n=0.30

- The ORC will cause benzene to instantaneously degrade on contact, since much more ORC than needed at each point will be injected; the residual ORC migrates downgradient to destroy benzene in its path.

- ORC "socks" will be installed in all eight reinjection wells from a depth of 30 to 60 feet below ground surface. ORC replacement socks estimated quarterly due to rapid use of ORC through reinjection of treated groundwater and not passive dissolution into groundwater.

- HLA estimated that only one pore volume will be required to achieve the MCL for benzene because the contaminated groundwater is being extracted and treated prior to reinjection. However, HLA assumed that due to the utilization of oxygen at the leading edge of ORC-oxygen cloud due to benzene oxidation, the oxygen will migrate at only half the speed of the groundwater. This will result in a estimated treatment duration of approximately 4 years.

- Groundwater modeling of the benzene plume beneath Herndon Annex and Azalea Park was conducted using the USEPA's "Well Head Protection Area , WHPA" program (USEPA, 1993). This modeling was developed to identify the number of extraction and reinjection wells required to address the benzene plume exceeding 10 ug/L (composite of Figures 1-3 through 1-6). This was also used to calculate the groundwater extraction and reinjection rates for the individual wells. See attached figure for well designation/locations and groundwater flow contours.

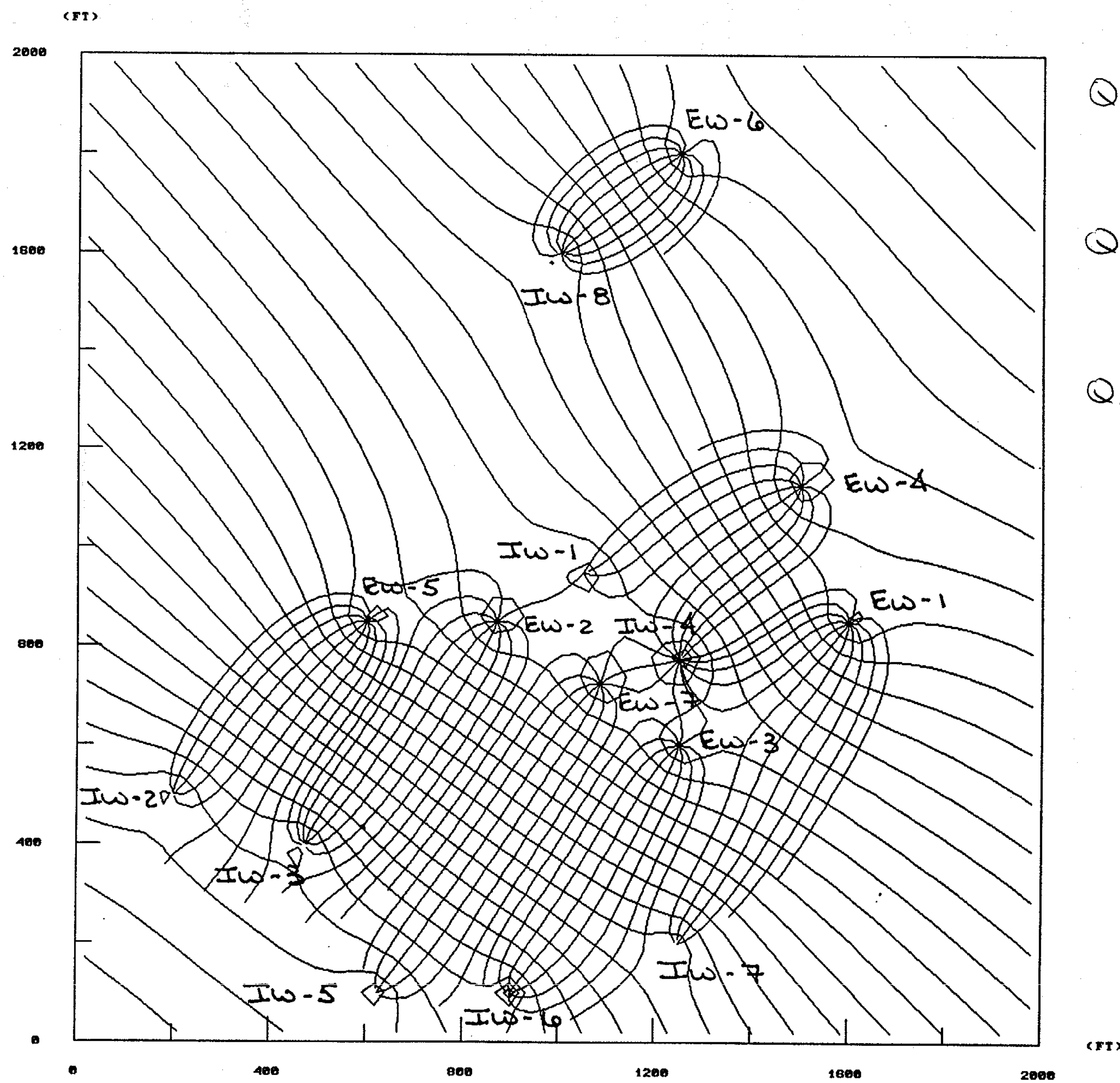
- Based on the natural attenuation calculations for the benzene plume under anaerobic conditions, the fringe areas (<10 ug/L) will naturally degrade to the MCL within approximately 5 years.

- Based on the WHPA modeling, the treatment duration of the groundwater plume >10 ug/L will have an estimated duration of 4 years. However, the maintenance of ORC within the reinjection wells will continue for a total of 5 years to enhance the degradation of the fringe benzene plume (<10 ug/L). This five-year duration will be used for the total estimated duration to achieve the MCL of 1 ug/L for benzene.

- WHPA Reference Document: USEPA, 1993. Well Head Protection Area Delineation Code, Version 2.2, prepared by HydroGeologic, Inc. for USEPA. September

4/1/99

Hrndon09.dat



$Q_{I_{1,8}}$ = 3850 cfd ~ 20gpm

$Q_{I_{2,3,5,6,7}}$ = 3465 cfd ~ 18gpm

Q_{I_4} = 6738 cfd ~ 40gpm

Herndon Annex F.S. 44226/0263051 6/18/99

Hrndn08.dat — 7 extraction wells, Q_T = 165 gpm
8 injection wells, Q_T = 165 gpm

Well #	x	y	Q
E1	✓ 1600'	~~800'~~ 850	25 gpm
E2	✓ 870'	✓ 850'	25 gpm
E3	✓ 1250'	✓ 600'	25 gpm
E4	✓ 1500'	✓ 1125'	25 gpm
E5	✓ 600'	~~900'~~ 850	25 gpm
E6	✓ 1250'	✓ 1800'	20 gpm
E7	✓ 1085'	✓ 725'	25 gpm
I1	✓ 1050'	✓ 950'	20 gpm
I2	✓ 200'	✓ 500'	19 ~~18~~ gpm
I3	475 ~~500'~~	✓ 400'	19 ~~18~~ gpm
I4	✓ 1250'	✓ 775'	35 gpm
I5	625 ~~700'~~	100 ~~200'~~	19 ~~18~~ gpm
I6	✓ 900'	✓ 100'	19 ~~18~~ gpm
I7	✓ 1250'	✓ 200'	19 ~~18~~ gpm
I8	✓ 1000'	✓ 1600'	20 gpm

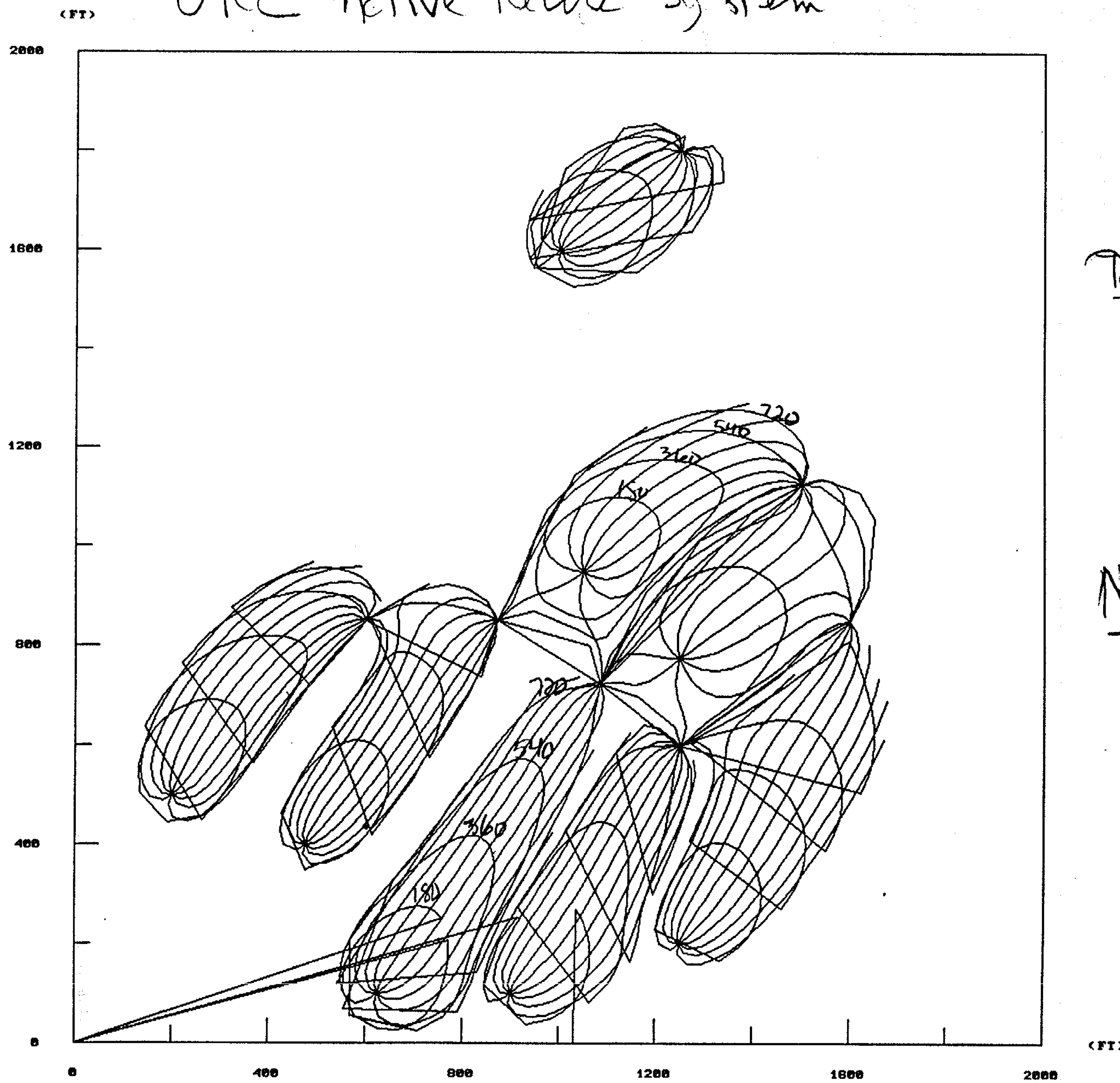
T = 1500 ft²/day
b = 50 ft
θ = 0.3
i = 0.005
Contours at 0.5' interval
Time for pathlines = 800 days

w/ changes hrndn09.dat. Revised 7/1/99

Total Northern Plume extraction = 20 gpm
Total Northern Plume injection = 20 gpm

Total Southern Plume extraction = 150 gpm
injection = 150 gpm

ORC Active Recirc System



Timelines

180
360
540
720 days

Note: if inject ORC at recharge wells, will take GW ~ 4 yrs for one PV

Harding Lawson Associates
Engineering and Environmental Services

SHEET 1 OF 1
JOB NO. 044226-0253051
DATE 7/16/99
COMPUTED BY DEH
CHECKED BY [signature]

PROJECT Herndon Annex Focused Feasibility Study
SUBJECT VOC Mass Emissions from Alternative 4

Alternative No. 4 - Enhanced Bioremediation w/ Ex-situ Air stripping.

- Shallow-tray air stripper would be used prior to reinjection and amendment w/ ORC.
- Two air strippers, one for northern plume (20 gpm) and one for southern plume (150 gpm).
- Max benzene concentration detected via DPT = 200 µg/L and 83 µg/L in monitoring well. Assume average concentration of 50 µg/L for all influent to air strippers. No other VOCs likely found in extracted gw.

$$\text{VOCs emitted} = \frac{150\,g}{min} \times \frac{1440\,min}{day} \times \frac{3.785\,l}{g} \times \frac{50\,\mu g}{l} \times \frac{g}{10^6\,\mu g} \times \frac{lb}{454}$$

$$= 0.09\ lb/day.$$

$$\sim < 1\ lb/day.$$

Max Theoretical

$$\text{VOCs emitted} = \frac{200\,\mu g/l}{50\,\mu g/l} \times 0.09\ lbs/d = 0.36\ lbs/d$$

$$\sim < 1\ lb/d$$

Max Total VOC emission well below FDEP criteria of 13.7 lbs/day; no off-gas treatment required.

APPENDIX D

DETAILED COST ESTIMATES OF REMEDIAL ALTERNATIVES

TABLE D-1

ALTERNATIVE NO.1 - NO ACTION
FIVE-YEAR SITE REVIEW COSTS

	Quantity	Unit	Unit Cost	Total Cost
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	16	hrs	$90.00	$1,440
Mid-level Engineer	16	hrs	$75.00	$1,200
ODCs	1	lump sum	$200.00	$200
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Annual Cost				**$19,640**
Present Worth 5 Year Review (i = 6%, n =5, 10..30 years)				**$47,959**
TOTAL O&M COSTS				**$47,959**
CONTINGENCY @10 PERCENT				**$4,796**
TOTAL COST OF ALTERNATIVE NO. 1				**$52,755**

TABLE D-2

ALTERNATIVE NO.2 - NATURAL ATTENUATION

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	$10,000
TOTAL DIRECT COSTS				**$10,000**
INDIRECT COSTS				
Health and Safety				$500
Administrative Fees				$1,000
Engineering and Design				$4,000
Construction Support Services				$1,000
TOTAL INDIRECT COSTS				**$6,500**
TOTAL CAPITAL COSTS				**$16,500**
OPERATION & MAINTENANCE COSTS				
GW Natural Attenuation Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program for Natural Attenuation within the entire VOC plume (yrs 1-30)				
11 Wells + 2QA/QC = 13 Samples				
Quarterly - 2 years, Biannual 3 years, Annual remaining 25 years				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,500.00	$1,500
Analysis-Natural Attenuation Parameters	13	samples	$200.00	$2,600
Analysis-TCL Organics (VOCs only)	13	samples	$150.00	$1,950
Summary Data Report (annual):				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	LS	$1,000.00	$1,000
Subtotal Natural Attenuation Annual Costs				**$16,350**
Present Worth Nat. Atten. Mon. @ I = 6%, n=30 yrs				**$353,863**

TABLE D-2

ALTERNATIVE NO.2 - NATURAL ATTENUATION

	Quantity	Unit	Unit Cost	Total Cost
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	16	hrs	$90.00	$1,440
Mid-level Engineer	16	hrs	$75.00	$1,200
ODCs	1	LS	$200.00	$200
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	LS	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	LS	$1,000.00	$1,000
Subtotal Five-Year Site Review Annual Costs				**$19,640**
Present Worth 5 Year Review (i = 6%, n =5, 10, 15, 20, 25 and 30 yrs)				**$47,959**
TOTAL PRESENT WORTH O&M COSTS				**$401,822**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$418,322**
CONTINGENCY @10 PERCENT				**$41,832**
TOTAL COST OF ALTERNATIVE NO. 2				**$460,154**

TABLE D-3

ALTERNATIVE NO. 3 - ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS.	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$5,000.00	$5,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,000.00	$2,000
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Sub-total Site Preparation/Mobilization				**$24,400**
ENHANCED BIODEGRADATION				
Enhanced Bioremediation Support System				
Utility Pole	1	poles	$550.00	$550
Power Cable	25	ft	$10.00	$250
Water Service Connection	1	each	$1,000.00	$1,000
Gauge, curb box, appurtenances	1	each	$1,000.00	$1,000
ORC Injection System (One-time Injection)				
ORC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (83 borings @ 2" ID, 60' bls)	4980	ft	$10.00	$49,800
ORC	4565	lb	$11.00	$50,215
ORC Injection Equipment (tank/pumps)	4	wks	$1,000.00	$4,000
Per Diem/Lodging (3 men @ 20 days)	60	days	$100.00	$6,000
Decontamination	20	hrs	$100.00	$2,000
Misc. Equipment and Supplies	1	LS	$4,000.00	$4,000
ORC Monitoring Network (10 existing MWs)				$0
Sub-total ORC Support System and Injection				**$120,315**
TOTAL DIRECT COSTS				**$154,715**
INDIRECT COSTS				
Health and Safety				$5,000
Administrative Fees				$5,000
Engineering, Design and UIC Permitting				$15,000
Construction Support Services				$10,000
TOTAL INDIRECT COSTS				**$35,000**
TOTAL CAPITAL COSTS				**$189,715**

TABLE D-3

ALTERNATIVE NO. 3 - ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
OPERATION & MAINTENANCE COSTS				
ORC and NA Monitoring O&M (quarterly 2 yrs and annual for 3 years)				
11 NAORC Wells + 2QA/QC = 13 Samples/event for 5 yrs				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,500.00	$1,500
Analysis-ORC Parameters	13	samples	$200.00	$2,600
Analysis-TCL Organics (VOCs only)	13	samples	$150.00	$1,950
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$1,000.00	$1,000
Subtotal ORC/NA Yearly Monitoring Costs (5 yrs)				**$16,350**
Present Worth ORC/NA Monitoring @ I = 6%, n=5 yrs				**$158,775**
Five-year Site Reviews (One time only yr 5)				
Meetings (attendance only)				
Senior Scientist	16	hrs	$90.00	$1,440
Mid-level Engineer	16	hrs	$75.00	$1,200
ODCs	1	lump sum	$200.00	$200
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Annual Costs				**$19,640**
Present Worth 5 Year Review (i = 6%, n = 5 yrs)				**$14,677**
TOTAL PRESENT WORTH O&M COSTS				**$173,452**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$363,167**
CONTINGENCY @10 PERCENT				**$36,317**
TOTAL COST OF ALTERNATIVE NO. 3				**$399,484**

TABLE D-4

ALTERNATIVE NO. 4 - ENHANCED BIOREMEDIATION WITH EX-SITU AIR STRIPPING INJECTION OF TREATED GROUNDWATER INTO WELLS WITH ORC

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	4	month	$150.00	$600
Office Trailer	4	month	$250.00	$1,000
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pads (2-30' x 40')	2	each	$5,000.00	$10,000
Treatment Buildings (2-20' x 30')	2	each	$15,000.00	$30,000
Fencing:				
2 Treatment Areas for equip/controls (30' x 40')	240	ft	$10.00	$2,400
Trailer Area (40' x 80')	240	ft	$10.00	$2,400
Gates	2	each	$150.00	$300
Office Equipment Rental	4	month	$2,000.00	$8,000
Utility Connections for trailer, sys equip, controls	1	LS	$15,000.00	$15,000
Toilet/water cooler service	16	wks	$50.00	$800
Miscellaneous Equipment	1	LS	$5,000.00	$5,000
Decon Equipment and Pad:				
Pressure Washer with Water Tank	4	month	$500.00	$2,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$4,000.00	$4,000
Labor (Site Preparation)				
Laborers (2 men @ 10 days @ 10 hrs/day)	20	days	$320.00	$6,400
Foreman/Superintendent (1 man @ 10 hrs/day)	10	days	$600.00	$6,000
Sub-total Site Preparation/Mobilization				**$95,900**
Groundwater Extraction and Injection System (7 extraction wells pumping @ 20-25 gpm each, 8 injection wells pumping @ 18-35 gpm each)				
Groundwater Extraction/Injection Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (15 wells @4" ID, PVC, 60' bls)	900	ft	$75.00	$67,500
Extraction/Injection Well Vaults	15	each	$2,500.00	$37,500
Pumps (7 extraction + 2 injection)	9	pumps	$5,000.00	$45,000
Per Diem/Lodging (3 men @ 20 days)	60	days	$100.00	$6,000
Decontamination	16	hrs	$100.00	$1,600
Investigation Derived Waste (soil and dev. Water)	1	LS	$20,000.00	$20,000
Misc. Equipment and Supplies	1	LS	$5,000.00	$5,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	2	poles	$550.00	$1,100
Power Cable	250	ft	$10.00	$2,500
Transformer	2	each	$1,500.00	$3,000
Telephone line for Telemetry	250	ft	$10.00	$2,500
Service Connection	2	each	$1,500.00	$3,000
Gauge, curb box, appurtenances	2	each	$1,500.00	$3,000

TABLE D-4

ALTERNATIVE NO. 4 - ENHANCED BIOREMEDIATION WITH EX-SITU AIR STRIPPING INJECTION OF TREATED GROUNDWATER INTO WELLS WITH ORC

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
Extraction wells to treatment systems (2" ID, PVC)	4100	ft	$18.00	$73,800
Discharge to Injection wells (2" ID, PVC)	4,700	ft	$18.00	$84,600
Flow Meters	15	each	$300.00	$4,500
Pressure Gauges	15	each	$16.50	$248
Telemetry	2	each	$10,000.00	$20,000
Temperature Gauges	2	each	$80.00	$160
Instrumentation Controls	2	each	$10,000.00	$20,000
Labor				
3 men @ 8 weeks @ 50 hrs/week	1200	hr	$32.00	$38,400
1 Engineer/Foreman @ 8 weeks @ 50 hrs/week	400	hr	$75.00	$30,000
Sub-total Gw Extraction/Injection System				**$470,908**
Ex-situ Shallow Tray Air Stripper Systems (2)				
Equalization Tank (1,000 gal)	1	each	$500.00	$500
Equalization Tank (10,000 gal)	1	each	$4,000.00	$4,000
Adjustable Flow Feed/Transfer pump	4	each	$2,000.00	$8,000
Shallow-Tray Air Stripper System w/ Blower (25 gpm)	1	LS	$10,000.00	$10,000
Shallow-Tray Air Stripper System w/ Blower (170 gpm)	1	LS	$30,000.00	$30,000
Sub-total Shallow-tray Air Stripper Systems				**$52,500**
Enhanced Bioremediation (ORC socks in 8 injection wells, 30' in length)				
ORC Socks replaced every 3 months = (4x8 wells) = 32	960	feet	$37.50	$36,000
Sub-total Enhanced Bioremediation Material				**$36,000**
TOTAL DIRECT COSTS				**$665,308**
INDIRECT COSTS				
Health and Safety				$20,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$115,000**
TOTAL CAPITAL COSTS				**$780,308**

TABLE D-4

ALTERNATIVE NO. 4 - ENHANCED BIOREMEDIATION WITH EX-SITU AIR STRIPPING INJECTION OF TREATED GROUNDWATER INTO WELLS WITH ORC

	Quantity	Unit	Unit Cost	Total Cost
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Site-Specific Remedial Goals				
Treatment System O&M (annual for 4 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$1,000.00	$12,000
Treatment System	12	month	$1,000.00	$12,000
System Maintenance				
Labor (1 operators @ 8 hrs/week, 52 weeks/year)	416	hrs	$45.00	$18,720
Aeration System Components	12	month	$1,000.00	$12,000
Extraction/Injection Well Flushing (annually)	1	LS	$15,000.00	$15,000
Sub-total Annual Treatment System O&M				**$69,720**
Sampling and Monitoring				
Extraction Well Influent Grab Samples (7 wells, 1 per month):				
TCL Organics (VOCs only)	84	samples	$150.00	$12,600
Effluent Grab Samples (1 per month/system):				
Full Suite Discharge Requirements	24	samples	$1,200.00	$28,800
Sub-total Annual GW Sampling and Monitoring				**$41,400**
Present Worth GW Treatment System I=6%, n=4 years				**$385,031**
Enhanced Bioremediation (ORC socks in 8 injection wells, 30' in length)				
Replacement ORC Socks per year (8 wellsx4x30')	960	feet	$37.50	$36,000
Sub-total Enhanced Bioremediation O&M				**$36,000**
Present Worth System O&M Costs @ I = 6%, n=4 yrs				**$124,740**
GW Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program for Enhanced Bioremediation of Groundwater Plume (5 years)				
11 wells + 2 QA/QC = 13 Samples, 2 times a year				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	each	$1,500.00	$1,500
Natural Attenuation Parameters	13	samples	$200.00	$2,600
Analysis - TCL Organics (VOCs Only)	13	samples	$150.00	$1,950
Summary Data Report:				
Mid-level Engineer	30	hrs	$75.00	$2,250
Senior Scientist	20	hrs	$90.00	$1,800
Associate Engineer	30	hrs	$60.00	$1,800
ODCs	1	LS	$1,500.00	$1,500
Subtotal NA Costs Per Sampling Event				**$19,100**
Present Worth GW Monitoring @I=6%, n=5 yrs				**$160,898**

TABLE D-4

ALTERNATIVE NO. 4 - ENHANCED BIOREMEDIATION WITH EX-SITU AIR STRIPPING INJECTION OF TREATED GROUNDWATER INTO WELLS WITH ORC

	Quantity	Unit	Unit Cost	Total Cost
Five-year Site Reviews (one time event)				
Meetings (attendance only)				
Senior Scientist	16	hrs	$90.00	$1,440
Mid-level Engineer	16	hrs	$75.00	$1,200
ODCs	1	lump sum	$200.00	$200
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five-Year Reviews				**$19,640**
Present Worth 5 Year Site Review @ i=6%, n=5 yrs				**$14,677**
TOTAL O&M COSTS				**$685,346**
TOTAL CAPITAL COSTS AND O&M COSTS				**$1,465,654**
CONTINGENCY @10 PERCENT				**$146,565**
TOTAL COST OF ALTERNATIVE NO. 4				**$1,612,219**