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# FINAL FOCUS FEASIBILITY STUDY FOR SOUTHERN LOBE TRICHLOROETHENE PLUME

NAS FORT WORTH TX

6/30/2005

HYDROGEOLOGIC

# CARSWELL AFB
# TEXAS

## ADMINISTRATIVE RECORD
## COVER SHEET

AR File Number 778

**DEPARTMENT OF THE AIR FORCE**
HEADQUARTERS AERONAUTICAL SYSTEMS CENTER (AFMC)
WRIGHT-PATTERSON AIR FORCE BASE OHIO

June 30, 2005

MEMORANDUM FOR ROBERT SULLIVAN (EPA REGION 6)

FROM: Mr. George Walters
1801 Tenth Street, Building 8, Suite 2
Wright Patterson AFB, OH 45433

SUBJECT: Final Focus Feasibility Study Southern Lobe Trichloroethene Plume, Former Carswell AFB, Texas
EPA ID No. TX0571924042

Dear Mr. Sullivan,

We respectfully submit the Final Focus Feasibility (FFS) Study Southern Lobe Trichloroethene Plume for Former Carswell Air Force Base (AFB) for your approval. Should you have any questions or require further information, please contact me at (937) 255-1988 or by email at george.walters@wpafb.af.mil.

Sincerely,

Mr. George Walters, IPT Chief AFP 4/6
ASC/ENVR
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Wright Patterson AFB, OH 45433

c:

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Mr. Noel Bennett (1 copy)

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# FINAL
# FOCUSED FEASIBILITY STUDY
# SOUTHERN LOBE TRICHLOROETHENE
# GROUNDWATER PLUME
# FORMER CARSWELL AFB, TEXAS

Prepared for

Air Force Center for Environmental Excellence, Brooks AFB, Texas
Aeronautical Systems Center, Wright Patterson AFB, Ohio
Air Force Real Property Agency, San Antonio, TX

Contract Number F41624-02-F-8899

June 2005

# FINAL
# FOCUSED FEASIBILITY STUDY
# SOUTHERN LOBE TRICHLOROETHENE
# GROUNDWATER PLUME
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Contract Number F41624-02-F-8899

Prepared by

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June 2005

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| 12a. DISTRIBUTION/AVAILABILITY STATEMENT<br>Unlimited | | | 12b. DISTRIBUTION CODE |
| 3. ABSTRACT (Maximum 200 words)<br>This document presents the remedial alternatives that were developed and evaluated to address contamination within the vicinity of the southern lobe of the basewide trichloroethene (TCE) groundwater plume at the former Carswell Air Force Base (AFB). More specifically, this Focused Feasibility Study (FFS) addresses a 187-acre portion of the former Carswell AFB that is located to the southeast of the Naval Air Station Fort Worth Joint Reserve Base (NAS Fort Worth JRB) Texas. The study area is being considered for public transfer under the Base Realignment and Closure (BRAC) program. | | | |
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# EXECUTIVE SUMMARY

This focused feasibility study (FFS) report documents the development and detailed evaluation of remedial alternatives proposed to address contamination within a 187-acre property located adjacent to the Naval Air Station Fort Worth Joint Reserve Base (NAS Fort Worth JRB). The subject property is located on a portion of the former Carswell Air Force Base (AFB) that is slated for transfer to the private sector under the Base Realignment and Closure (BRAC) program, hence commonly referred to as the "BRAC property". Presently, the BRAC property is used as a golf course. A large trichloroethene (TCE) plume originating primarily from Air Force Plant 4 (AFP 4) and the former Carswell AFB (i.e., southern lobe TCE plume) has impacted groundwater underlying the golf course portion of the BRAC property (Figure ES.1). Over the past 5 years while conducting investigations and risk assessments to support this FFS, several interim remedial actions and demonstration studies have been conducted which have significantly reduced the size and toxicity of the TCE plume.

A major goal of this FFS is to evaluate remedial alternatives that ensure the protection of human health and the environment for several land use options that have been proposed for the property. This FFS serves as the principal document supporting the selection of a preferred alternative.

AFP 4 was placed on the National Priorities List (NPL) in August 1990 due to a large release of TCE arising from past disposal practices at AFP 4. The source areas are currently being remediated under a Federal Facility Agreement (FFA) among the United States (U.S.) Environmental Protection Agency (EPA) Region VI, the Texas Commission on Environmental Quality (TCEQ), (formerly the Texas Natural Resources Conservation Commission [TNRCC]) and Aeronautical Systems Center (ASC) (Rust Geotech, 1995). The dissolved TCE plume has migrated east of the primary source areas of AFP 4 and currently extends under NAS Fort Worth JRB and the BRAC property (collectively the former Carswell AFB). At the Former Carswell AFB, the regional TCE plume can be divided into northern, central, and southern lobes. The southern lobe, which has impacted groundwater underlying the BRAC property, is the main subject of this FFS.

Though the dominant contaminant in the Terrace Alluvium shallow aquifer is TCE, *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and vinyl chloride (VC), are also present at concentrations above their respective maximum contaminant levels (MCLs). With the exception of soil contamination within the individual landfills and other solid waste management units/areas of concern (SWMUs/AOCs) at the site (as explained in the individual Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) reports for those units), there is no evidence of soil contamination at the BRAC property. The Baseline Risk Assessment (HGL, 2002a, 2002b, 2001a) for the site concluded that there was no significant risk to human health or the environment from surface water or sediment contamination at the site. Therefore, this FFS addresses remedial alternatives for the contaminants of concern (COCs) only in the shallow groundwater (i.e., Terrace Alluvium) at the site, as the deep aquifer has not been impacted by the contamination. The remedial alternatives do not address surface water, sediment or soil.

**Remedial Action Objectives/Remedial Alternatives**

The overall objective of remedial action at the BRAC property is to protect human health and the environment by meeting MCLs at the site. To achieve these goals, Remedial Action Objectives (RAO) 1 and 2 were developed. To fully consider and evaluate a full range of remediation options, four remedial alternatives beneath the two RAOS were developed as part of this FFS.

- RAO 1 Alternative 1 (the No Additional Action Alternative): Retain federal control of the BRAC property; continue existing program of monitoring, land use controls and remediation through the operation and maintenance (O&M) of the existing permeable reactive barrier (PRB).
- RAO 2 (Alternatives 2-4): Transfer the BRAC property to the public while maintaining land use restrictions until MCLs are achieved.

**No Additional Action Alternative – RAO 1**

Under RAO 1, the federal government would maintain control of the BRAC property, and it is assumed that the current land use/land ownership would continue indefinitely. The current land use consists of a golf course which covers the area that is currently impacted by the plume. Continued federal control of the property would ensure that the residential area south of the TCE plume would not be expanded, and that groundwater would not be used for any purpose (i.e., drinking water, irrigation, etc.) until MCLs were met at some point in the future. Construction could occur at the site, but it would be limited to small-scale projects such as road and utility repairs. Continued federal control would ensure that no construction requiring substantial excavation or trenching would occur. The existing AFP 4 Record of Decision (ROD) would mandate any actions.

**Property Transfer – RAO 2**

Under this alternative, the groundwater would be remediated to achieve applicable or relevant and appropriate requirements (ARARs), and the land would be transferred to the private sector. Because the property transfer would occur before attainment of ARARs, institutional controls (ICs) would be used to protect human health through land use restrictions.

When the property is transferred, ICs would be established to ensure that the property above the groundwater plume is used only for commercial or industrial purposes until MCLs were met. ICs would ensure that no one would be exposed to the groundwater via either the soil-gas inhalation pathway or the drinking water pathway. The ICs also would ensure that industrial/commercial workers are not exposed to groundwater contaminants via the use of water for industrial/commercial purposes. In this situation, the only potential exposure to groundwater contaminants would be by construction workers working in excavations for new buildings and new utilities, and industrial/commercial workers in a building located above the plume. The ICs would include excavation restrictions to ensure that excavation workers are protected.

When MCLs are achieved, future residences (although not currently in the land use plans) could be built above the groundwater plume and the residents could, theoretically, use the shallow aquifer as a source of potable water although it is a Class 3 water source. The property would most likely continue to be used as a golf course.

## ALTERNATIVES

Remedial technologies and associated process options were identified and qualitatively evaluated. During this preliminary screening process, remedial alternatives and process options were eliminated or retained based on cost, effectiveness, and implementability. As part of the alternative development process, process options were combined under individual alternatives to achieve MCLs. Four remedial action alternatives, presented in Table ES-1, were developed from the representative technology process options.

**Table ES-1**
**Remedial Action Alternatives**

| Property Not Transferred | Property Transferred |
|---|---|
| **Alternative 1** | **Alternative 2** |
| **No Federal Boundary Change**<br>• Maintain PRB<br>• Long Term Monitoring<br>• Land Use Controls | **Federal Boundary Change**<br>• Monitored Natural Attenuation<br>• Land Use Controls restricting residences and potable/groundwater supply wells |
| | **Alternative 3** |
| | **Federal Boundary Change**<br>• Pump-and-Treat<br>• Cometabolic Biosparging |
| | **Alternative 4** |
| | **Federal Boundary Change**<br>• Additional PRBs<br>• Monitored Natural Attenuation |

### Alternative 1 - No Additional Action

As required by the National Contingency Plan (NCP), the no action alternative is evaluated in order to provide a comparative baseline in which other alternatives can be evaluated. Under this alternative, all groundwater would be left "as is" without implementing any additional containment, removal, treatment, or other mitigating actions. For the purposes of this FFS, however, Alternative 1 is modified from the typical "no action" required by the NCP to "no additional action" because there are already several remedial technologies that have been installed within or upgradient of the BRAC property and these remedies will continue to operate. This modification will make the comparative analysis of the various alternatives more meaningful and will provide a sound basis for the cost comparisons presented in Section 6.0.

Alternative 1 consists of the following three components: (1) an existing PRB located along the western boundary of the BRAC property; (2) a long-term monitoring (LTM) program; and (3) an area of phytoremediation (which is no longer being monitored) located along the northwestern boundary of the BRAC property (Figure ES.2). The PRB and phytoremediation area were installed on the BRAC property as part of two separate technology demonstration studies. Because of their in-situ nature and the fact that they will continue to operate, the PRB and the phytoremediation area were included as part of each alternative being considered.

**Alternative 2**

Alternative 2 consists of each item described in Alternative 1 as well as monitored natural attenuation (MNA) for treatment of the residual plume to MCLs. ICs would be required until the groundwater reached MCLs. This alternative is depicted in Figure ES.3. Alternative 2 assumes the property is transferred to the public.

**Alternative 3**

Alternative 3 consists of pump-and-treat along the western and northwestern boundaries for containment purposes, and biosparging within the plume to initiate cometabolic metabolism of TCE (Figure ES.4) for treatment of the residual plume to MCLs. Alternative 3 assumes the property is transferred to the public. ICs would be in place until the groundwater reached MCLs.

**Alternative 4**

Alternative 4 consists of PRBs along the western and northwestern boundaries (in addition to the existing PRB) to treat the groundwater coming onto the site to MCLs. MNA processes would be relied on to remediate existing groundwater contamination underlying the BRAC property. The Alternative 4 remedial configuration is shown in Figure ES.5. Alternative 4 assumes the property is transferred to the public. ICs would be in place until the groundwater reached MCLs.

## DETAILED ANALYSIS OF ALTERNATIVES

Section 121 of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, specifies statutory requirements for remedial actions. These requirements include protection of human health and the environment, compliance with ARARs, and a preference for permanent solutions that incorporate treatment as a principal element to the maximum extent practicable. To assess whether alternatives meet the requirements, EPA has identified in the NCP (EPA, 1988) nine criteria that must be evaluated for each alternative retained through the screening stage [Sect. 300.430(e)(9)(iii)]:

- overall protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, and volume through treatment;
- short-term effectiveness;
- implementability;
- cost;
- state acceptance; and
- community acceptance.

Of the nine criteria listed above, the first two – overall protection of human health and the environment, and compliance with ARARs – are considered to be threshold criteria. The remedial action alternative selected must meet these two requirements. The next five criteria (long-term effectiveness and permanence; reduction of toxicity, mobility and volume reduction through treatment; short-term effectiveness; implementability; and cost) are balancing criteria. The final two criteria, state acceptance and community acceptance, are modifying criteria. The modifying criteria of state and community acceptance will be considered following public comment on the proposed plan. Each of the alternatives was screened against the threshold criteria and the balancing criteria; a summary of the screening can be found in Table ES-2.

## COSTS

Costs associated with implementation of each alternatives are summarized in Table ES-2. The present value cost for Alternative 1 ($2,988,000) will be required in addition to each alternative. Long term monitoring costs and PRB maintenance and sampling costs, are included for a 30-year period under Alternative 1. The remaining alternatives are ranked in the following descending order relevant to net present worth:

- Alternative 2 $1,199,000
- Alternative 4 $16,455,000
- Alternative 3 $19,351,000

# Table ES-2
## Individual Evaluation of Final Alternatives

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Human Health Protection | No reduction in risk beyond that achieved by the existing PRB and natural attenuation; protective of human health due to controls maintained by the Federal government | Reduction of risk through remediation of groundwater to MCLs; protective of human health in the interim via LUCs. | See Alternative 2 | See Alternative 2 |
| Environmental Protection | There is no current risk to ecological communities. Ecological receptors will continue to be protected. | There is no current risk to ecological communities. Ecological receptors will continue to be protected. | See Alternative 2 | See Alternative 2 |
| Compliance with ARARs | Not applicable. | All ARARs will be achieved. Future optimizations/5 Year Reviews will ensure MCLs are obtained. | See Alternative 2 | See Alternative 2 |
| Magnitude of Residual Risk | The continued operation of the existing PRB is expected to attenuate residual contamination, resulting in risk reduction; maintenance of Federal control over the property will protect human health through elimination of exposure pathways | Risk reduced to acceptable levels through reduction in contaminant concentrations. | See Alternative 2 | See Alternative 2 |
| Adequacy and Reliability of Controls | Existing PRB will continue to reduce contaminant concentrations flowing onto the BRAC property. PRB will not affect contamination flowing onto the property in the area north of the PRB's northern terminus. Maintenance of Federal ownership of the land will ensure reliable control of future land use. | Existing PRB will continue to reduce contaminant concentrations flowing onto the BRAC property. PRB will not affect contamination flowing onto the property in the area north of the PRB's northern terminus. Reliability of this alternative also depends on ability to maintain effective operation of the AFP 4 East Parking Lot Pump and Treat System so it continues to contain the TCE plume for as long as the continuing source term is present. May require additional optimization to be adequate. Reliability of institutional controls depends on effective site monitoring. | System will provide adequate control of contaminants flowing onto the BRAC property and degradation of residual contamination currently present on the BRAC property. Pump-and-treat system must be maintained as long as source is present. Reliability of this approach depends on ability to maintain effective hydraulic control of contamination from NAS Fort Worth JRB until MCLs are achieved and maintained upgradient of the property boundary. | Additional PRBs will provide adequate control of contaminants flowing onto the BRAC property. MNA will reduce residual concentrations on the BRAC property, but will take longer to achieve MCLs than Alternative 3 and has less reliability than Alternative 3 in achieving MCLs. Reliability of this alternative also depends on ability to maintain effective operation of the AFP 4 East Parking Lot Pump and Treat System so it continues to contain the TCE plume for as long as the continuing source term is present. |

## Table ES-2 (continued)
## Individual Evaluation of Final Alternatives

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Need for 5 year review | Review would be required to ensure adequate protection of human health and the environment. | See Alternative 1 | See Alternative 1 | See Alternative 1 |
| Community Protection | No increase in risk to community from present level. Current land use and conditions are protective of human health. | The community will be protected provided that LUCs are maintained and effectively monitored until MCLs are met. | Most effective alternative in the short-term due to active removal of residual contamination on the BRAC property. Long-term effectiveness depends on maintenance of the hydraulic controls over the groundwater flowing onto the BRAC property. Ensures protection of the community by remediating groundwater on BRAC property to MCLs, thereby eliminating the need to prevent future use of the shallow groundwater. LUCs will ensure protectiveness in interim. | This alternative will effectively contain contaminated groundwater from moving onto the BRAC property immediately after completion of the PRB installation. The time frame to meet MCLs on the BRAC property by MNA will be longer than for the cometabolic processes (Alternative 3). Long-term effectiveness depends on maintenance of the PRBs that treat the groundwater flowing onto the BRAC property. Ensures protection of the community by remediating groundwater on BRAC property to MCLs, thereby eliminating the need to prevent future use of the shallow groundwater. LUCs will ensure protectiveness in interim. |
| Worker Protection | No additional risk to workers. | See Alternative 1 | Limited worker exposure during pump-and-treat well and pipeline installation. Some level of dermal protection from groundwater contact will be required. Protection from air stripper discharge and methane gas may be required. | Limited worker exposure during trenching activities. Dermal protection from groundwater and excavated soil contact will be required. |
| Environmental Impacts | Environmental impacts unchanged from existing conditions | See Alternative 1 | Impact to the environment would be minimal. The volume of groundwater pumped will not significantly impact surface water levels. | Trenching for PRB installation will have minimal impact on the environment. |

## Table ES-2 (continued)
## Individual Evaluation of Final Alternatives

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Time until Action Complete | NA | One year for establishment of land use controls. Land use controls and existing PRB must be maintained until MCLs are met which is expected to be between 20 and 50 years. Optimization efforts (if required) could reduce time until action is complete. | 5 years to achieve MCLs on the BRAC property. Hydraulic control of the upgradient groundwater must be maintained until MCLs are achieved and maintained (through EPL system containment) upgradient of the property. MCLs are ancipated to be achieved between 20 and 50 years. | Between 10-15 years to achieve MCLs on the BRAC property. Effective treatment of the groundwater flowing onto the BRAC property must be maintained until remediation or continued containment of the continuing source at AFP-4. MCLs are ancipated to be achieved between 20 and 50 years. |
| Amount destroyed or treated | No treatment of contaminants beyond that currently achieved by the existing PRB and natural attenuation. | This alternative will partially contain the contaminants flowing on the BRAC property. Residual contamination will be destroyed through MNA or an optimization of the current remedy. | This alternative will treat the residual contaminants on the BRAC property and contain/treat contaminants flowing onto the BRAC property. | See Alternative 2 |
| Reduction of Toxicity, Mobility, or Volume | Reduction of toxicity and contaminant mobility in vicinity of existing PRB, and downgradient of PRB through natural attenuation. | Reduction of toxicity and contaminant mobility in vicinity of existing PRB, and downgradient of PRB through MNA. Additional optimization may be required to reduce volume. | Complete reduction in toxicity of groundwater on the BRAC property. Hydraulic controls will prevent future migration of contaminants onto the BRAC property. | Complete reduction in toxicity of groundwater on the BRAC property. PRBs will reduce toxicity of groundwater flowing onto the BRAC property. |
| Irreversible Treatment | Contaminant treatment provided by the existing PRB is irreversible. | Contaminant treatment provided by the existing PRB and MNA are irreversible. LUCs are reversible. | Destruction of contaminants by cometabolic processes is irreversible. Contaminants will not be destroyed by the pump-and-treat system, but will be transferred to the ambient air through air stripping. | Destruction of contaminants by natural attenuation and abiotic zero valent iron (ZVI) reactions is irreversible. |

## Table ES-2 (continued)
## Individual Evaluation of Final Alternatives

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Ability to Construct and Operate | With the exception of groundwater monitoring, no construction or operation is necessary. Maintenance on the PRB may be necessary every 10 years. The methods and effectiveness of this maintenance is not well documented and may be difficult. | See Alternative 1 | Pump-and-treat and methane injection require relatively simple operations. Construction of both systems is relatively straightforward. | PRBs require no operation. Construction is moderately difficult due to large trenching requirement. Maintenance on the PRB may be necessary every 10 years. The methods and effectiveness of this maintenance is not well documented and may be difficult. |
| Ease of Doing More Action if Needed | Activities currently conducted under the No Additional Action Alternatives can be easily modified. | Land use controls could be easily enhanced with other technologies, process options etc. | Simple to extend pump-and-treat or methane injection system if necessary. | The materials and services to extend the PRBs are available from several firms. |
| Ability to monitor Effectiveness | Present monitoring will provide adequate notice of potential exposure. | See Alternative 1 | Existing and proposed monitoring network will provide adequate notice of potential exposure, and sufficient information to evaluate the remedial effectiveness. | See Alternative 3 |
| Ability to Obtain Approvals and Coordinate with Other Agencies | None required | Requires the filing of deed restrictions. | May requires an injection permit and an NPDES discharge permit (a waiver can be obtained for a CERCLA site). Requires coordination with Westworth Redevelopment Authority. | Requires coordination with Westworth Redevelopment Authority. |
| Availability of Services and Capacities | No additional services or capacities required | See Alternative 1 | Requires delivery of methane used for cometabolic injection. Suppliers are available in the local area. Qualified drillers are readily available in the state. Qualified plumbers are readily available in the state. | Requires specialized geotechnical construction capability. Several qualified geotechnical contractors operate within the U.S. |
| Availability of Equipment, Specialists, and Materials | None required | None required | Pump-and-treat systems are readily available from multiple suppliers. Components for cometabolic injection of methane are locally available. Specialists to operate and maintain cometabolic and pump-and-treat systems are readily available. | Suppliers of ZVI are available. Equipment for PRB installation is readily available. No specialists are required for PRB operation |

# Table ES-2 (continued)
# Individual Evaluation of Final Alternatives

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Availability of Technologies | None required | None required | Pump-and-treat technologies readily available. Cometabolic technology will require pilot testing. | PRB technology is readily available and an operating PRB is already in-place. |
| Capital Cost | $0 | $36,000 | $11,080,000 | $5,736,000 |
| Present Value of O&M | $2,198,000 | $1,122,000 | $8,198,000 | $2,676,000 |
| Present Value of Periodic Costs | $790,000 | $41,000 | $73,000 | $1,980,000 |
| Total Present Value Costs | $2,988,000 | $1,199,000 [1,4] | $19,351,000[1] | $16,455,000[1] |

[1] Implementation of the no-additional action alternative for the BRAC property involves the continued O&M of an existing PRB and the execution of long-term monitoring. Alternatives 2, 3, and 4's costs are in addition to the costs for Alternative 1 (which will be required for any of the 3 alternatives).

[2] Alternative 2 may also include optimization of the existing remedial technologies at the site.

[3] Alternatives 3 and 4 include the technologies in Alternative 2.

[4] Costs do not include any additional optimization costs which could be required if MNA is determined to be ineffective in reaching MCLs.

BLRA – Baseline Risk Assessment

The expected accuracy of the cost estimates ranges from -30 to +50 percent. These costs are projected for a 30-year time frame. Results of the cost analysis are presented in more detail in Appendix D.

**SUMMARY**

The results of the comparative analysis are summarized in Table ES-2. All of the alternatives provide protection of human health and the environment and comply with ARARs. Alternatives 3 and 4 will be more reliable because they do not rely on ICs for as long a period.

Alternatives 2 through 4 reduce toxicity and volume through treatment with time frames ranging from 5 to 50 years. The most expensive alternative is Alternative 3 ($19.4 million), while the least expensive is Alternative 2 ($1.2 million).

The decision regarding which alternative will be implemented depends primarily on balancing cost against length of time to reach MCLs, Alternative 2 is significantly less costly than Alternatives 3 and 4. The success of Alternatives 3 and 4 depends on the effectiveness of their designs and the implementation of the designs. It is expected that Alternative 4 would be more effective than Alternative 2 and 3. Alternative 3 is the most costly and most aggressive approach, estimated to achieve groundwater concentrations for unrestricted use in 5 years.

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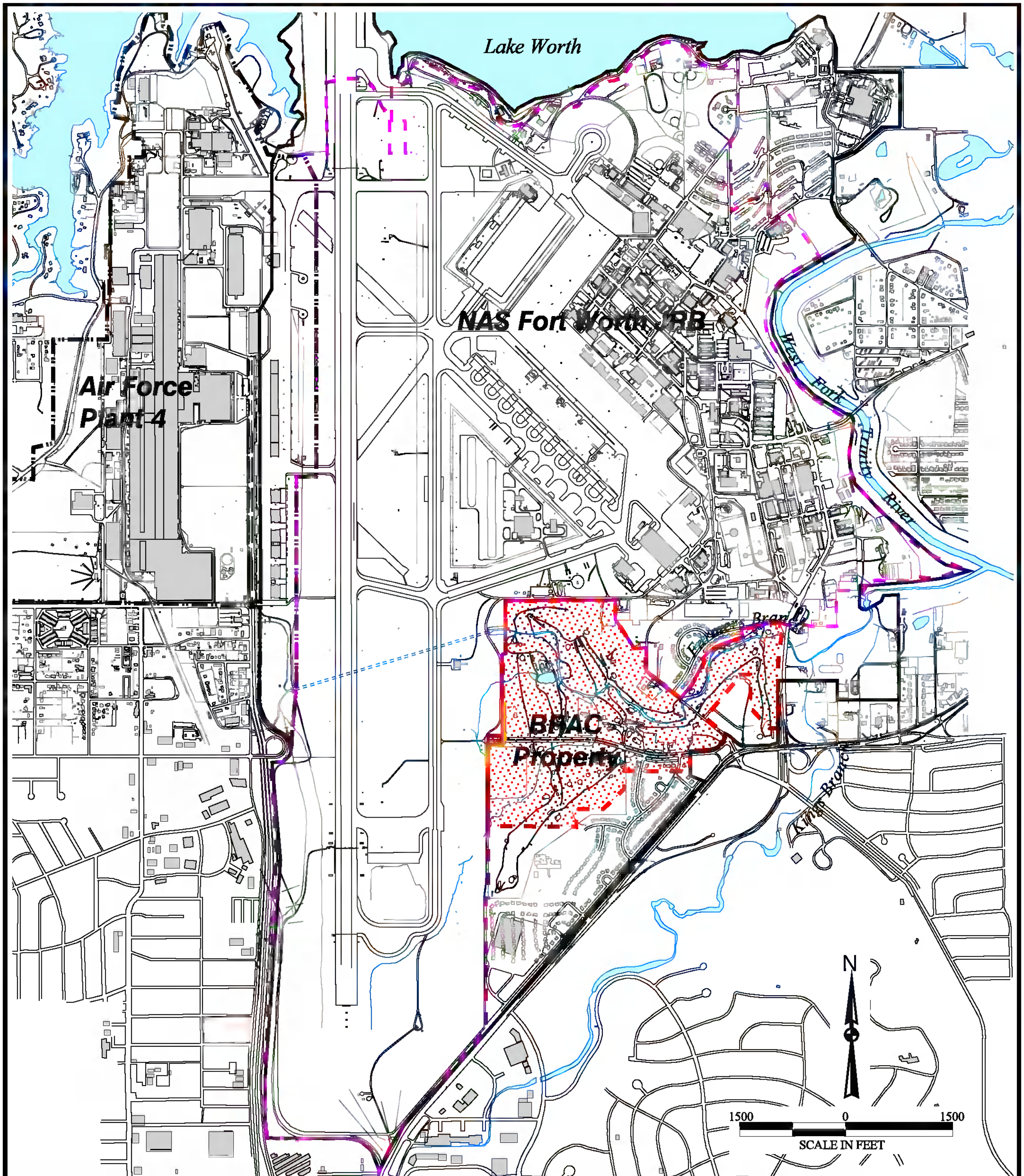


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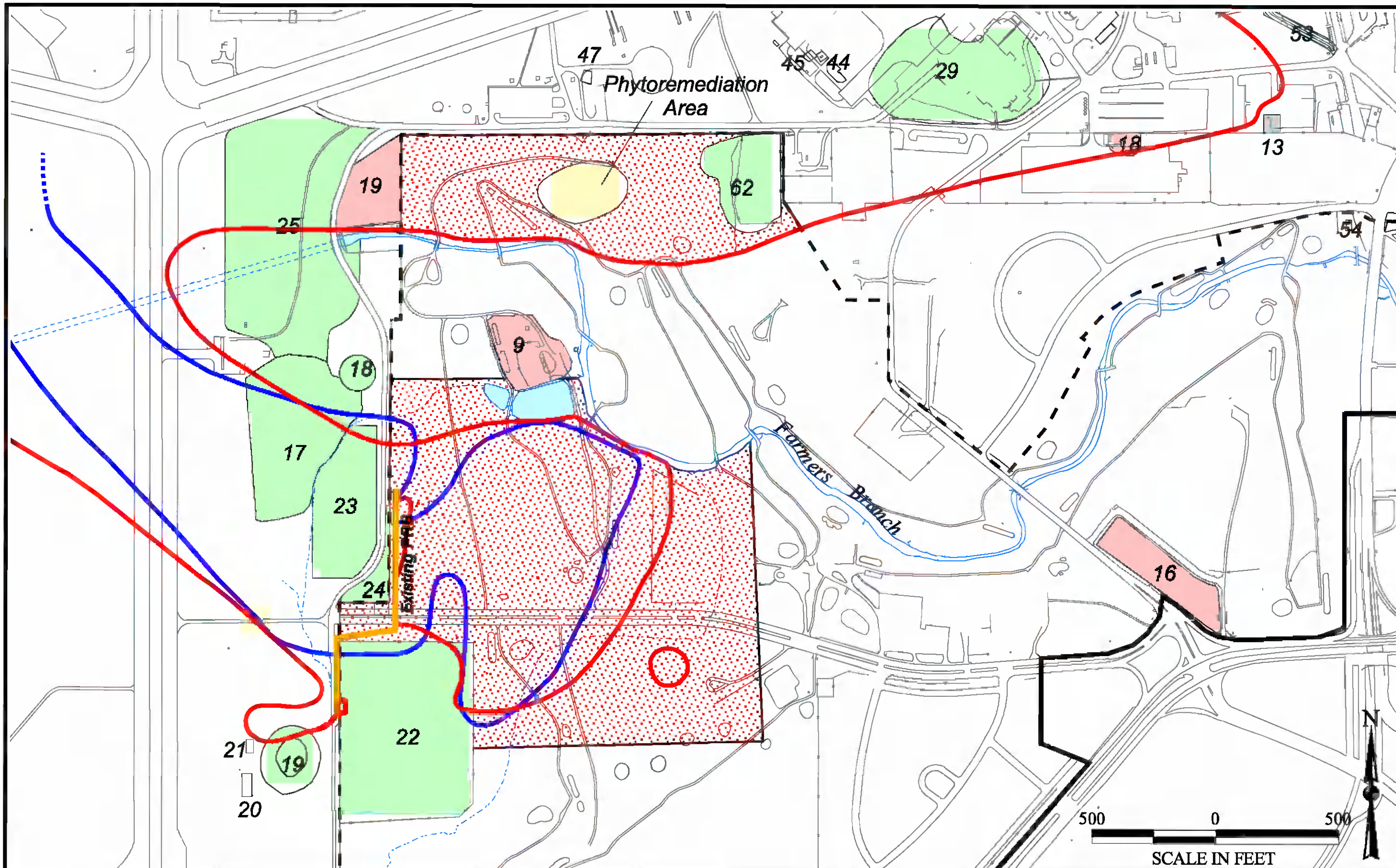
*Revised: 06/29/05 TH*
*Source: HydroGeoLogic, Inc—GIS Database*

**Legend**

- NAS Fort Worth JRB Boundary
- Former Carswell AFB Boundary
- Air Force Plant 4 Boundary
- Risk Assessment/FFS Area
- Permeable Reactive Barrier (PRB)

**Figure ES.1**
**Area Covered by Risk Assessment and Focused Feasibility Study**



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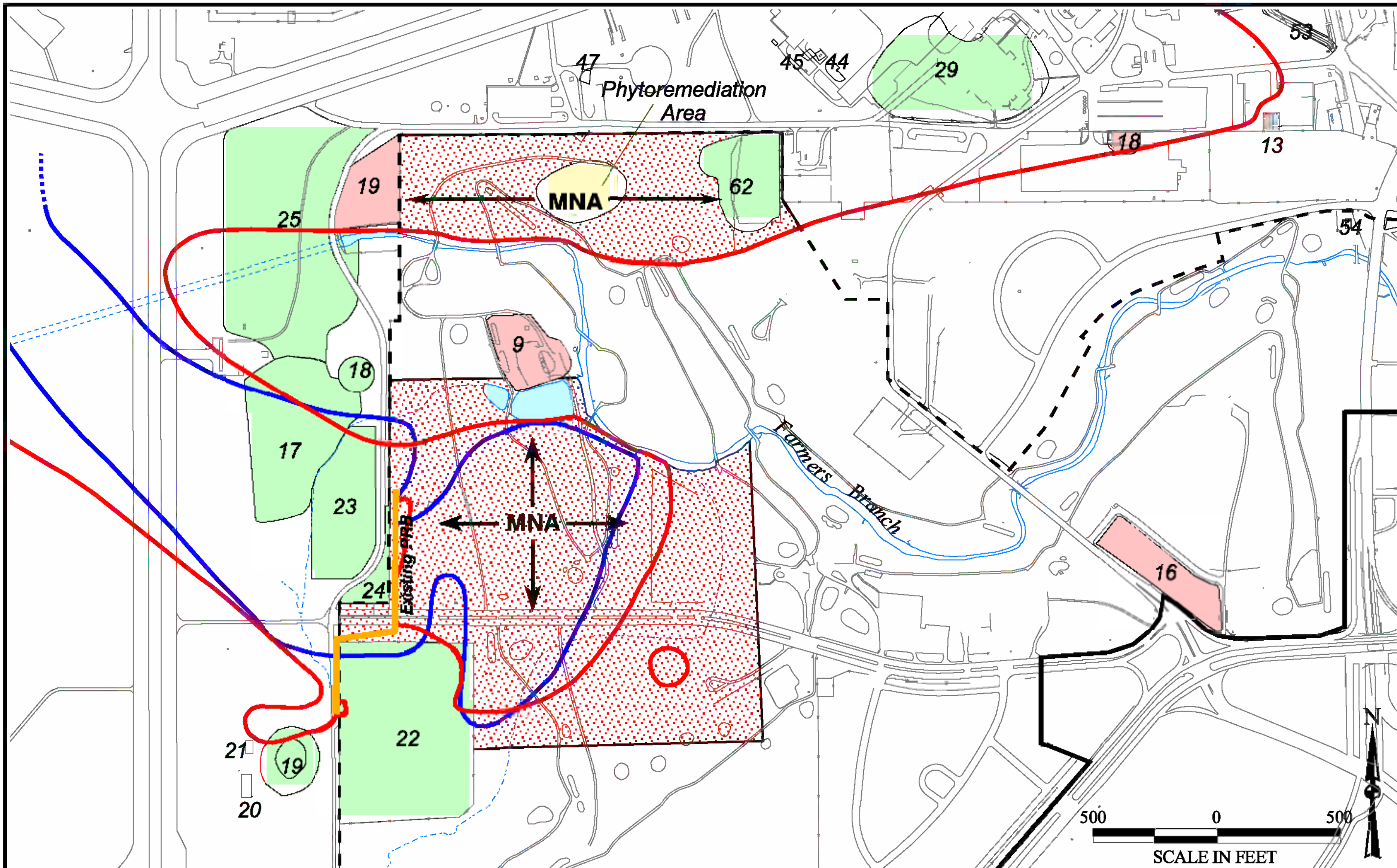
*Revised: 06/29/05 TH*
*Source: HydroGeoLogic, Inc.*
*ArcView GIS Database, 2001*

**Legend**

| Symbol | Description | Symbol | Description |
|---|---|---|---|
| (pink fill) | Area of Concern | (solid black line) | Former Carswell AFB |
| (white outline) | Solid Waste Management Unit | (dashed black line) | NAS Fort Worth JRB |
| (red dotted fill) | ICs/LTM (Approximate Area) | (red line) | TCE Concentration Contour (5 µg/L) |
| | | (blue line) | DCE Concentration Contour (70 µg/L) |

**Figure ES.2**
**Alternative 1**
**No Federal Boundary Change**
**No Additional Action**

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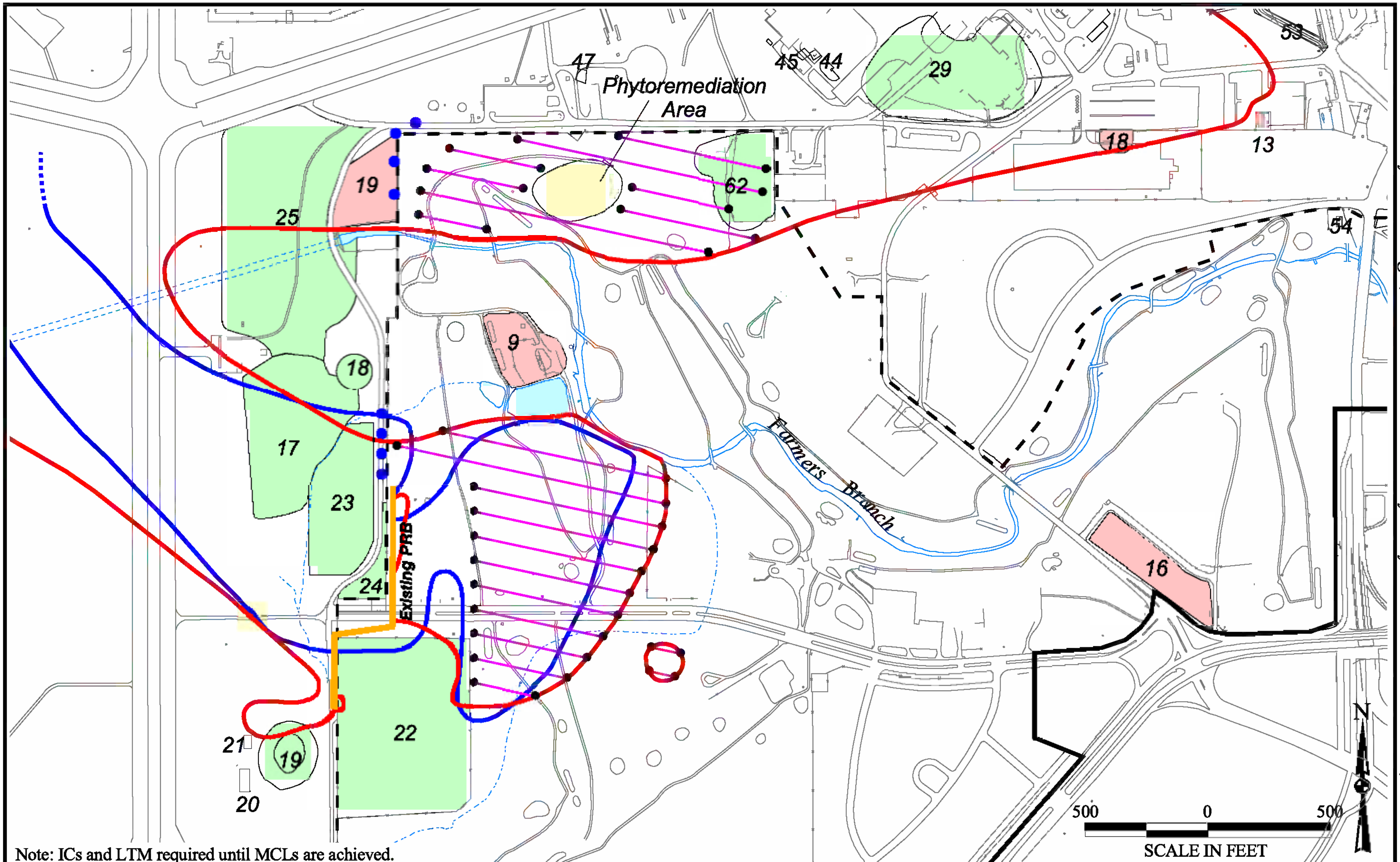
*Project: GSA002-007-06-07-03*
*Revised: 06/29/05 TH*
*Source: HydroGeoLogic, Inc. ArcView GIS Database, 2003*

**Legend**

- Area of Concern
- Solid Waste Management Unit
- ICs/LTM (Approximate Area) (Until MCLs are achieved)
- MNA = Monitored Natural Attenuation
- Former Carswell AFB
- NAS Fort Worth JRB
- TCE Concentration Contour (5 µg/L)
- DCE Concentration Contour (70 µg/L)

**Figure ES.3**
**Alternative 2**
**Monitored Natural Attenuation**

Air Force Center for Environmental Excellence

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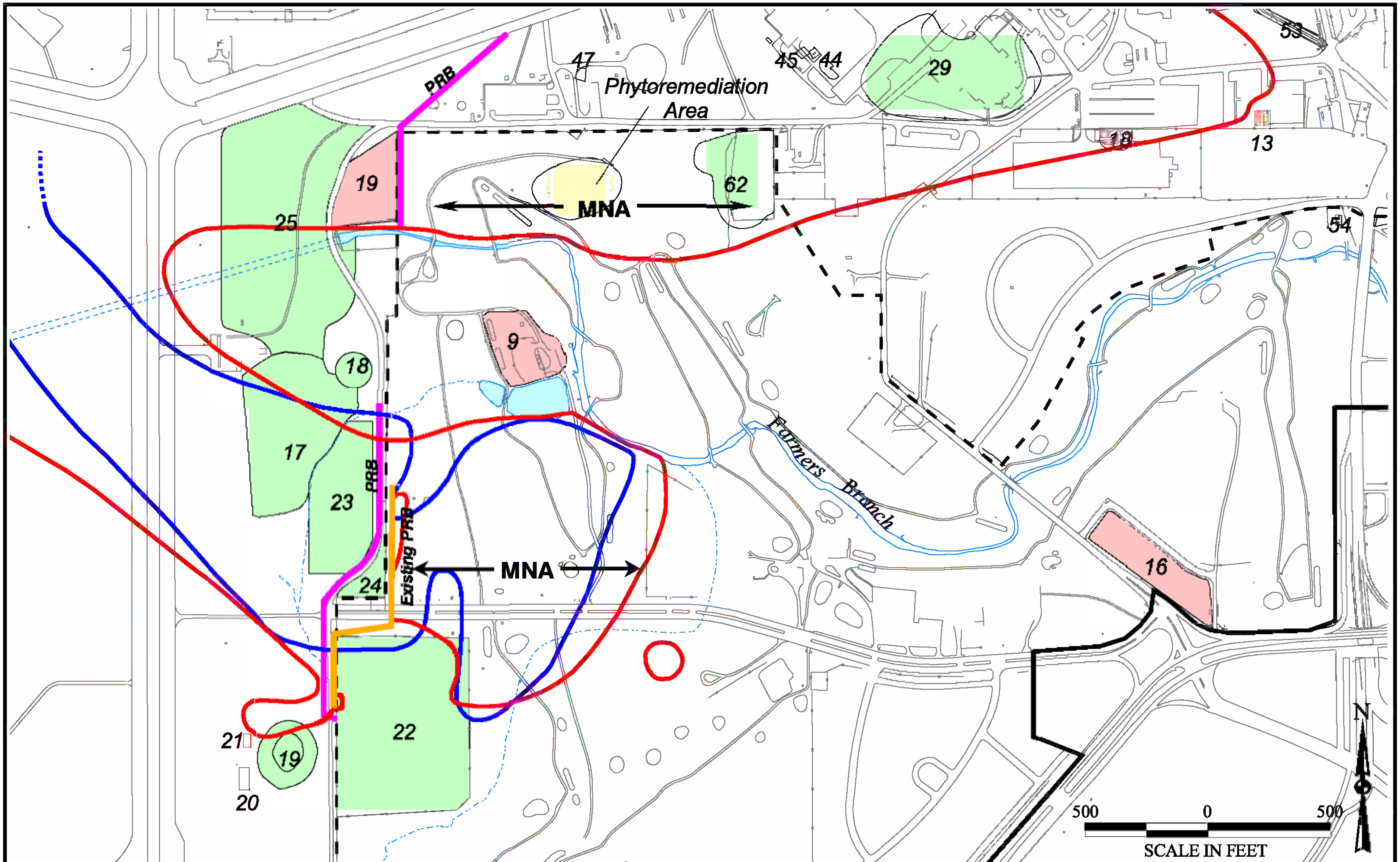
*Project: GSA002-007-06-07-03*
*Revised: 06/29/05 TH*
*Source: HydroGeoLogic, Inc. ArcView GIS Database, 2001*

**Legend**

- Area of Concern
- Solid Waste Management Unit
- Former Carswell AFB
- NAS Fort Worth JRB
- TCE Concentration Contour (5 µg/L)
- DCE Concentration Contour (70 µg/L)
- Methane/Air Injection Well
- Pumping Well

**Figure ES.4**
**Alternative 3**
**Pump and Treat with Cometabolic Biosparging**

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Project: GSA002-007-06-07-03
Revised: 06/29/05 TH
Source: HydroGeoLogic, Inc.
ArcView GIS Database, 2001

**Legend**

- Area of Concern
- Solid Waste Management Unit
- Former Carswell AFB
- NAS Fort Worth JRB
- TCE Concentration Contour (5 µg/L)
- DCE Concentration Contour (70 µg/L)
- **MNA** Monitored Natural Attenuation

**Figure ES.5**
**Alternative 4**
**Additional PRBs and MNA**

# PREFACE

This Focused Feasibility Study (FFS) was prepared for the Air Force Center for Environmental Excellence (AFCEE), Aeronautical Systems Center (ASC) and the Air Force Real Property Agency (AFRPA), under Contract Number F41624-95-D-8005, Delivery Order 36, and Contract No. F41624-02-F-8899 issued to HydroGeoLogic, Inc. (HGL) by AFCEE. This FFS documents remedial alternatives that were developed and evaluated to address contamination within the vicinity of the southern lobe of the basewide trichloroethene (TCE) groundwater plume at the former Carswell Air Force Base (AFB). More specifically, this FFS addresses a 187-acre portion of the former Carswell AFB that is located to the southeast of the Naval Air Station Fort Worth Joint Reserve Base (NAS Fort Worth JRB). The study area is slated for public transfer under the Base Realignment and Closure (BRAC) program. Both the BRAC property and the NAS Fort Worth JRB are located to the east (i.e., hydraulically downgradient) of U.S. Air Force Plant No. 4 (AFP 4). AFCEE's Contracting Officer's Representative (COR) is Ms. Teri Dupriest. Ms. Norma Landez is the Base Environmental Coordinator for AFRPA, and the ASC Customer Representative is Mr. George Walters.

This report was prepared in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies under the Comprehensive Environmental Response, Compensation and Liability Act* (EPA, 1988).

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACC | Air Combat Command |
| AFB | Air Force Base |
| AFCEE | Air Force Center for Environmental Excellence |
| AFP 4 | Air Force Plant 4 |
| AFRPA | Air Force Real Property Agency |
| AOC | Area of Concern |
| ARAR | applicable or relevant and appropriate requirement |
| ASC | Aeronautical Systems Center |
| BRAC | Base Realignment and Closure |
| BTEX | benzene, toluene, ethylbenzene, and xylenes |
| °C | degrees Celsius |
| CAA | Clean Air Act |
| *cis*-1,2-DCE | *cis*-1,2-dichloroethene |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| cfs | cubic feet per second |
| cm | centimeters |
| cm/s | centimeters per second |
| COC | Contaminant of Concern |
| COPEC | chemicals of potential ecological concern |
| COR | Contracting Officer's Representative |
| CWA | Clean Water Act |
| $m^3$/hour | cubic meters per hour |
| DCA | 1,1-dichloroethane |
| DCE | dichloroethene |
| DNAPL | dense non-aqueous phase liquid |
| DO | dissolved oxygen |
| DOD | Department of Defense |
| DQO | data quality objective |
| EEG | Ellis Environmental Group, LLC |
| EPA | U.S. Environmental Protection Agency |
| EPL | East Parking Lot |
| EQ | ecological hazard quotient |
| ERA | Environmental Restoration Account |
| ERD | Environmental Restoration Division |
| ERH | electrical resistance heating |
| ERT | Environmental Restoration Technology |
| ESE | Environmental Science and Engineering, Inc. |

## LIST OF ACRONYMS AND ABBREVIATIONS (continued)

| | |
|---|---|
| ETI | EnviroMetal Technologies, Inc. |
| | |
| °F | degrees Fahrenheit |
| F | data qualifier indicating analyte was detected at concentration less than PQL but greater than MDL |
| FDTA | Fire Department Training Area |
| $Fe^{+2}$ | ferrous iron |
| FFA | Federal Facilities Agreement |
| FFS | Focused Feasibility Study |
| ft/d | feet per day |
| ft/ft | feet per foot |
| FTA | Fire Training Area |
| | |
| gpd/ft | gallons per day per foot |
| $gpd/ft^2$ | gallons per day per square foot |
| gpm | gallons per minute |
| GRA | General Response Action |
| GSAP | Groundwater Sampling and Analysis Program |
| | |
| HHRA | Human Health Risk Assessment |
| HI | hazard index |
| HMTA | Hazardous Materials Transportation Act |
| HQ | hazard quotient |
| HSA | hollow stem auger |
| HGL | HydroGeoLogic, Inc. |
| | |
| IC | institutional control |
| ILCR | incremental lifetime cancer risk |
| IRA | interim remedial action |
| | |
| lbs | pounds |
| LTM | long term monitoring |
| | |
| m | meters |
| $\mu g/kg$ | micrograms per kilogram |
| $\mu g/L$ | micrograms per liter |
| mg/L | milligrams per liter |
| MNA | monitored natural attenuation |
| mV | millivolts |
| MCL | maximum contaminant level |
| MDL | method detection limit |
| MOU | Memorandum of Understanding |
| MSC | mean sea level |

## LIST OF ACRONYMS AND ABBREVIATIONS (continued)

| | |
|---|---|
| NAS Fort Worth JRB | Naval Air Station Fort Worth Joint Reserve Base |
| NCDC | National Climatic Data Center |
| NCP | National Contingency Plan |
| NEPA | National Environmental Policy Act |
| NESHAP | National Emissions Standards for Hazardous Air Pollutants |
| NFA | no further action |
| NGVD | National Geodetic Vertical Datum |
| NOAEL | no observed adverse effects level |
| NPDES | National Pollutant Discharge Elimination System |
| NPL | National Priorities List |
| O&M | operation and maintenance |
| OPR | Office of Primary Responsibility |
| ORP | oxidation-reduction potential |
| OSHA | Occupational Safety and Health Administration |
| P.E. | Professional Engineer |
| PCE | tetrachloroethene |
| pCi | picocurie |
| POL | petroleum, oil, and lubricant |
| PQL | practical quantitation limit |
| PRB | permeable reactive barrier |
| PVC | polyvinyl chloride |
| QAPP | Quality Assurance Project Plan |
| Radian | Radian Corporation |
| RAO | Remedial Action Objectives |
| RCRA | Resource Conservation and Recovery Act |
| RFA | RCRA Facility Assessment |
| RFI | RCRA Facility Investigation |
| RI/FS | Remedial Investigation/Feasibility Study |
| ROD | Record of Decision |
| RRS | Risk Reduction Standard |
| SAC | Strategic Air Command |
| SARA | 1986 Superfund Amendments and Reauthorization Act |
| SDWA | Safe Drinking Water Act |
| SQL | sample quantitation limit |
| SVE | soil vapor extraction |
| SVOC | semi-volatile organic compound |
| SWMU | solid waste management unit |
| TAC | Texas Administrative Code |

## LIST OF ACRONYMS AND ABBREVIATIONS (continued)

| | |
|---|---|
| TCA | 1,1,2-trichloroethane |
| TCE | trichloroethene |
| TCEQ | Texas Commission on Environmental Quality |
| TCLP | Toxicity Characteristic Leaching Procedure |
| TDLR | Texas Department of Licensing and Regulation |
| TNRCC | Texas Natural Resource Conservation Commission |
| TOC | total organic carbon |
| TPDES | Texas Pollutant Discharge Elimination System |
| TRRP | Texas Risk Reduction Program |
| TSD | Treatment, Storage, and Disposal |
| TWC | Texas Water Commission |
| TWDB | Texas Water Development Board |
| URS | URS Corporation |
| U.S. | United States |
| USC | United States Code |
| USGS | U.S. Geological Survey |
| UST | underground storage tank |
| VC | vinyl chloride |
| VDEQ | Virginia Department of Environmental Quality |
| VOC | volatile organic compound |
| WAA | waste accumulation area |
| ZVI | zero valent iron |

# FINAL
# FOCUSED FEASIBILITY STUDY
# SOUTHERN LOBE TRICHLOROETHENE
# GROUNDWATER PLUME
# FORMER CARSWELL AFB, TEXAS

## 1.0 INTRODUCTION

This focused feasibility study (FFS) report documents the development and detailed evaluation of remedial alternatives proposed to address contamination within a 187-acre property located adjacent to the Naval Air Station Fort Worth Joint Reserve Base (NAS Fort Worth JRB) (Figure 1.1). This property is located on a portion of the former Carswell Air Force Base (AFB) that is slated for public transfer, under the Base Realignment and Closure (BRAC) program. Throughout this document, this property is referred to as the "BRAC property" (Figures 1.2 and 1.3). Presently, the BRAC property is used as a golf course. A large trichloroethene (TCE) plume originating primarily from Air Force Plant 4 (AFP 4) and the former Carswell AFB (i.e., southern lobe TCE plume) has impacted groundwater underlying a portion of the BRAC property (Figure 1.4). Over the past 5 years while conducting investigations risk assessments to support this FS, several interim remedial actions and demonstration studies have been conducted which have significant reduced in the size and toxicity of the TCE plume.

The TCE groundwater plume and the development of the FFS are being addressed under the AFP 4 Federal Facilities Agreement (FFA) as part of the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). A major goal of this FFS is to evaluate remedial alternatives that ensure the protection of human health and the environment.

Historical environmental investigations, long-term monitoring (LTM), and treatability studies conducted over the past decade define environmental conditions at the BRAC property and form the basis for this FFS. The results of these activities are summarized in the following documents:

- Final Report Southern Lobe Trichloroethene Groundwater Plume Delineation (HydroGeoLogic, Inc. [HGL], 2000a);
- Final Basewide Groundwater Sampling and Analysis Program 1999 Annual Report, (HGL, 2000b);
- Final Completion Report, Remedial Action at Landfills LF-04, LF-05, LF-08, Waste Burial Area WP-07 (IT Corporation, 2001);

- RCRA Facility Investigation Report, Groundwater/dense non-aqueous phase liquid (DNAPL) Investigation at Waste Pile 07 (CH2M HILL, 2002).
- Draft May 2004 Semi-Annual Long Term Monitoring of the Southern Lobe Trichloroethene Plume (HGL, 2004); and
- Final October 2004 Semi-Annual Long Term Monitoring of the Southern Lobe Trichloroethene Plume (HGL, 2005).

In addition to these investigations, a data gaps investigation was performed to support this FFS (HGL, 2000c). Several monitoring wells were installed to further delineate the lateral extent of the TCE plume; three deep wells were installed to delineate the vertical extent of the TCE plume; an assessment was performed on the aqueduct that runs beneath the flightline from AFP 4 to the BRAC property; and aquifer testing was performed to quantify hydraulic conductivities, which were subsequently used to calculate groundwater velocities at the site. The results of this data gaps investigation are explained further in Section 2.0 and in Appendix A.

The data gaps investigation and the listed historical environmental investigations define the nature and extent of contamination; identify the factors affecting the contaminant fate and transport; and document the site conditions that will control the implementation and effectiveness of proposed remedial technologies and alternatives. In addition to the aforementioned environmental investigations, a baseline human health and ecological risk assessment was completed for the BRAC property (HGL, 2001a, 2002a, 2002b). Pertinent portions of the historical environmental investigations and the baseline risk assessment are summarized in Section 2.0 of this FFS report.

In the Spring 2002, a permeable reactive barrier (PRB) was constructed along the western BRAC property as a treatability study. This PRB substantially changed the conditions at the site and this FFS (which was draft at that time) was modified to adjust to the changing conditions at the site. The PRB and subsequent performance monitoring are summarized in Section 2.0 of this report.

This FFS develops and evaluates remedial actions for contaminated media within the BRAC property. The FFS is divided into 8 sections and 5 appendices, as follows:

- Section 1.0, Introduction;
- Section 2.0, Background Information;
- Section 3.0, Remedial Action Objectives (RAOs);
- Section 4.0, Identification and Screening of Remedial Technologies and Process Options;
- Section 5.0, Development of Alternatives;
- Section 6.0, Detailed Analysis of Remedial Action Alternatives;

- Section 7.0, Comparative Analysis of Alternatives;
- Section 8.0, References;
- Appendix A, Data Gaps Investigation;
- Appendix B, Risk Calculations for Land Use Controls;
- Appendix C, Technology and Alternative Screening;
- Appendix D, Cost Back-Up; and
- Appendix E, Calculation of Remedial Action Timeframe for Monitored Natural Attenuation

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# 2.0 BACKGROUND INFORMATION

The following sections detail information pertaining to the former Carswell AFB, AFP 4, and NAS Fort Worth JRB.

## 2.1 INSTALLATION DESCRIPTION

The former Carswell AFB is located in Tarrant County, Texas, 8 miles west of downtown Fort Worth (Figure 1.1). The BRAC Property and the NAS Fort Worth JRB is located downgradient (east – southeast) of AFP 4. Before initial base construction in 1941, the area that is now occupied by the BRAC property, AFP 4, and the NAS Fort Worth JRB consisted of woods and pasture in an area called White Settlement. NAS Fort Worth JRB started as a modest dirt runway built to service the aircraft manufacturing plant located where AFP 4 is situated.

In August 1942, the base was opened as Tarrant Field Airdrome and was used to train pilots to fly the B-24 under the jurisdiction of the Gulf Coast Army Air Field Training Command. In May 1943, the field was re-designated as Fort Worth Army Air Field with continued use as a training facility for pilots. The Strategic Air Command (SAC) assumed control of the installation in 1946, and the base served as the headquarters for the 8$^{th}$ Air Force.

In 1948, the base was renamed Carswell AFB, and the 7th Bomber Wing became the base host unit. The Headquarters 19th Air Division was located at Carswell AFB in 1951 where it remained until September 1988 (A.T. Kearney, 1989). The SAC mission remained at Carswell AFB until 1992 when the Air Combat Command (ACC) assumed control of the base upon disestablishment of SAC. In October 1994, the United States (U.S.) Navy assumed responsibility for much of the facility, and its name was changed from Carswell AFB to NAS Fort Worth JRB. The Naval Air Station (NAS) Dallas and elements of Glenview and Memphis NASs were combined into the NAS Fort Worth JRB to streamline naval operations into one central area. Over time, the principal activities on the base have been maintaining and servicing fighter jet aircraft, fuel tankers, C-130s, and bombers (SAIC, 2002).

AFP 4 was placed on the NPL in August 1990 because of a large release of TCE arising from past disposal practices at AFP 4. While the source areas are currently being remediated under a FFA between the U.S. Environmental Protection Agency (EPA) Region VI, the Texas Commission on Environmental Quality (TCEQ), (formerly the Texas Natural Resources Conservation Commission [TNRCC]) and Aeronautical Systems Center (ASC) (Rust Geotech, 1995), the dissolved TCE plume has migrated east of AFP 4 and extends under NAS Fort Worth JRB and beneath the BRAC property. The regional TCE plume can be subdivided into northern, central, and southern lobes at the former Carswell AFB site. The southern lobe, which has impacted groundwater underlying the BRAC property, is the main subject of this FFS (Figure 1.4).

## 2.2 INSTALLATION HISTORY OF CONTAMINATION

Since 1942, most hazardous waste generated through operations and activities at the former Carswell AFB have been disposed of in landfills, reused on base, or processed through the Defense Property Disposal Office for off-base recycling or disposal. A total of 68 Solid Waste Management Units (SWMUs) have been identified at the NAS Fort Worth JRB and former Carswell AFB. Many were addressed as part of a Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) (A.T. Kearney, 1989a), with additional SWMUs added later via letters from the TNRCC. Additionally, 20 areas of concern (AOCs) were identified in either Permit HW-50289 for Carswell AFB issued by the TNRCC (formerly Texas Water Commission [TWC]) on February 13, 1991 (TWC, 1991), or by individual letters from the TNRCC. Since 1984, many of these sites (which include landfills, fire training areas, oil/water separators, and hazardous waste accumulation areas [WAAs]) have been investigated. A number of the SWMUs and AOCs identified have been determined to require no further action (NFA) and are currently considered closed by the TCEQ (TNRCC, 1995). All SWMUs and AOCs are listed in Table 2.1 and Table 2.2, respectively, and the locations of the SWMUs and AOCs at or near the BRAC property are shown on Figure 2.1.

Though the majority of TCE contamination impacting the BRAC property is believed to be from AFP 4, there are as many as two other potential source areas that may have also contributed contamination to the southern lobe of the basewide TCE plume:

- SWMUs 19 and 21 – The former fire training area and associated waste oil underground storage tank are located on the southern edge of the plume and west of the base boundary. The Final RCRA Facility Investigation (RFI) conducted at these three SWMUs for site closure was approved by TCEQ in October 2003 (HGL, 2003a; TCEQ, 2003).

- SWMU 24 – Waste Burial Area Number 7 (WP-07) is located in the center of the southern lobe TCE plume, just west of the base boundary. A Final Completion Report (IT Corporation (IT), 2001) and a subsequent dense non-aqueous phase liquid investigation (CH2M HILL, 2002) concluded that while WP-07 historically contributed to the plume, it is no longer a source area.

A brief description of these units is provided below.

SWMU 19 was used as a fire training area from 1963 until approximately 1991 by the base fire department to simulate aircraft fires for training exercises. SWMU 21 consisted of a 9,500-gallon UST that was used to store waste oils and solvents from the flightline industrial shops, for eventual use at the inner bermed area of SWMU 19 during training exercises. SWMU 21 was reported to have been installed in 1963 and removed sometime before 1993. Although SWMU 21 was reported to have been removed, no documentation is available to confirm this (Dames and Moore, 1995).

**Table 2.1**
**Solid Waste Management Units at the Former Carswell AFB, Texas**

| SWMU | Description | OPR |
|---|---|---|
| 1 | Pathological Waste Incinerator (NFA) | BRAC |
| 2 | Pathological Waste Storage Shed (NFA) | BRAC |
| 3 | Metal Cans (NFA) | BRAC |
| 4 | Facility Dumpsters (NFA) | BRAC |
| 5 | Building 1627 Waste Accumulation Area for Building 1628 (NFA) | ERA |
| 6 | Building 1628 Wash Rack and Drain (NFA) | ERA |
| 7 | Building 1628 Oil/Water Separator (NFA) | ERA |
| 8 | Building 1628 Sludge Collection Tank (NFA) | ERA |
| 9 | Building 1628 Work Station Waste Accumulation Area (NFA) | ERA |
| 10 | Building 1617 Work Station Waste Accumulation Area (NFA) | ERA |
| 11 | Building 1618 Waste Accumulation Area for Buildings 1617 and 1619 (NFA) | ERA |
| 12 | Building 1602 Former Waste Accumulation Area (NFA) | ERA |
| 13 | Building 1710 Visual Information Center Work Station Former Waste Accumulation Areas (NFA) | ERA |
| 14 | Building 1060 Bead Blaster Collection Tray (NFA) | BRAC |
| 15 | Building 1060 Paint Booth Vault (NFA) | BRAC |
| 16 | Building 1059 Waste Accumulation Area (NFA) | ERA |
| 17 | Landfill No. 7 (NFA) | ERA |
| 18 | Fire Training Area No. 1 (NFA) | ERA |
| 19 | Fire Training Area No. 2 (NFA) | ERA |
| 20 | Waste Fuel Storage Tank (NFA) | ERA |
| 21 | Waste Oil Tank (NFA) | ERA |
| 22 | Landfill No. 4 (NFA) | BRAC |
| 23 | Landfill No. 5 (NFA) | ERA |
| 24 | Waste Burial Area 7 (NFA) | ERA |
| 25 | Landfill No. 8 (NFA) | ERA |
| 26 | Landfill No. 3 (NFA) | ERA |
| 27 | Landfill No. 10 (NFA) | ERA |
| 28 | Landfill No. 1 (NFA) | ERA |
| 29 | Landfill No. 2 (NFA) | ERA |
| 30 | Landfill No. 9 (NFA) | ERA |
| 31 | Building 1050 Former Waste Accumulation Area (NFA) | ERA |
| 32 | Building 1415 Waste Accumulation Area for Building 1410 (NFA) | ERA |
| 33 | Building 1436 Waste Accumulation Area for Building 1420 (NFA) | ERA |
| 34 | Building 1194 Former Waste Accumulation Area (NFA) | ERA |
| 35 | Vehicle Refueling Shop (Building 1194) Oil/Water Separation System (NFA) | ERA |
| 36 | Building 1191 Former Waste Accumulation Area (NFA) | ERA |
| 37 | Vehicle Maintenance Shop (Building 1191) Oil/Water Separation System (NFA) | ERA |
| 38 | Building 1269 Polychlorinated Biphenyl Transformers Building (NFA) | BRAC |
| 39 | Building 1643 Former Waste Accumulation Area (NFA) | ERA |
| 40 | Building 1643 Oil/Water Separation System (NFA) | ERA |
| 41 | Building 1414 Oil/Water Separation System, Field Maintenance Squadron Aerospace Ground Equipment (NFA) | ERA |
| 42 | Building 1414 Former Waste Accumulation Area (NFA) | ERA |
| 43 | Building 1414 Non Destructive Inspection Waste Accumulation Point (NFA) | ERA |

**Table 2.1 (continued)**
**Solid Waste Management Units at the Former Carswell AFB, Texas**

| SWMU | Description | OPR |
|---|---|---|
| 44 | Building 1027 Oil/Water Separation System at the Aircraft Washing Hangar (NFA) | ERA |
| 45 | Building 1027 Waste Oil Tank Vault (NFA) | ERA |
| 46 | Building 1027 Waste Accumulation Area (NFA) | ERA |
| 47 | Building 1015 Jet Engine Test Cell Oil/Water Separator (NFA) | ERA |
| 48 | Building 1048 Fuel Systems Shop Floor Drains (NFA) | ERA |
| 49 | Aircraft Washing Area No. 1 (NFA) | ERA |
| 50 | Aircraft Washing Area No. 2 (NFA) | ERA |
| 51 | Central Waste Holding Area/Waste Accumulation Areas 1187 and 1189 (NFA) | ERA |
| 52 | Building 1190 Oil/Water Separation System (NFA) | ERA |
| 53 | Storm Water Drainage System (NFA) | ERA |
| 54 | Storm Water Interceptors | ERA |
| 55 | East Gate Oil/Water Separator | ERA |
| 56 | Building 1405 Waste Accumulation Area (NFA) | ERA |
| 57 | Buildings 1432/1434 Waste Accumulation Area (NFA) | ERA |
| 58 | Pesticide Rinse Area (NFA) | BRAC |
| 59 | Building 8503 Weapons Storage Area Waste Accumulation Area (NFA) | BRAC |
| 60 | Building 8503 Radioactive Waste Burial Site (NFA) | BRAC |
| 61 | Building 1319 Waste Accumulation Area for Building 1320 (NFA) | ERA |
| 62 | Landfill No. 6 (NFA) | ERA |
| 63 | Entomology Dry Well (NFA) | ERA |
| 64 | French Underdrain System (NFA) | ERA |
| 65 | Weapons Storage Area Disposal Site (NFA) | BRAC |
| 66 | Sanitary Sewer System | BRAC |
| 67 | Building 1340 Oil/Water Separator (NFA) | ERA |
| 68 | Petroleum, oil, and lubricant Tank Farm (NFA) | ERA |

Notes:
BRAC - Base Realignment and Closure
ERA - Environmental Restoration Account
NFA - No further action
OPR - Office of Primary Responsibility

**Table 2.2**
**Areas of Concern**
**Former Carswell AFB, Texas**

| AOC | Description | OPR |
|---|---|---|
| 1 | Former Base Service Station/Former Base Gas Station | ERA |
| 2 | Airfield Groundwater Plume (NFA) | ERA |
| 3 | Waste Oil Dump (NFA) | ERA |
| 4 | Fuel Hydrant System (NFA) | ERA |
| 5 | Grounds Maintenance Yard (NFA) | ERA |
| 6 | Recreational Vehicle Storage Area (NFA) | ERA |
| 7 | Former Base Refueling Area (NFA) | ERA |
| 8 | Aerospace Museum (NFA) | BRAC |
| 9 | Golf Course Maintenance Yard (NFA) | BRAC |
| 10 | Building 1064 Oil/Water Separator (NFA) | ERA |
| 11 | Building 1060 Oil/Water Separator (NFA) | ERA |
| 12 | Building 4210 Oil/Water Separator (NFA) | ERA |
| 13 | Building 1145 Oil/Water Separator (NFA) | ERA |
| 14 | Unnamed Stream (NFA) | ERA |
| 15 | Storage Shed Building 1190 (NFA) | ERA |
| 16 | Family Camp (NFA) | BRAC |
| 17 | Suspected Former Landfill (NFA) | ERA |
| 18 | Suspected Former Fire Training Area A (NFA) | ERA |
| 19 | Suspected Former Fire Training Area B (NFA) | ERA |
| 20 | Southern Lobe of the TCE Plume (NFA) | ERA |

Notes:
BRAC - Base Realignment and Closure
ERA - Environmental Restoration Account
NFA - No further action
OPR - Office of Primary Responsibility

The use of SWMU 24 as an active landfill commenced during the 1960s. The unit received drums of cleaning solvents, tetraethyl leaded sludge, and small quantities of undetermined waste. No live or dead ordnance was found. Based on aerial photographs, operations appear to have ended by 1983. All landfill activity associated with SWMU 24 during the period of operation was contained within the perimeter fencing for the unit.

In February 1991, a geophysical survey was conducted at SWMU 24. Results from this survey revealed nine distinct geophysical anomalies, indicating the presence of buried metal objects beneath the ground surface. In October 1991, thirty-four 55-gallon drums and ten 5-gallon buckets were excavated. These drums and buckets contained a total of 131 gallons of TCE and 169 gallons of TCE-contaminated liquid. A post excavation confirmation geophysical survey was conducted in April 2000, and 12 additional anomalies indicated the presence of additional metallic objects beneath the ground surface. In July 2000, trenching activities uncovered 20 drums, some of which contained small quantities of TCE. All anomalies were investigated, contaminated soils were removed, and confirmation soil samples were collected for chemical analysis. The site soils were approved for closure by the TCEQ under Risk Reduction Standard (RRS) 2 and no longer appear to present a potential risk to human health or the environment. Though SWMU 24 historically contributed to the TCE plume, the groundwater/DNAPL investigation at this site (CH2MHILL, 2002) concluded that this site is no longer a contributing source of the existing dissolved TCE plume.

Other than AFP 4, SWMUs 19 and 21, and SWMU 24 (WP-07), no other current or historical sources of TCE have been identified at the site. According to a recent groundwater flow model created by the USGS, AFP 4's source at the Building 181 area is being contained by the East Parking Lot (EPL) groundwater pump and treat system. This is discussed further in Section 2.11.

## 2.3 PHYSIOGRAPHY

The former Carswell AFB is located along the border zone between two physiographic provinces. The southeastern part of the base is situated within the Grand Prairie section of the Central Lowlands Physiographic Province. Most of the former Carswell AFB is located within this province. This region is characterized by broad, eastward-sloping terrace surfaces that are interrupted by westward-facing escarpments. The land surface is typically grass covered and treeless except for isolated stands of upland timber. The northwestern part of the former Carswell AFB is situated within the Western Cross Timbers Physiographic Province. This area is characterized by rolling topography and a heavy growth of post and blackjack oaks (Radian, 1989). Surface elevations for this region range from about 850 feet above National Geodetic Vertical Datum (NGVD) west of the base to approximately 550 feet above NGVD along the eastern side of the base.

## 2.4 REGIONAL GEOLOGY

The major geologic units of interest for the region, from youngest to oldest, are as follows: (1) the Quaternary (Terrace) Alluvium (including fill material and terrace deposits), (2) the

Cretaceous Goodland Limestone, (3) the Cretaceous Walnut Formation, (4) the Cretaceous Paluxy Formation, (5) the Cretaceous Glen Rose Formation, and (6) the Cretaceous Twin Mountains Formation. The regional dip of these stratigraphic units beneath the former Carswell AFB is between 35 to 40 feet per mile in an easterly to southeasterly direction. The former Carswell AFB is located on the relatively stable Texas Craton, west of the faults that lie along the Ouachita Structural Belt. No major faults or fracture zones have been mapped near the base (Radian, 1986).

## 2.5 SITE HYDROGEOLOGY

The following five hydrogeologic units, listed from the shallowest to the deepest, located in the NAS Fort Worth JRB area are: (1) an upper saturated zone referred to as the Terrace Alluvium, (2) an aquitard of predominantly dry limestone with interbedded clay and shale layers of the Goodland and Walnut formations, (3) an aquifer in the sandstone of the Paluxy Formation, (4) an aquitard of relatively impermeable limestone in the Glen Rose Formation, and (5) a major aquifer in the sandstone of the Twin Mountains Formation. An areal distribution of geologic units is provided in Figure 2.2. A stratigraphic column is included as Figure 2.3. The three upper lithologic units beneath NAS Fort Worth JRB are examined in more detail in the following paragraphs. A geologic cross section of the three units is provided as Figure 2.5, with the location of the cross section depicted in Figure 2.4.

### 2.5.1 Terrace Alluvium Deposits

The uppermost groundwater in the area occurs within the pore space of the grains of silt, clay, sand, and gravel deposited by the Trinity River. In some parts of Tarrant County, primarily in those areas adjacent to the Trinity River, groundwater from the terrace deposits is used for irrigation and residential use. However, groundwater from the terrace deposits is not often used as a source of potable water due to its limited distribution, poor yield, and susceptibility to surface/storm-water pollution (U.S. Geological Survey [USGS], 1996). Turbidity measurements are taken during groundwater sampling and routinely display high readings (over 1000 NTUs). No potable water supply wells are completed in the Terrace Alluvium within 0.5 miles of the former Carswell AFB. Recharge to the water-bearing deposits occurs through infiltration from precipitation and from surface water bodies.

Flow between aquifers is restricted by the Goodland/Walnut formations; therefore, the Terrace Alluvium groundwater has no significant hydraulic connection to the underlying aquifers at the former Carswell AFB.

The primary flow direction of water in the Terrace Alluvium is generally eastward toward the West Fork Trinity River, although localized variations exist across the site as depicted in the southern lobe groundwater elevation map (Figure 2.6). Groundwater discharge occurs into surface water on-site, specifically into Farmers Branch Creek.

More details on the site-specific hydrogeology of the Terrace Alluvium deposits were determined from several aquifer pumping tests and a series of slug tests performed in over 30 wells throughout the FFS area as part of the data gaps investigation (HGL, 2000c). The hydrogeological data was collected to evaluate the local hydrogeologic conditions at the site and for use in the design of groundwater remediation systems. The main hydrogeologic feature within the Terrace Alluvium is a buried paleochannel that lies beneath the site in a predominantly east-west orientation. The paleochannel is a narrow depression in the bedrock surface thought to be a meander channel of an ancestral Trinity River, incised into bedrock at some time in the past. The presence of the paleochannel creates an area of increased hydraulic conductivity by virtue of the relatively coarser sands and gravels deposited in the channel compared to the finer sands and silts deposited outside, and later above, the former river channel. The thicknesses of the Terrace Alluvium underlying the BRAC property ranges from a maximum of approximately 40 feet in the center of the paleochannel to as little as 8 feet outside of the paleochannel. A bedrock map and a representative cross section (Figures 2.7 and 2.8) display the variations in the bedrock surface. Boring logs from installed wells also are included in Appendix A.3.

Water elevations within the Terrace Alluvium were measured two to four times a year between April 1995 and October 2004. The site-specific potentiometic surface derived from the October 2004 gauging event is depicted in Figure 2.6. The primary groundwater flow direction in the area of the BRAC property is west to east from NAS Fort Worth JRB to the former Carswell AFB property line. The orientation of the TCE plume in this portion of the site generally mimics the groundwater flow path. There are several other components to groundwater flow in the area. The southern portion of the BRAC site reveals a northeastern flow component. The direction of groundwater flow within the paleochannel, is primarily southwesterly, before assuming a westerly flow near the eastern NAS Fort Worth JRB/BRAC area property boundary. The areal hydraulic gradient within the vicinity of the BRAC area ranges between 0.006 and 0.009 feet per foot (ft/ft) as determined from gauging events. A higher, localized groundwater gradient exists at the southern extent of the paleochannel in the BRAC area and generally follows the bedrock gradient along this portion of the site. The groundwater gradient in this area of the site is approximately 0.06 ft/ft. The groundwater flow velocity (advective velocity), based on the hydraulic conductivities and gradients, range from a high of 25.4 to 29.2 feet per day (ft/d) (0.54 to 0.62 centimeters per second [cm/s]) upgradient of BRAC property in monitoring well LF04-03, within the paleochannel, and within several eastern portions of the site, near the BRAC property line, to a low of 0.3 ft/d (0.006 cm/s) in the non-paleochannel alluvial sediments in monitoring well WHGLTA002. The flow velocity in the central portion of FFS area, near the location of the PRB is approximately 2.0 ft/d. A map depicting the velocities is included as Figure A.1-1 in Appendix A.1.

The hydraulic conductivity within and near the BRAC property was determined by analyzing data obtained from an October 2000 aquifer pumping test and from slug tests performed in February 2001 and April 2002. An unconfined solution using Neuman, Theis, and Cooper-Jacob methods was used to evaluate the aquifer test data. The slug test data was evaluated using the Bouwer & Rice solution. The hydraulic conductivity in the aquifer pumping test area ranged from approximately 108 ft/d to 180 ft/d with the typical values generally about 110 ft/d (transmissivity of approximately 1100 $ft^2/d$). Results obtained from the slug tests revealed a range of hydraulic conductivities from 219 ft/d within the paleochannel, approximately 600 feet upgradient of the NAS Fort Worth JRB and BRAC area boundary, to less than 10 ft/d in the alluvial sediments outside of the paleochannel. A secondary area of high hydraulic conductivity is present in the easternmost portion of the BRAC property. Hydraulic conductivity, as determined from slug tests performed in February 2001 for this portion of the BRAC property, was found to be as high as 280 ft/d. Slug test data collected from wells nearest to the NAS Fort Worth JRB/ BRAC area property line range between 15.3 ft/d to 95.6 ft/d. Results from the October 2000 aquifer pumping test and February 2001 slug tests are summarized in Appendix A.1.

Another influence on groundwater flow within the Terrace Alluvium is the subterranean aqueduct located beneath the runway and main flightline area of NAS Fort Worth JRB (Figure 2.9). The aqueduct is located south of AFP 4 and bisects the NAS Fort Worth JRB runway in a generally east-west direction. The aqueduct allows Farmers Branch Creek to flow east from the White Settlement community, across the base and through the proposed BRAC area, where it discharges into the West Fork Trinity River. The aqueduct consists of two large drainage culverts buried beneath the flightline area. An aqueduct assessment was performed to evaluate its potential contribution to the southern lobe TCE plume and its effect on local groundwater flow. Details on this assessment can be found in Appendix A.2. After reviewing the original as-built drawings of the aqueduct, it was determined that the culverts are set on bedrock at the eastern and western edges as shown in Figure 2.9. In the area where the paleochannel exists, the aqueduct is not set on the bedrock due to the greater depth to bedrock. The aqueduct (combined with the bedrock and lower conductivity deposits outside the paleochannel) appears to act as a barrier to groundwater flow.

### 2.5.2 Goodland/Walnut Aquitard

The groundwater within the terrace deposits is isolated from groundwater within the lower aquifers by the low permeability rocks of the Goodland Limestone and Walnut formations. The primary inhibitors to vertical groundwater movement within these units are the fine-grained clay and shale layers that are interbedded with layers of limestone. Some groundwater movement does occur between the individual bedding planes of both of these units, but the vertical hydraulic conductivity has been calculated to range between $1.2 \times 10^{-9}$ cm/s to $7.3 \times 10^{-11}$ cm/s for the former Carswell AFB and AFP 4 area. Vertical advective velocities range from $1.16 \times 10^{-3}$ ft/d to $5.22 \times 10^{-3}$ ft/d (ESE, 1994).

Immediately east of the AFP 4 building, the Goodland/Walnut aquitard is breached, and creates a "window" to the Terrace Alluvium groundwater. The Paluxy "window" was discovered while installing monitoring wells. The Paluxy window area (as determined by Parsons, 1998) is depicted in Figure A.1-1 in Appendix A.1. The terrace alluvium is in direct communication with the groundwater in the Paluxy aquifer in this area as confirmed by groundwater samples collected from the Paluxy (Earth Tech, 2002). There is no evidence that a similar window exists on the BRAC property.

As part of the data gap investigations, three monitoring wells were installed and screened in the upper sands of the Paluxy Formation (WHGLPU001, WHGLPU003, and WHGLPU004). When drilling the wells, the Walnut Formation was observed to be fractured along bedding planes and appeared to have higher hydraulic conductivities than the Upper Paluxy. An additional monitoring well (WHGLWN002) was installed in the Walnut Limestone formation in order to characterize the unit. The boring logs for the wells are included in Appendix A.3. Wells WHGLPU004 and WHGLWN002 are a pair, one completed in the shallow Walnut Formation, and one completed in the deeper Paluxy Formation; therefore the wells have the same lithology and boring log. These 3 Paluxy wells were abandoned in 2003 and 2004.

### 2.5.3 Paluxy Aquifer

The Paluxy aquifer is an important source of potable water for the Fort Worth area. Many of the surrounding communities, particularly White Settlement, obtain their municipal water supplies from the Paluxy aquifer. Groundwater from the Paluxy aquifer also is used at some of the surrounding farms and ranches for agricultural purposes. Water levels have declined in the northern portion of the Paluxy aquifer and risen for most of the southern portion of the Paluxy aquifer. Water levels in Tarrant County show an increase of 5 to 25 feet between 1989 to 1997. The water level change in one Paluxy well in Tarrant County ranged from +0.36 ft to -13.75 ft per year between 1989-1997 (Texas Water Development Board [TWDB], 1999). Water levels in the NAS Fort Worth JRB vicinity have not decreased due to its proximity to the Lake Worth recharge area and the fact that the base does not withdraw water from the Paluxy aquifer. Drinking water at the base is supplied by the city of Fort Worth, which uses Lake Worth as its water source. The groundwater of the Paluxy aquifer is contained within the openings created by gaps between bedding planes and cracks and fissures in the sandstones of the Paluxy Formation. Just as the Paluxy Formation is divided into upper and lower sand members, the aquifer is likewise divided into upper and lower aquifers. The upper sand is finer grained and contains a higher percentage of shale than the lower sand. Radian (1989) estimated the hydraulic conductivity and transmissivity to be 130 to 140 gallons per day per square foot (gpd/$ft^2$) and 1,263 to 13,808 gallons per day per foot (gpd/ft), respectively.

## 2.6 SURFACE WATER

NAS Fort Worth JRB is situated within the Trinity River Basin adjacent to Lake Worth. The main surface water features of interest are Lake Worth, the West Fork Trinity River, Farmers Branch Creek, and the golf course pond, which drains into Farmers Branch Creek. Only Farmers Branch Creek and the golf course pond are located within the area being discussed in this FFS.

The flow of Farmers Branch Creek is directed through an aqueduct that runs beneath the flightlines before it discharges onto the BRAC property (Figure 2.9). Surface drainage in the Flightline Area is generally to the north and east toward Farmers Branch Creek. Farmers Branch Creek ultimately discharges to the West Fork Trinity River, located on the eastern boundary of the former Carswell AFB. Eight seeps exist along Farmers Branch Creek as depicted on Figure 1.3. The evaluation of groundwater flow at the Flightline Area suggests that the surface water bodies may receive groundwater inflow, and possibly contaminants associated with the groundwater. In 1990, a staff gage was installed in Farmers Branch Creek and professionally surveyed during the additional Stage 2 field activities. Synoptic groundwater and surface water-level measurements made in June 1990 were used to estimate flow volumes and evaluate communication between shallow (upper zone) groundwater and surface water (Radian, 1991). Estimated flow volumes at the time of sampling (April 1990) were approximately 6 cubic feet per second (cfs) for the four locations on Farmers Branch Creek and approximately 0.2 cfs for the unnamed tributary. Observed flow in Farmers Branch Creek during field activities was extremely variable, ranging from <5 to >100 cfs (after heavy rains). The creek is generally considered to be a gaining stream, meaning that it is recharged by groundwater; however, portions of it are losing, and the entire stream can be "losing" during heavy rainfall events.

Two unnamed tributaries flow across the Flightline Area and discharge into Farmers Branch Creek. Most of the base drainage is intercepted by a series of storm drains and culverts, directed to oil/water separators, and discharged to the West Fork Trinity River downstream of Lake Worth. A small portion of the north end of the base drains directly into Lake Worth.

Lake Worth borders NAS Fort Worth JRB to the north; the lake was constructed in 1914 as a source of municipal water for the city of Fort Worth. The surface area of the lake is approximately 2,500 acres. The Paluxy aquifer discharges to Lake Worth near its western extent. However, in the portion of the lake near Bomber Road at AFP 4, the top of the Paluxy aquifer is recharged by Lake Worth. There does not appear to be a hydraulic connection between the Paluxy aquifer and the lake in the eastern portion, where the Walnut Formation separates the Paluxy aquifer and Lake Worth. The elevation of the lake is fairly constant at approximately 594 feet above national geodetic vertical datum (NGVD), the fixed elevation of the dam spillway (USGS, 1996).

The West Fork Trinity River, a major river in north-central Texas, defines the eastern boundary of the NAS Fort Worth JRB. The Trinity River flows southeast toward the Gulf of Mexico. Because the river has been dammed, the 100- and 500-year flood plains downstream of the dam do not extend more than 400 feet from the center of the river or any of its tributaries. Farmers Branch Creek discharges into the West Fork Trinity River at the eastern edge of the former Carswell AFB.

Storm water that enters the NAS Fort Worth JRB storm water drainage system and is discharged directly into Lake Worth or is collected and discharged at outfalls into the West Fork Trinity River. The outfalls are permitted under the National Pollutant Discharge Elimination System (NPDES), and monitoring results document compliance with permit discharge limitations (IT Corporation, 1997). Storm water that does not enter the site drainage system drains via sheet flow and runoff east toward the West Fork Trinity River. A portion of the base is drained by Farmers Branch Creek beginning within the community of White Settlement and flows eastward. Most of the flow in the creek is due to surface runoff, with some groundwater recharge from the Terrace Alluvium. Just south of AFP 4, Farmers Branch Creek flows beneath the runway within the aqueduct.

## 2.7 CLIMATE

The climate in the Fort Worth area is classified as humid subtropical with hot summers and dry winters. Tropical maritime air masses control the weather during much of the year, but the passage of polar cold fronts and continental air masses can create large variations in winter temperatures (TNRCC, 1996). In the Dallas-Fort Worth area, daily mean temperatures range from 43.4 degrees Fahrenheit (°F) in January to 85.3°F in July. The highest recorded temperature is 113°F, and the lowest temperature is 2°F. Freezing temperatures occur an average of 25 days in the year (National Climatic Data Center (NCDC), 2000).

Average relative humidity (after noon) ranges from 51 percent in September and October to 62 percent in January (NCDC, 2000). Mean annual precipitation recorded at the base is approximately 32 inches. The wettest months are April and May, with a secondary maximum in September. The period from November to March is generally dry, with a secondary minimum in August. Snowfall accounts for a small percentage of the total precipitation between November and March. On the average, measurable snowfall occurs 2 days per year (TNRCC, 1996). Thunderstorm activity occurs at the base an average of 45 days per year, with the majority of the activity between April and June. Hail may fall 2 to 3 days per year. The maximum precipitation ever recorded in a 24-hour period is 5.9 inches.

During 2001, the average annual temperature in the area was 65.6°F, and monthly mean temperatures varied from 42.7°F in January to 86.7°F in July. The average daily minimum temperature in January was 33°F, and the lowest recorded temperature was 19°F. The average daily maximum temperature was 96.7°F in July and the highest temperature recorded at the base during 2001 was 100°F in July. Freezing temperatures occur at the former Carswell AFB an average of 11 days per year (National Weather Service, 2001).

Lake evaporation near the former Carswell AFB is estimated to be approximately 57 inches per year. Evapotranspiration over land areas may be greater or less than lake evaporation depending on vegetative cover type and moisture availability. Average net precipitation is expected to be equal to the difference between average total precipitation and average evapotransporation, or approximately -25 inches per year. Mean cloud cover averages 50 percent at the former Carswell AFB, with clear weather occurring frequently during the year. Some fog is present an average of 83 days per year. Wind speed averages 7 knots; however, a maximum of 80 knots has been recorded. Predominant wind direction is from the south-southwest throughout the year (TNRCC, 1996).

## 2.8 BIOLOGY

Approximately 374 acres, or 14 percent, of the former Carswell AFB is considered to be unimproved, indicating the presence of seminatural to natural biological/ecological conditions. The base lies in the Cross Timbers and Prairies regions of Texas, where native vegetation is characterized by alternating bands of prairies and woodlands. Native and cultivated grasses such as little bluestem, Indian grass, big bluestem, side oats, grama, and buffalo grass cover the higher elevations on the base. Forested areas occur primarily on the lower land and along the banks of streams. Common wood species include oak, elm, pecan, hackberry, and sumac. Several non-native species such as catalpa and chinaberry also are common (Radian, 1989).

Typical wildlife on the base includes black-tailed jackrabbits in grassy areas along the runway. In addition, there are cottontail rabbits, gray squirrels, and opossums in the wooded areas. Common birds include morning doves, meadowlarks, grackles, and starlings. Hunting and trapping are not allowed on the base, but in the nearby rural areas they are a very popular form of recreation (Radian, 1989).

Reported game fish include black bass, sunfish, and catfish, all of which can be found in Lake Worth, Farmers Branch Creek, and one small pond located on base near the golf course equipment shed. According to the Texas Department of Parks and Wildlife and the U.S. Fish and Wildlife Service, there are no threatened or endangered species known to occur on NAS Fort Worth JRB. None of the federally listed endangered plant species for Texas are known to occur within 100 miles of Tarrant County. Of the federally listed endangered animal species, only the peregrine falcon and the whooping crane are known to occasionally inhabit the area; however, none of these is suspected to reside in the vicinity of the former Carswell AFB (Radian, 1989).

## 2.9 DEMOGRAPHICS

Approximately 1,446,219 people reside within Tarrant County, Texas. Of this population, 462,172 reside within the city limits of Fort Worth (U.S. Census Bureau, 2000). Several smaller cities and villages make up the remainder of the population. The communities of White Settlement, Lake Worth, Westworth Village, River Oaks, and Sansom Park lie within a 3-mile radius of the NAS Fort Worth JRB. The following populations that reside in the cities and villages are based on 2000 census data (U.S. Census Bureau, 2000): White Settlement (city) 15,763; Lake Worth (city) 4,727; Westworth Village (town) 2,260; River Oaks (city) 6,722; and Sansom Park (city) 4,002. Six schools are located within a 2-mile radius of the former Carswell AFB (Rust Geotech, 1995).

The area surrounding the former Carswell AFB is highly urbanized due to its proximity to the city of Fort Worth. The area is composed of a combination of residential, commercial, and light industrial properties that employ the majority of local residents (Rust Geotech, 1995).

## 2.10 NATURE AND EXTENT OF CONTAMINATION

### 2.10.1 Soils Contamination

With the exception of soil contamination within the individual landfills and other SWMUs/ AOCs at the site (as explained in the individual RFI reports for those units), there is no evidence of soil contamination at the BRAC property.

### 2.10.2 Surface Water/Sediment Contamination

Surface water, seep, and sediment samples were collected from Farmers Branch Creek in 1998 (HGL, 2000a). Additional surface water samples are collected semi-annually as part of the AFP 4 Long Term Monitoring (LTM) program (EarthTech, 2002). Inorganic compounds detected in surface water above background levels were: aluminum, antimony, calcium, mercury, and zinc. The following volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) were detected in surface water: 1,1-dichloroethane (DCA), 1,1-dichloroethene, bis(2-ethylhexyl)phthalate, *cis*-1,2-dichloroethene (*cis*-1,2-DCE), PCE, and TCE. Concentrations of TCE in surface water ranged from 0.35 μg/L to 200 μg/L within Farmers Branch Creek (HGL, 2001a). Concentrations of TCE in the seeps ranged from 1.9 μg/L in Seep 4 (S-4) to 2.1 μg/L in S-2 along Farmers Branch Creek.

Compounds detected in sediment at levels above background concentrations were: arsenic, iron, magnesium, manganese, nickel, vanadium, and zinc. Concentrations of TCE in sediment ranged from 2.1 micrograms per kilogram (μg/kg) to 56 μg/kg within Farmers Branch Creek (HGL, 2001a).

### 2.10.3 Groundwater Contamination

#### 2.10.3.1 Terrace Alluvium

The dominant contaminant in Terrace Alluvium groundwater at the site is TCE. Figure 2.10 displays the degradation process of TCE. *Cis*-1,2-DCE and VC are also present at concentrations above their respective MCLs. The latest TCE, *cis*-1,2-DCE, and VC plume contours are depicted in Figure 1.4 and Figures 2.11 and 2.12.

Based on data collected between April and October 2004, the TCE concentrations ranged from below detection limits in the eastern and southern portions of the BRAC property, to 1,500 μg/L in monitoring well LF05-14. When the PRB was designed, it was predicted that residual contamination downgradient of the PRB would be gradually removed by the flushing action of the remediated groundwater flowing out of the PRB. Monitoring well LF05-14 was included in the PRB performance monitoring sampling for the first time in October 2004. Well LF05-14 is not downgradient of the PRB, but is downgradient of the portion of the TCE plume which is north of the PRB terminus. Therefore, the concentrations in well LF05-14 likely reflect the untreated groundwater.

*Cis*-1,2-DCE concentrations range from below detection limits in the eastern and southern portions of the BRAC property to 770 μg/L in monitoring well WHGLTA069 in the western portion of the property. VC concentrations range from below detection limits in the northwestern, eastern, and southern portions of the BRAC property to 270 μg/L in monitoring well LF04-4E located in the southwestern portion of the property. Trans-1,2-DCE concentrations range from below detection limits in the eastern and southern portions of the BRAC property to 110 μg/L in monitoring well WHGLTA069 in the western portion of the property. Additional PRB performance monitoring data can be found in Section 2.11.3. TCE concentrations have reduced substantially in the area immediately downgradient of the PRB.

Benzene was detected at low concentrations within the phytoremediation area, which is located in the northwestern portion of the BRAC property. Concentrations were below the detection limit except for 0.18 μg/L, 0.40 μg/L, and 4.0 μg/L in monitoring wells WJEGTA525, WJEGTA511, and WJECTA512, respectively.

Geochemical parameters, such as pH, temperature, conductivity, oxidation-reduction potential (ORP), and dissolved oxygen (DO), are routinely collected at the site during each groundwater sampling event using a flow-through chamber and sampling probes. In 1999, prior to construction of the PRB, HGL performed a natural attenuation study on the BRAC property to evaluate the potential for microbial processes to support natural attenuation of the TCE. Details of this pre-PRB study are provided in Appendix C.2.4. The evaluation indicated that, in general, the groundwater had limited potential for natural microbial processes to remediate the TCE contamination.

In 2002, the ZVI PRB was constructed along a portion of the boundary between the BRAC property and NAS Ft. Worth JRB. The presence of the PRB is affecting the downgradient groundwater quality through two separate processes. First, the remediated groundwater is flushing out residual contamination. Second, the performance monitoring data suggest that the reactive media have supported development of a microbial population capable of TCE reductive dechlorination within and immediately downgradient of the PRB. In areas of the BRAC property not affected by the PRB, however, conditions remain too oxidizing to support reductive dechlorination of TCE.

As part of the data gaps investigation to support this FFS, seven wells (WHGLTA043 through WHGLTA049) were installed within the BRAC property to further delineate TCE migration at the property boundary and to provide additional data on the interaction between surface water (Farmers Branch Creek) and groundwater. The boring log and well construction diagrams for these wells can be found in Appendix A.3. Figure 1.3 presents wells WHGLTA043 through WHGLTA045, WHGLTA048, and WHGLTA049. Monitoring wells WHGLTA046 and WHGLTA047 have been abandoned. The plume was fully delineated with these wells. Over the past several years, TCE concentrations have decreased at the leading edge of the plume to levels below MCLs. A combination of upgradient source containment and remediation, installation of the PRB, and natural attenuation appears to be the cause of the significant and rapid decrease in concentrations. Historical TCE contour maps are included as Appendix A.4.

#### 2.10.3.2 Walnut and Paluxy Formation

TCE concentrations in one Paluxy monitoring well (WHGLPU001, Figure 1.3) were 4 μg/L, 5 μg/L, 1 μg/L, and non-detect over the four consecutive semi-annual sampling events in 2000 and 2001. The most likely cause of the detections from the initial sampling events is contamination pulled down from the Terrace Alluvium during well installation. Subsequent sampling events detected no concentrations of any other VOCs. These 3 Paluxy wells were abandoned in 2003 and 2004 to prevent any potential contamination pathway to the drinking water aquifer. No other deep wells at the former Carswell AFB have contained VOCs.

## 2.11 ONGOING REMEDIATION EFFORTS

Several environmental remediation systems are in place to address the basewide TCE plume at AFP 4 and the BRAC property:

- Soil Vapor Extraction and former Electrical Resistance Heating (ERH) at the Building 181 source area (i.e., the primary TCE source area at AFP 4);
- Groundwater pump-and-treat system at the EPL (i.e., located directly downgradient of the Building 181 TCE source area);
- PRB along the property boundary separating the NAS Fort Worth JRB from the BRAC property; and
- Phytoremediation area located north of Farmers Branch Creek and east of the NAS Fort Worth JRB boundary. This demonstration project is no longer funded but the trees are still present and are close to maturity. No additional data will be collected to monitor their effectiveness.

The location of each of these remediation systems is shown on Figure 2.13. During the development of FFS remedial alternatives, it was assumed that with the exception of the ERH at the Building 181 source area, these remediation systems would continue to operate.

### 2.11.1 Soil Vapor Extraction and Electrical Resistance Heating

Building 181, the Chemical Process Facility, is part of the Assembly Building/Parts Plant, which is a mile-long building located in the approximate center of AFP 4 (Figure 2.13). Spills of TCE reportedly occurred within the Chemical Process Facility. Trenches, sumps, floor drains, and buried pipelines are present throughout this manufacturing facility and represent possible pathways for contaminant migration beneath the building. The key contaminant of potential concern at Building 181 is TCE, which was detected at concentrations ranging from below detection limits to 0.22 milligrams per kilogram (mg/kg) in soil samples collected from borings up to depths of approximately 59 ft near the perimeter of Building 181. Soils saturated with TCE also were found during the installation of a soil-vapor extraction system under Building 181. TCE in the soil under Building 181 is believed to be the main source of the basewide TCE groundwater plume (Jacobs, 2002).

The selected remedy to prevent soil contamination from leaching to the Terrace Alluvium groundwater at AFP 4 Building 181 is soil vapor extraction (SVE). The Building 181 SVE pilot system was installed by Environmental Science and Engineering, Inc. (ESE) and started operation in June 1996. The full-scale Building 181 SVE Treatment System was constructed in 1999 and includes 36 SVE wells and 3 dual-phase extraction wells. These dual-phase enhanced recovery wells have operated intermittently in the past and are generally dry or do not have a high enough water level for pumping. Additionally, condensate from the Terrace Alluvium is collected in the system. This water also is treated using an air stripper followed by off-gas treatment with vapor phase carbon (Jacobs, 2002).

An ERH pilot study was conducted in the Building 181 area between August and December 2000 to evaluate the effectiveness of ERH at AFP 4. The results of the pilot study indicated that ERH would be an appropriate choice for removing DNAPL in the subsurface beneath Building 181 (URS, 2001). In 2002, a full scale implementation was initiated over a one-half acre area inside the northwest corner of Building 181. For the full scale system, 66 electrodes with 92 SVE wells were installed, and the system began heating in May 2002. Heating continued for 220 days and was terminated on December 19, 2002. The ERH process beneath Building 181 was used in conjunction with the existing SVE system (URS, 2002). A project total mass removal (pilot + full-scale) calculated the recovery of TCE at 1,743 pounds. The average TCE concentration in soil was reduced by 93% and post-heating soil sampling results were below the remedial action objective (RAO) for soil. The average TCE concentration in groundwater was reduced 88% and sampling results indicate concentrations were below the 10 mg/L RAO. The SVE system is currently shutdown and post-monitoring activities to assess any rebound effects and ensure compliance with RAOs are being evaluated through an LTM program.

### 2.11.2 East Parking Lot and Window Pump-and-Treat System

The largest plume of groundwater contamination, and the only portion of the AFP 4 plume that affects the southern lobe TCE plume at the former Carswell AFB, is the basewide TCE groundwater plume. This plume begins at the groundwater divide located south and west of the Assembly Building/Parts Plant and Building 12. The plume extends in an easterly and northeasterly direction toward the EPL and later spreads east and southeast in the direction of the former Carswell AFB (Jacobs, 2002).

One major source has been identified at AFP 4 for the southern lobe TCE groundwater plume as shown in Figure 2.13.

The extent of the basewide TCE groundwater plume is defined by elevated concentrations of TCE, *cis*-1,2-dichloroethene, trans-1,2-dichloroethene, vinyl chloride, and PCE. However, by far the greatest occurrence of any single organic compound is TCE. Concentrations of TCE in the vicinity of the TCE source area at Building 181 were reduced by approximately 70 percent during the operation of the ERH system. In well MW-10 TCE concentrations were reduced from 76,500 μg/L in April 2002 to 21,700 μg/L in November 2002. TCE concentrations have rebounded slightly since the system was turned off in December 2002, with TCE concentrations detected as high as 37,000 μg/L in well MW-10 during the October 2004 AFP 4 basewide TCE groundwater sampling event (Earth Tech, 2005).

An interim groundwater pump-and-treat system was built in 1991 to remediate the basewide TCE groundwater plume. As part of the interim system operation, ten (10) extraction wells were operated at 50 to 70 gallons per minute (gpm). Construction of the current groundwater treatment plant for the EPL and Paluxy window area was completed in October 2001. The current system conveys groundwater from 51 wells including: five (5) Paluxy Upper Sand wells, thirty (30) Terrace Alluvium wells, fifteen (15) Terrace Alluvium (hydraulic control wells), and one (1) horizontal well. Three (3) Terrace Alluvium (standby wells) are connected to the system; however, they are not operated at this time. The treatment system consists of mechanical filtration, air strippers, and carbon treatment prior to discharge to the Publicly Owned Treatment Works (POTW). The design flow of the treatment system is 102 gpm with a maximum capacity of 140 gpm. Various problems with construction implementation of the system modifications limited the production capability of the system and, therefore, limited hydraulic control of the EPL plume. Shaw Environmental assumed responsibility for operation and maintenance (O&M) of the EPL remedial system on November 1, 2001. Data collected as part of system performance monitoring indicate that hydraulic capture has been achieved by the system and groundwater contaminant concentrations exhibit an overall downward trend in the Window Area. This containment of the plume is further supported by a recent groundwater flow modeling effort conducted by the USGS. Particle tracking indicates that with the EPL extraction wells operating that groundwater from the Building 181 area is contained.

### 2.11.3 Permeable Reactive Barrier

A 1,126-foot long, 2-foot wide PRB composed of 50 percent ZVI and 50 percent sand was installed by HGL at the property boundary between the NAS Fort Worth JRB and the BRAC property during April and May 2002. The project was initiated as an AFCEE Environmental Restoration Technology (ERT) demonstration project, but was also funded by AFCEE Environmental Restoration Division (ERD), AFRPA, and ASC to remediate the TCE plume (and related degradation products) and help prevent migration onto the BRAC property slated for transfer.

The $10^{th}$ event of post-PRB performance monitoring results from October are summarized in Table 2.3, and presented in Figure 2.17. Along Transects 1, 2, and 3, the PRB achieves a TCE removal efficiency greater than 99%. Along Transect 1, the effluent chlorinated ethene concentrations are less than the MCL. Along Transect 2, the effluent TCE and vinyl chloride concentrations slightly exceed the MCL while the effluent *cis*-1,2-DCE concentration is less than the MCL. The effluent TCE concentration at Transect 3 is less than the MCL, while the effluent *cis*-1,2-DCE and vinyl chloride concentrations exceed the MCL. At Transect 4, the effluent concentrations of TCE and its daughter products exceed the MCLs.

It does not appear from groundwater data that groundwater is bypassing around the ends of the PRB. Because the PRB was installed along the BRAC/NAS Fort Worth JRB property boundary, contamination already present on the BRAC property was cut off from the remainder of the plume extending from AFP 4 (which is now being contained by the EPL). The data from the downgradient monitoring wells indicate that the treated groundwater is flushing residual contamination downgradient of the PRB.

# Table 2.3
## Selected Analytical and Field Data from 10th Quarter PRB Performance Monitoring

| | TCE µg/L | *cis*-1,2-DCE µg/L | Vinyl Chloride µg/L | ORP mV | DO mg/L | pH | Nitrate mg/L | Sulfate mg/L |
|---|---|---|---|---|---|---|---|---|
| **TRANSECT 1** | | | | | | | | |
| WHGLTA070 -upgradient | 1,300 | 370 | 13 | 20.1 | 0.76 | 6.2 | 0.51 | 62 |
| WHGLFE001 - in PRB well | 1,200 | 370 | 13 | -188.7 | 0.98 | 6.34 | 0.83 | 63 |
| WP07-10C - downgradient | 0.47 F | 19 J | ND | -232.4 | 0.75 | 7.9 | ND | ND |
| **TRANSECT 2** | | | | | | | | |
| WP07-10B -upgradient | 1,200 | 390 | 6.8 F | 68.9 | 2.92 | 6.6 | 1.3 | 53 |
| WHGLFE002 - in PRB well | 1,200 | 370 | 10 F | 17.9 | 0.59 | 6.75 | 1.5 | 51 |
| WGHLTA071 -downgradient | 11 | 18 | 2.5 | -123.2 | 0.70 | 6.97 | ND | 0.26 |
| **TRANSECT 3** | | | | | | | | |
| WGHLTA076 – upgradient* | 1,000 J | 410 J | 15 J | -15.8 | 0.67 | 6.48 | 1.6 | 42 J |
| WHGLFE003 - in PRB well* | 9 | 180 J | 83 J | -206.7 | 0.17 | 6.92 | ND | 0.75 |
| WGHLTA075 –downgradient* | 2 | 370 J | 55 | -146.5 | 0.45 | 6.89 | ND | 0.94 |
| **TRANSECT 4** | | | | | | | | |
| WGHLTA077 – upgradient* | 11 J | 3.4 J | ND | 264.4 | 3.41 | 6.16 | 0.39 | 67 |
| WHGLFE004 - in PRB well | 69 | 38 | 13 | -93.5 | 4.73 | 7.18 | 0.33 | 61 |
| WGHLTA056 -downgradient | 35 | 32 | 3.1 | -165.9 | 1.75 | 7.45 | ND | 8 |

Notes:
* Wells were not sampled during October 2004. Reported data are from May 2004.
ND = non-detected
F = The analyte was positively identified but the associated value is below the reporting limit.
J = The analyte was positively identified but the quantitation is an estimation.

The ZVI degrades the TCE through two potential pathways. In one pathway, TCE degrades directly to chloroacetylene, which is unstable and degrades rapidly to ethene. In the second pathway, TCE degrades to ethene via *cis*-1,2-DCE and VC. Both *cis*-1,2-DCE and VC also are degraded within the PRB, but at a slower rate than the TCE. The data from the treatability study performed by EnviroMetal Technologies, Inc. (ETI) indicated that in the laboratory virtually no TCE was degraded by reductive dechlorination to *cis*-1,2-DCE and VC. Production of *cis*-1,2-DCE or VC was not observed during the treatability study (HGL, 2002c).

Two potential explanations for the apparent production of *cis*-1,2-DCE and VC within the reactive media were developed. First, the treatability study did not reliably mimic field conditions. Perhaps field conditions favor the reductive dechlorination pathway instead of the chloroacetylene pathway. In this situation, *cis*-1,2-DCE and VC would be generated within the PRB, and the residence time might not be adequate to fully degrade these compounds. The observed TCE degradation was consistent with the simulated level, indicating that the model developed from the treatability study reliably predicted TCE degradation. A second explanation is that microbial activity is occurring within the PRB. Additional analyses were performed during the May 2004 semi-annual sampling event in order to better assess the PRB performance and the biodegradation within and downgradient of the PRB (HGL, 2004). Results indicated that site conditions have the potential to support the microbial reductive dechlorination of TCE. The TOC, hydrogen ($H_2$), and volatile fatty acid data, however, suggest that downgradient of the PRB an inadequate supply of electron donor is present to allow complete dechlorination of the residual chlorinate ethenes. In this situation, the primary means of natural attenuation will be through volatilization, dilution, and dispersion. These processes appear to be effective in preventing downgradient movement of the leading edge of the residual plume.

### 2.11.4 Phytoremediation

A field-scale demonstration designed to test the ability of eastern cottonwood trees to remediate shallow TCE contaminated groundwater was initiated in April 1996 by the U.S. Air Force ASC Environmental Safety and Health Division Engineering Directorate (Eberts et. al., 1999). The principal objective of the demonstration project was to generate cost and performance data related to this application of phytoremediation for the purpose of technology transfer.

The site selected for the demonstration project is on the former Carswell AFB adjacent to the northwestern boundary of the BRAC property (Figure 2.16). Approximately 440 whips (sections of 1-year old stems harvested from branches of eastern cottonwood during the dormant season) that were approximately 5 centimeters (cm) long and 220 cottonwood trees of 2.5 to 3.8 cm caliper (trunk diameter) were planted in two separate rectangular-shaped plantations at the demonstration site. Each plantation is 15 by 75 meters (m) and is oriented approximately perpendicular to the direction of groundwater flow.

For this field study, the primary mechanism by which the trees would affect the TCE plume distribution was transpiration. It was hypothesized that a stand of mature trees could substantially decrease the flow of groundwater, and thus the associated flux of TCE, across the demonstration area. A series of groundwater monitoring wells were installed to measure the effects of the trees on the groundwater levels and the water chemistry.

Data collected during the last eight years after the trees were planted indicate the eastern cottonwood trees are decreasing the TCE concentrations by means of their root systems, followed by the biological alteration of TCE within the trees (USGS, 2004). Appendix E provides time trend graphs of the historical chlorinated solvent data for whips, calipers, between planted trees, mature cottonwoods, as well as upgradient and downgradient wells.

Canopy diameter is an important parameter that controls leaf area and transpiration. When the trees mature and form a closed leaf canopy across the test plantations, the trees should have a more pronounced effect on the groundwater flow. The trees should reach maturity in 2007. Funding for this project was eliminated in 2005, so while the trees will continue to have an affect on the groundwater flow and contaminant reduction, the results will not be measured to the same level as they have been since the inception of the treatability study.

## 2.12 SUMMARY OF BASELINE RISK ASSESSMENT

A baseline Human Health Risk Assessment (HHRA) and a baseline Ecological Risk Assessment were performed to support the FFS. The HHRA and Ecological Risk Assessment focused solely on the BRAC property. The results of the baseline HHRA and baseline Ecological Risk Assessment are summarized below. For details on how these assessments were performed, please refer to the Baseline Risk Assessment Report (HGL, 2001a) and the Baseline Risk Assessment Addenda (HGL, 2002a and 2002b).

The purpose of the baseline HHRA and the baseline Ecological Risk Assessment was to identify the level of current and potential future threat posed to human health and the environment by the existing contamination at the site. The HHRA considered the current use of the property and the possible future use(s) of the property in its evaluation.

It should be noted that, excluding the amended evaluation for exposure of residents to soil vapors in basements, the HHRA was performed using data from 1999. Since that time, the groundwater plume across the BRAC property has decreased in size. In addition, the PRB was installed along a section of the western boundary with NAS Fort Worth JRB. Performance monitoring data demonstrate that the PRB is substantially reducing the TCE concentrations in that section of the groundwater plume.

Typically, HHRAs are performed using a single concentration which, for the reasonable maximal exposure scenario, is generally the 95 percent upper confidence limit. For the baseline HHRA, this approach was used for estimation of the threats posed by chemicals in the surface water and sediment. For the groundwater evaluation, however, a risk contouring approach was used. For each groundwater monitoring well used to delineate the plume in this HHRA, the associated carcinogenic risk and non-cancer hazard was calculated. The risks and hazards were then contoured. The risk isopleths for the resident have been updated with April 2002 data (before PRB installation) and are provided as Figures 2.15 and 2.16. Therefore, a range of possible risks and hazards are provided for the groundwater exposure scenarios, while a single point estimate is provided for each of the surface water and sediment exposure scenarios.

### 2.12.1 Human Health Risk Assessment

The following exposure scenarios were evaluated in the HHRA:

- Residents to chemicals in groundwater through:
  - ingestion of tap water;
  - inhalation of volatiles released by tap water;
  - dermal contact during showering; and
  - inhalation of soil gas trapped in basements.
- Construction workers to chemicals in the groundwater through:
  - dermal contact while working in an excavation;
  - inhalation of volatiles while working in an excavation; and
  - incidental ingestion while working in an excavation.
- Recreational user to chemicals in the surface water and sediment through:
  - incidental ingestion while wading in Farmers Branch Creek;
  - dermal contact while wading and fishing in Farmers Branch Creek; and
  - ingestion of fish caught in Farmers Branch Creek.
- Trespasser to chemicals in the surface water and sediment through:
  - incidental ingestion while wading in Farmers Branch Creek; and
  - dermal contact while wading in Farmers Branch Creek.
- Maintenance workers to chemicals in surface water and sediment through:
  - incidental ingestion while working along the edges of Farmers Branch Creek; and
  - dermal contact while working along the edges of Farmers Branch Creek.

For the construction worker scenario it was assumed that the excavation or trench would intersect the groundwater table. The depth to groundwater at the site varies from greater than 20 feet below grade along the western boundary with NAS Fort Worth JRB to only a couple of feet below grade along Farmers Branch Creek and along the eastern property boundary. Because of the safety requirements associated with allowing personnel to enter an excavation that is 20 feet deep, it is unlikely that workers would actually work in a trench or excavation that would intersect the groundwater table along the western property boundary. This area is where the highest concentrations of COCs are observed. The most likely locations for construction workers to encounter groundwater in a trench or excavation would be along Farmers Branch Creek and eastward from the vicinity of the Hawks Creek Golf Course Clubhouse. Several of the chemicals identified in the baseline HHRA as contaminants of potential concern, such as bis(2-ethylhexyl)phthalate and chloroform, were not detected in groundwater samples collected from these sections of the BRAC property.

For the resident exposure scenario, it was assumed that an individual would install a well in the shallow aquifer and use this groundwater as a source of potable water. In addition, it was assumed that the resident's house would have a basement. At this time, no building on the

BRAC property has a basement and the shallow aquifer is not used as a potable water supply. Current residents of the BRAC property obtain their potable water from a municipal water supply. Therefore, the residential exposure scenario evaluated in the HHRA is a hypothetical future land use scenario.

Currently, and in the reasonably foreseeable future, the portion of the BRAC property located above the plume is used as a golf course. Because there is no soil contamination at the site, generally golfers are not expected to be exposed to the site contaminants. It is possible that a golfer may hit a golf ball into Farmers Branch Creek and then may wade into the creek to retrieve the ball. In this situation, the potential exposure to surface water and sediment contaminants would be substantially less than the exposure calculated for the recreational user.

The results of the HHRA are summarized in Table 2.4.

#### 2.12.1.1 Residential Scenario

*Use of Shallow Groundwater as a Potable Water Source:*
Carcinogenic risks associated with use of the shallow aquifer as a source of potable water were calculated for an age-adjusted resident. An age-adjusted resident is an individual who spends six years living at the site as a child and the next 24 years living at the site as an adult. For the evaluation of the non-cancer hazards posed by the use of the groundwater, a child resident was assumed.

Non-cancer hazards to potential future residents are provided in Figure 2.15. Hazard indices (HIs) were not calculated for the southern section of the BRAC property because no contaminants were detected in the groundwater samples collected from that area. The current residential area is located in the southern section of the BRAC property. In the northern section of the BRAC property, the HI (the cumulative non-cancer hazard) for organic compounds ranged from 0.05 to 241. The HI was lowest in the northeastern section of the property and highest along the western boundary with NAS Fort Worth JRB. The dominant contributors to the excessive non-cancer hazards are TCE and *cis*-1,2-DCE with maximum hazard quotients (HQs) of 221 and 20, respectively. An HQ less than one is protective of human health. VC concentration in groundwater monitoring well WP07-10B and chloroform concentration in groundwater monitoring well WP07-10C resulted in HQs greater than 1. These wells are located immediately east of the western property boundary with NAS Fort Worth JRB. As mentioned previously, these calculations were performed on 1999 data before PRB was installed.

Carcinogenic risks to potential future residents are presented in Figure 2.16. In the southern section of the BRAC property, where the current residential area is located, the groundwater did not contain detectable levels of any of the contaminants of concern. Therefore, no cancer risks were calculated for this section of the BRAC property. For the northern section of the BRAC property, the cumulative incremental lifetime cancer risks (ILCRs) ranged from 3.76 x $10^{-7}$ in the northeast to 2.56 x $10^{-3}$ adjacent to the western property boundary with NAS Fort Worth JRB. The highest ILCR (based on the 1999 data) exceeds the EPA target risk range of $10^{-6}$ to $10^{-4}$ (EPA, 1991). The dominant contributors to this cumulative carcinogenic risk are

**Table 2.4**
**Summary of Non-Cancer Hazards and Carcinogenic Risks from the Baseline Risk Assessment**

| Receptor | Groundwater | Soil Gas | Surface Water | Sediment | Cumulative |
|---|---|---|---|---|---|
| **Incremental Lifetime Cancer Risk (ILCR)** | | | | | |
| Resident | NA – 2.56 x $10^{3}$ | NA – 8.5 x $10^{7}$ | Not an exposure pathway | Not an exposure pathway | NA – 2.56 x $10^{3}$ |
| Construction Worker | NA – 2.29 x $10^{-5}$ | Not an exposure pathway | Not an exposure pathway | Not an exposure pathway | NA – 2.29 x $10^{-5}$ |
| Trespasser | Not an exposure pathway | Not an exposure pathway | 1.5 x $10^{-8}$ | 2.5 x $10^{-8}$ | 4.1 x $10^{-8}$ |
| Maintenance Worker | Not an exposure pathway | Not an exposure pathway | 5.5 x $10^{8}$ | 3.9 x $10^{8}$ | 9.4 x $10^{8}$ |
| Recreational User | Not an exposure pathway | Not an exposure pathway | 4.7 x $10^{-8}$ | 3.3 x $10^{-8}$ | 8 x $10^{-8}$ |
| **Hazard Index** | | | | | |
| Resident | NA - 241 | NA - 0.17 | Not an exposure pathway | Not an exposure pathway | NA – 241 |
| Construction Worker | NA – 69 | Not an exposure pathway | Not an exposure pathway | Not an exposure pathway | NA - 69 |
| Trespasser | Not an exposure pathway | Not an exposure pathway | 0.0025 | 0.0027 | 0.0053 |
| Maintenance Worker | Not an exposure pathway | Not an exposure pathway | 0.0022 | 0.0009 | 0.0032 |
| Recreational User | Not an exposure pathway | Not an exposure pathway | 0.0045 | 0.0019 | 0.0064 |

NA = Not applicable; wells in the current on-site residential area were non-detect for all COPCs, and therefore no ILCR or HI is associated with these locations.

JRB, concentrations of PCE, 1,1-DCE, 1,4-dichlorobenzene and bis(2-ethylhexyl)phthalate resulting in carcinogenic risks greater than 1 x $10^{-5}$ to the hypothetical future resident were observed.

*Soil Vapor Intrusion:*
If an unconfined aquifer is contaminated with volatile compounds, these compounds may volatilize out of the water into the soil gas and then diffuse upwards through the soil column. If a building is overlying the plume, the volatile compounds may diffuse across the foundation. If the building is built on a slab, typically the air circulation within the building combined with the greater distance to groundwater will prevent the accumulation of the soil gas. On the other hand, if the building has a basement, soil vapors may accumulate and pose a threat to the building occupants. The baseline HHRA considered the hypothetical future scenario in which a residence with a basement is constructed over the groundwater plume.

The original Baseline Risk Assessment (HGL, 2001a) relied on the Johnson-Ettinger model, an EPA approved model, to screen the volatile chemicals of potential concern for intrusion into a residential basement. Because of concerns associated with the reliability of the Johnson- TCE and VC. In a few of the groundwater monitoring wells adjacent to the western boundary with NAS Fort Worth Ettinger model, actual soil gas data were collected in March 2002. Soil gas sampling locations are shown on Figure 2.17. These data were used to further assess the potential threats to a hypothetical future resident from the soil gas exposure pathway.

In order to calculate the inhalation risk to a potential future resident, it is necessary to convert the soil-gas concentration to the concentration expected to be observed in the air inside the basement. To be realistic, this conversion should take into account dilution caused by the movement of fresh ambient air throughout the house and the barrier effect of the foundation. The Baseline Risk Assessment Addendum (HGL, 2002b) developed a reduction factor to account for both of these processes. The reduction factor was based on the empirical ratio derived by EPA to relate the concentration of radon in indoor air to the concentration of radium in the underlying soil. Because radon is an inert gas and its half-life is long compared to the advective transport across the foundation barrier, radon is an appropriate surrogate for estimating the indoor air concentrations of VOCs present in the soil gas. Indeed, because radon has a lower molecular weight than TCE, DCE and VC, the radon should transfer from the soil gas to the indoor air more readily than the chlorinated compounds. Therefore, the use of the ratio for radon should overestimate the actual ratio for the chlorinated compounds. Based upon a national survey of thousands of homes, EPA determined that, on average, 1 picocurie (pCi) radium/$g_{soil}$ results in 1.25 pCi radon/L of indoor air (EPA, 1994). By using the conversion in Sextro et al. (1987) based on average soil density, porosity and radon emanating fraction, 1 pCi radium/$g_{soil}$ equates to 662.5 pCi/L radon in soil gas. The resulting ratio of radon in indoor air to radon in soil gas is $1.89 \times 10^{-3}$.

Because the groundwater plume does not extend across the southern section of the site, there is no pathway by which volatile compounds from the groundwater could accumulate in basements in that area. Therefore, the site does not have an unacceptable threat to human health via the soil-gas pathway in the southern portion of the BRAC property.

In the majority of the soil-gas samples, neither 1,1-DCE nor VC were detected. In those samples that contained detectable levels of these chemicals, their concentrations contributed negligibly to the overall risk. The cumulative risk associated with all the samples was primarily due to the TCE.

In the northeastern section, where the groundwater is shallow, three soil-gas samples did not contain detectable amounts of the volatile contaminants of concern (TCE, 1,1-DCE and VC). Other samples in this same area resulted in carcinogenic risks ranging from $2.7 \times 10^{-10}$ to $2.1 \times 10^{-7}$.

In the northwestern part of the property where the groundwater contaminant concentrations are the highest, the groundwater is relatively deep (greater than 20 feet below grade). In this area, with the exception of sample SGHGL-013, the carcinogenic risks ranged from $1.5 \times 10^{-8}$ to $8.5 \times 10^{-7}$. Sample SGHGL-013 had an anomalously high TCE concentration, two to three orders of magnitude greater than the concentrations in two nearby samples. The groundwater concentrations beneath the two nearby samples were similar to the groundwater concentration under sample SGHGL-013. The soil in the vicinity of sample SGHGL-013 was excavated, but a cause for the anomalous TCE concentration was not found. The risk associated with the TCE concentration in sample SGHGL-013 was $6.7 \times 10^{-5}$.

Excluding the anomalous TCE concentration in soil-gas sample SGHGL-013, the non-cancer hazards associated with soil gas intrusion into a hypothetical basement were less than 0.0014. The non-cancer hazard estimated from the soil gas concentration of sample SGHGL-013 was 0.17.

#### 2.12.1.2 Construction Worker Scenario

As described in Section 2.12.1, the potential carcinogenic risks and non-cancer hazards for a construction worker were based on the assumption that this receptor would be working inside a trench or excavation that intersects the groundwater. In this situation, the construction worker would be in direct contact with the groundwater and would also inhale chemicals that volatilize from the groundwater present in the bottom of the excavation. It was assumed that the worker would work under such conditions for a full year. This scenario is extremely conservative. The section of the plume that has the highest contaminant concentrations also has a depth to groundwater of greater than 20 feet. It is unlikely that a construction project would excavate to that depth and, if one did, it is unlikely that the excavation work would last for a full year.

The carcinogenic risks to the construction worker ranged from $5.36 \times 10^{-9}$ in the northeast corner of the BRAC property to $2.29 \times 10^{-5}$ near the northwestern property boundary. TCE was the dominant contributor to the carcinogenic risk estimated across the site. For the maximum risks, bis(2-ethylhexyl)phthalate also contributed substantially to the risk. This compound, however, was detected in only two groundwater monitoring wells located above the deep section of the groundwater plume. Because bis(2-ethylhexyl)phthalate is a SVOC, its primary exposure pathway is through ingestion and dermal contact. Therefore, if an excavation did not intersect the groundwater table, then the actual risks posed by the observed concentrations of bis(2-ethylhexyl)phthalate would be minimal. On the other hand, because of TCE's volatility, a worker could still be exposed to TCE via inhalation even if the excavation did not intersect the water table. In this situation, however, the risks would be less than that presented in the baseline HHRA because there would be no direct contact with the groundwater.

The non-cancer hazards for the hypothetical construction worker ranged from an HI of 0.02 in the northeastern corner of the BRAC property to an HI of 69 near the western property boundary. As with carcinogenic risk, TCE was the dominant contributor to the non-cancer hazards estimated across the site. HQs for VC and *cis*-1,2-DCE were greater than 1 at a few groundwater monitoring wells located along the western property boundary. The dominant route of exposure was inhalation.

#### 2.12.1.3 Maintenance Worker

The maintenance worker for the golf course was assumed to sporadically contact the surface water and sediment in Farmers Branch Creek during routine maintenance operations. For exposure of the maintenance worker to the surface water, the carcinogenic risk was estimated to be 5.5 x $10^{-8}$, and the non-cancer hazard was calculated to be 0.0022. The carcinogenic risk and non-cancer hazard for exposure to the sediment were equally low: 3.9 x $10^{-8}$ and 0.0009, respectively. The cumulative carcinogenic risk to the maintenance worker from the BRAC property was 9.4 x $10^{-8}$. The cumulative non-cancer hazard was 0.0032. The contaminants present on the BRAC property do not pose unacceptable health threats to the maintenance worker.

#### 2.12.1.4 Trespasser

It was assumed that the trespasser would be exposed to the surface water and the sediment in Farmers Branch Creek. Exposure to the surface water is estimated to have a carcinogenic risk of 1.5 x $10^{-8}$ and a non-cancer hazard of 0.0025. Exposure to the sediment is estimated to have a carcinogenic risk of 2.5 x $10^{-8}$ and a non-cancer hazard of 0.0027. The cumulative carcinogenic risk is 4.1 x $10^{-8}$ and the cumulative non-cancer hazard is 0.0053. Both of these values are substantially below the values considered to be protective of human health. The surface water and sediment do not pose unacceptable threats to a hypothetical trespasser.

#### 2.12.1.5 Recreational User

The recreational user was hypothesized to be an adult who would wade and fish in Farmers Branch Creek. A comparison of the surface water concentrations to risk-based screening levels indicated that consumption of fish caught in Farmers Branch Creek does not pose an unacceptable threat to human health. Details of this comparison are provided in Sections 2.1.4.1 and 2.1.4.2, and Table 4 of the Baseline Risk Assessment (HGL, 2001a). The recreational user's exposure to the surface water was associated with a carcinogenic risk of 4.7 x $10^{-8}$ and a non-cancer hazard of 0.0045. Hypothetical exposure to the sediment resulted in a carcinogenic risk of 3.3 x $10^{-8}$ and a non-cancer hazard of 0.0019. For the recreational user, the cumulative carcinogenic risk was 8 x $10^{-8}$ and the cumulative non-cancer hazard was 0.0064. The contamination present on the BRAC property does not pose unacceptable health threats to a recreational user.

### 2.12.2 Ecological Risk Assessment Results

Because there is no soil contamination on the BRAC property, the Ecological Risk Assessment evaluated the potential threats to animals and plants that may be exposed to the surface water and sediment in Farmers Branch Creek. Different receptor species were selected to represent the possible cross section of various animals that may live in or frequent Farmers Branch Creek. Because the highly landscaped nature of the golf course and the steep channel banks, a riparian community has not been able to develop substantially along Farmers Branch Creek. Therefore, actual use of the Farmers Branch Creek by the selected receptor species is expected to be limited. For this reason, the Ecological Risk Assessment is considered to be conservative.

It should be noted that, based on correspondence from Texas Parks and Wildlife, no sensitive environments are present on the BRAC property. In addition, no threatened or endangered species have been identified on the BRAC property. The correspondence from Texas Parks and Wildlife is provided in Appendix E of the Baseline Risk Assessment (HGL, 2001a).

To assess potential impacts to aquatic species, the Ecological Risk Assessment compared surface water and sediment concentrations to surface water and sediment screening benchmarks provided by the TCEQ. The comparison of the surface water concentrations to the TCEQ benchmarks resulted in identification of the following chemicals of potential ecological concern (COPECs): aluminum, copper, mercury and zinc. The copper, mercury and zinc in the surface water were retained as COPECs because these are potential bioaccumulators. The aluminum concentrations in the surface water on the BRAC property are consistent with background levels. Therefore, the aluminum in the surface water is not expected to pose additional risk above background conditions. Evaluation of the upper trophic level receptors, the ones potentially affected by the bioaccumulating metals, indicated that these metals pose minimal risk.

For sediment, antimony, arsenic, iron, manganese, nickel, zinc, *cis*-1,2-DCE, barium, vanadium, cadmium, copper and mercury were initially identified as COPECs. The barium and vanadium were retained as COPECs for the sediment because no sediment benchmark could be found. Farmers Branch Creek does not provide habitat conditions that would support the development of a stable, diverse and productive benthic community. For this reason, localized exposure to the sediment COPECs would not be expected to have a significant effect on the benthic community relative to the effects exerted by the poor habitat. Cadmium, copper and mercury were sediment COPECs because of their potential to bioaccumulate. Evaluation of the upper trophic level receptors indicated that these metals pose minimal risk.

To evaluate potential effects to terrestrial species, the following mammals and birds were selected as receptor species: deer mouse, eastern cottontail, raccoon, mink, northern bobwhite, common snipe, American bittern and bald eagle. Because there is no soil contamination, terrestrial plants were not evaluated.

Under the most conservative analysis for the receptor species, the ecological hazard quotient (EQ) for the northern bobwhite was less than one for all COPECs. For the other receptors, the most conservative EQs for one or more chemicals exceeded one. Therefore, the Ecological Risk Assessment proceeded to the next step in which the exposure assumptions are modified to more accurately represent the actual habitat at the site and the intake estimates are compared to no observed adverse effects levels (NOAELs). With the more realistic exposure assumptions, the EQs for all receptors except the deer mouse and mink were less than 1. For the deer mouse, the EQ for arsenic was 2.05 and the EQ for vanadium was 2.85. For the mink, the EQ for arsenic was 1.17, the EQ for vanadium was 2.01, and the EQ for aluminum was 4.85. Even the modified exposure scenario for the mink is likely very conservative. This exposure scenario assumed that the mink would obtain 75 percent of its food from Farmers Branch Creek. In all likelihood, due to the highly modified nature of the stream within the golf course area, the mink will obtain a substantially lower percentage of its food from this section of Farmers Branch Creek. The next step in the Ecological Risk Assessment process was to compare the contaminant intakes to the lowest observed adverse effect levels. This comparison resulted in EQs less than one for all receptors. Based on this stepwise evaluation and the uncertainty assessment, it was concluded that chemicals in the surface water and sediment of Farmers Branch Creek posed minimal risk to terrestrial ecological receptors.

In light of the uncertainties associated with the Ecological Risk Assessment, the background concentrations of various metals, and the poor habitat conditions of Farmers Branch Creek, it is expected that risks to the ecological community on the BRAC property from site-related contaminants will be minimal.

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# 3.0 REMEDIAL ACTION OBJECTIVES

An important step before the selection of treatment technologies suitable for remediation of the BRAC property is the development of RAOs. An RAO is a site-specific goal that defines the objective of proposed remedial actions. RAOs should specify: (1) the COC(s); (2) exposure route(s) and receptor(s); and (3) an acceptable contaminant level or range of levels for each exposure route (i.e., a preliminary remediation goal) (EPA, 1988). An RAO is used to develop remedial action alternatives that protect human health and the environment either by reducing the contaminant concentration to the specified level or by eliminating the exposure pathway(s). Typically, RAOs are developed based upon site-specific risk assessments and applicable or relevant and appropriate requirements (ARARs). ARARs for the BRAC property are listed in Table 3.1.

As outlined in Title 40, Code of Federal Regulations (CFR), Part 300.430(e)(2)(i), the National Oil and Hazardous Substances Pollution Contingency Plan provides the following guidance for the identification and development of an RAO:

- An RAO for a systemic toxicant must be established below the concentration that could cause an adverse health effect as a result of exposure through the identified complete exposure pathways.
- An RAO for a carcinogen should not cause an increase in the lifetime cancer risk that is above the range of $1 \times 10^{-6}$ to $1 \times 10^{-4}$ (EPA, 1991).
- ARARs should be used when available, including MCLs, MCL goals, and ambient water quality criteria.
- An RAO can consider factors related to technical limitations, uncertainties, and other pertinent information.

The following section describes the development of site-specific RAOs for the BRAC property.

## 3.1 APPROACH

The overall objective of remedial action at the BRAC property is to protect human health and the environment. MCLs are the goal for each remedial alternative listed in this FS. Each of the 3 remedial alternatives will rely on ICs until these MCLs can be achieved. The ICs protect human health while remediation is ongoing through either elimination of the exposure pathway or restrictions on the extent of exposure.

**Table 3.1**
**ARARs for the Former Carswell AFB**

| Arar Category | Federal or State Law or Regulation | Citation | Description | Comments |
|---|---|---|---|---|
| Location Specific | ***Federal*** | | | |
| | National Environmental Policy Act (NEPA) | 40 CFR 1500 | Council on environmental quality regulations | Evaluates impacts of remediation on the environment. |
| | | 40 CFR 6 | EPA NEPA regulations | Regulations specific to EPA actions. |
| | | 32 CFR 989 | DOD-Air Force NEPA regulations | Regulations specific to DOD-Air Force actions; the Air Force must evaluate and disclose impacts that will occur as a result of remediation |
| | Clean Water Act (CWA) | Section 404 (33 United States Code [USC] 1344) | Wetland protection requirements | Applicable to activities that may impact wetlands. |
| | Migratory Bird Treaty Act | 16 U.S.C. 703-712 50 CFR 10, 20, and 21 | Regulates the taking of migratory birds | This act prohibits the "taking" of migratory birds without a permit. Would apply if cleanup activity will result in potential destruction of migratory birds or their habitat. |
| Action Specific | ***Federal*** | | | |
| | National Emissions Standards for Hazardous Air Pollutants (NESHAPs) | 40 CFR Part 61 | Air emission standards for hazardous air pollutants | Remedial actions involving air emissions must comply with these standards. |
| | Fish and Wildlife Coordination Act | 16 USC 661-666 | Requires consultation with the U.S. Fish and Wildlife Service when federal department or agency proposes or authorizes any modification of any stream or other water body and adequate provision for protection of fish and wildlife resources. | This requirement would be applicable if modification of Farmers Branch Creek may be required. Consultation with the U.S. Army Corps of Engineers is required as part of the CWA Section 404 permit process. |

## Table 3.1 (continued)
## ARARs for the Former Carswell AFB

| Arar Category | Federal or State Law or Regulation | Citation | Description | Comments |
|---|---|---|---|---|
| Action Specific (cont.) | ***Federal*** | | | |
| | Endangered Species Act | 50 CFR 17, 402 | Requires action to conserve endangered species within critical habitats upon which endangered species depend; includes consultation with Department of Interior. | The requirement would be most applicable to bird and fish species found in the Farmers Branch Creek ecosystem. Consultation with federal and state agencies can be accomplished simultaneously with requirements under the Fish and Wildlife Coordination Act. A review of the installation biological inventory could assist in disclosing whether endangered species are present. |
| | Clean Water Act (CWA) | 33 CFR 322 | Structures or work within navigable waters of the United States | May be applicable to Farmers Branch Creek. |
| | | 33 CFR 323 | Discharges of dredge or fill material to waters of the United States | May be applicable to Farmers Branch Creek. |
| | Hazardous Materials Transportation Act (HMTA) | 49 CFR 107 | Hazardous materials program procedures | This may apply if hazardous materials are transported off-site as part of a remediation. |
| | | 49, CFR 171, 172, 173, 174, 177 | Hazardous materials regulations | Includes general information, communication requirements, emergency response information, and carriage by rail and public highway. Carriage by vessel or aircraft is not anticipated. |
| | Resource Conservation and Recovery Act (RCRA) | 40 CFR 241 | Land disposal of solid waste | May be applicable if cleanup alternative involves on-site disposal of special solid waste. |
| | | 40 CFR 257 | Classification of disposal facilities and practices | Not applicable since no landfills are present at the site which may pose an adverse environmental or health risk. |

**Table 3.1 (continued)**
**ARARs for the Former Carswell AFB**

| Arar Category | Federal or State Law or Regulation | Citation | Description | Comments |
|---|---|---|---|---|
| Action Specific (cont.) | ***Federal*** | | | |
| | Resource Conservation and Recovery Act (RCRA) (cont.) | 40 CFR 260 | Identification and listing of hazardous wastes | Identifies solid waste subject to regulations as hazardous wastes. |
| | | 40 CFR 262 | Hazardous waste generator standards | Waste may be generated if dredging of sediments along Farmers Branch Creek is required. |
| | | 40 CFR 263 | Hazardous waste transportation standards | Waste will be transported, including samples, as a result of remediation. Manifests are required. |
| | | 40 CFR 264 | Standards for treatment, storage, and disposal (TSD) facilities | Specific standards may be relevant and appropriate to alternatives that require the management of hazardous wastes. |
| | | 40 CFR 265 | Interim status standards | Specific standards may be relevant and appropriate to alternatives that require the management of hazardous wastes. |
| | | 40 CFR 268 | Land disposal restrictions (LDRs) | Identifies wastes restricted from land disposal unless specific exemptions exist. |
| | | 40 CFR 280 | Underground storage tank regulations | Applies to owners/operators of underground storage tanks. A geophysical survey is currently being conducted to possibly identify a UST in the area. |
| | ***State*** | | | |
| | Specific Air Emission Requirements for Hazardous or Solid Waste Management Facilities | 30 TAC Subchapter L | Air emission requirements | Excavation or other activities resulting in air emissions must comply with these regulations. |

## Table 3.1 (continued)
## ARARs for the Former Carswell AFB

| Arar Category | Federal or State Law or Regulation | Citation | Description | Comments |
|---|---|---|---|---|
| Action Specific (cont.) | ***State*** | | | |
| | Texas Endangered Species Requirements | 31 TAC, Part 2, Chapter 69 | Requires action to conserve endangered species within critical habitats upon which endangered species depend; includes consultation with Department of Interior. | The requirement would be most applicable to bird and fish species found in the Farmers Branch Creek ecosystem. Consultation with federal and state agencies can be accomplished simultaneously with requirements under the Fish and Wildlife Coordination Act. A review of the installation biological inventory could assist in disclosing whether endangered species are present. |
| | Texas Risk Reduction Program | 30 TAC Chapter 350 | Substantive requirements for cleanup | Remedial actions must comply with the state program cleanup requirements. The TRPP is only an ARAR if the facility elects to proceed under it (rather than RRRs) or if the TCEQ makes the facility fall under the rules. |
| | Texas Water Code | Title 2, Chapter 26, Subchapter D | Texas NPDES program requirements | Substantive requirements that are more stringent than federal requirements must be complied with in cleanup processes that include the discharge of groundwater or waste water to surface water. |
| | | Title 2, Chapter 26, Subchapter G | Oil and hazardous substances spill prevention and control | Also known as Texas Hazardous Substances Spill Prevention and Control Act. Establishes policy to prevent the spill or discharge of hazardous substances into waters of the state of Texas. |
| | | Title 2, Subtitle 6, Chapter 40 | Establishes spill response requirements | Applicable to activities involving spills of hazardous materials into surface water bodies. |

**Table 3.1 (continued)**
**ARARs for the Former Carswell AFB**

| Arar Category | Federal or State Law or Regulation | Citation | Description | Comments |
|---|---|---|---|---|
| Action Specific (cont.) | ***State*** | | | |
| | Texas Water Quality Standards | 30 TAC §307 | State surface water quality standards | Substantive portions that are more stringent than federal requirements must be complied with for treatment alternatives that involve discharge to surface water. |
| | Water Quality Certification | 30 TAC §279 | Substantive requirements associated with Texas NPDES discharges | Substantive portions that are more stringent than federal requirements must be complied with for treatment alternatives that involve discharge to surface water. |
| | Texas Solid Waste Disposal Act | Title 2, V.T.C.A., Texas Health & Safety Code | Includes implementation of the Federal Resource Conservation and Recovery Act | Regulates the management and control of municipal hazardous waste and industrial wastes. Includes generators, transporters and owners/operators of TSD facilities. |
| | Texas Industrial Solid Waste and Municipal Hazardous Waste Regulations | 30 TAC §335 Subchapters A, B, C, D, E, F, H, and S. | Texas requirements for solid and hazardous waste management | Relevant and appropriate requirements for potential remedial actions. |
| Chemical Specific | ***Federal*** | | | |
| | Clean Water Act (CWA) | 40 CFR 129 | Toxic pollutant effluent standards | Applicable if any toxic pollutants listed at 129.4 are discharged to surface water. |
| | | 40 CFR 130 and 131 | Protection of surface water quality | Applicable to the evaluation of alternatives that would require the discharge of treated waster to surface water. |
| | Safe Drinking Water Act (SDWA) | 40 CFR 141, 143 | National primary and secondary drinking water standards | Established maximum contaminant levels (MCLs) for organics, inorganics, radioactivity, and turbidity. These standards also serve as groundwater cleanup standards at CERCLA sites. |
| | Clean Air Act (CAA) | 40 CFR 50 | National primary and secondary ambient air quality standards | Establishes standards for sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide and lead. |

**Table 3.1 (continued)**
**ARARs for the Former Carswell AFB**

| Arar Category | Federal or State Law or Regulation | Citation | Description | Comments |
|---|---|---|---|---|
| Chemical Specific (cont.) | | 40 CFR 61 | NESHAPS | Possibly applicable due to vinyl chloride. |
| | ***State*** | | | |
| | Texas Drinking Water Standards | 30 TAC §290 | State of Texas MCLs | Relevant and appropriate if more stringent than federal standards. |

To fully consider and evaluate a full range of remediation options, four alternatives were developed under the 2 RAOs as part of this FFS. These RAOs correspond to the two land use/land ownership options are possible for the BRAC property.

- RAO 1 Alternative 1 (the No Additional Action Alternative): Retain federal control of the BRAC property; continue existing program of monitoring, land use controls and remediation through the O&M of the existing PRB and phytoremediation site.
- RAO 2 (Alternatives 2-4): Transfer the BRAC property to the public while maintaining land use restrictions until MCLs are achieved.

For each of these scenarios, residents that live outside the current federal property boundary will be protected by ensuring that all COCs are less than or equal to MCLs at the downgradient property boundary. Furthermore, when the BRAC property is released to the public, on-site residents will be protected through active remediation and interim land use restrictions. In addition, maintenance and construction workers will be protected to cumulative ILCR levels of less than $1x10^{-4}$ and a HI of less than 10 for each of the two land use/land ownership scenarios as detailed in Appendix B.

## 3.2 CONTAMINANTS OF CONCERN

### 3.2.1 Contaminants of Human Health Concern

The exposure scenarios that were evaluated in the baseline risk assessment assumed that use of the BRAC property was unrestricted. Therefore, the risk assessment results apply to the situation where residents are allowed to ingest groundwater underlying the site. This exposure scenario does not apply to RAO 1 but does apply to RAO2. Therefore, preliminary COCs were identified based on the results of the baseline HHRA. Because of the decrease in contaminant concentrations observed since 1999 (the baseline HHRA was based on 1999 data), the baseline HHRA overestimates the risks currently associated with the site. The following provides the rationale used to identify preliminary COCs:

- On-Site Groundwater COCs – Potential future resident ILCR in excess of $1x10^{-5}$ or potential future resident HQ greater than 1.
- Off-site migration of groundwater COCs – Identified as exceeding MCLs.
- Surface Water – Identified as exceeding an ILCR of $1x10^{-5}$ or a HQ of 1 for maintenance workers, trespassers, and/or recreational users.
- Sediment – Identified as exceeding an ILCR of $1x10^{-5}$ or a HQ of 1 for maintenance workers, trespassers, and/or recreational users.

Risk and hazard estimates for each receptor are summarized in Section 2.12.1. The ILCR and HQ values for each COC under the resident exposure scenario are described in Section 2.3 and

Figures 1 through 8 and Figures 17 through 26 of the Baseline Risk Assessment (HGL, 2001a). Based on these figures, the following COCs were identified:

**Groundwater:**

Carcinogenic COCs:
- 1,1-DCE
- PCE
- TCE
- VC
- 1,4-dichlorobenzene
- bis(2-ethylhexyl)phthalate

Non-cancer COCs:
- chloroform
- *cis*-1,2-DCE
- TCE
- VC

- **Surface Water** – No COCs were identified. All ILCRs are less than $1x10^{-5}$ and all HQs are less than 1.
- **Sediment** – No COCs were identified. All ILCRs are less than $1x10^{-5}$ and all HQs are less than 1.

### 3.2.2 Contaminants of Ecological Concern

Based on the results of the ecological risk assessment (Section 2.12.2), there is minimal ecological risk associated with sediments and surface water in Farmers Branch Creek. Other than soil capped under a clay liner at Landfill 4 (SWMU 22), soil contamination has not been detected within the boundaries of the BRAC property; therefore, there is no ecological risk associated with soils. Contaminant concentrations within the BRAC property are not expected to increase in groundwater, surface water, sediment, or soils. As a result, ecological impacts associated with site-related contaminants are not anticipated in the future.

## 3.3 REMEDIATION LEVELS

The remediation levels for the COCs are the MCLs. The only COC which does not have an MCL is bis(2-ethylhexyl)phthalate. Therefore, a risk-based concentration for this chemical assuming residential use of the groundwatrer was calculated using the same exposure assumptions for ingestion and dermal contract as described in the HHRA. Because bis(2-ethylhexyl)phthalate is not volatile, exposure via inhalation was not considered. The concentration associated with an ILCR of $10^{-5}$ was 18 $\mu$g/L. This concentration was identified as the remediation level for that COC.

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# 4.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

This section describes the development of remedial technologies and process options in support of the FFS.

## 4.1 INTRODUCTION

Remedial technologies and process options were identified and screened in accordance with EPA guidance (EPA, 1988). A stepped approach was required to identify and screen the potential technologies for remedial action at this site. The Baseline Risk Assessment (HGL, 2001a) concluded that contaminants occurring within the surface water and sediment are below risk-based levels. With the exception of soils capped under a clay liner at Landfill 4, site investigations consistently indicate that no soil contamination exists within the FFS area (BRAC property) and all contaminant source areas are located upgradient of the BRAC property. Source controls have been implemented at upgradient source areas (AFP 4) as described in Section 2.11. Consequently, this technology screening focuses on methods to remediate contaminants of concern in groundwater and does not address remediation of specific source areas or other media.

Following the characterization of site-specific problems and contaminant pathways, General Response Actions (GRAs) were identified to meet the RAOs. Appendix C.1 presents the results of the initial screening assessment that identified potential response actions, technologies, and process options available for remediating the BRAC property. This section presents a more detailed evaluation of remedial technologies and process options for groundwater remediation that remain after performing the initial technology screening evaluation.

## 4.2 VOLUME AND EXTENT OF AFFECTED MEDIA

To properly develop and evaluate the GRAs, the contaminant volume and extent of contamination must be estimated. Based on the data collected at the site, groundwater contamination at the BRAC property is present only in the Terrace Alluvium (Section 2.10). Contamination is found in an east-west trending plume (bisected by Farmers Branch Creek) that is believed to have originated primarily from the AFP 4 area located to the northwest of the BRAC property. The contaminated volume of groundwater greater than the MCL of 5 $\mu$g/L in the Terrace Alluvium is estimated at $6.8 \times 10^7$ gallons. The calculations for the volume of contaminated groundwater are found in Appendix C.3.

As discussed in Section 2.4, the Terrace Alluvium is underlain by the Walnut Limestone (confining unit) and then the Paluxy aquifer. Minor concentrations of TCE were detected in the Paluxy groundwater at well WHGLPU001 during the first three sampling events (4, 5 and 1 $\mu$g/L, respectively) performed in 2000. No VOCs have been detected at this well or any other Paluxy well within the FFS area since the 2000 sampling events.

## 4.3 GENERAL RESPONSE ACTIONS

A GRA is a broad class of responses that exceeds, attains, or partially attains the determined RAO for a particular medium by decreasing contaminant concentrations or by eliminating exposure pathways. GRAs identified for the FFS area include:

- No Action
- ICs
- Groundwater collection and recovery
- Containment
- In-situ groundwater treatment
- Ex-situ groundwater treatment
- Discharge of treated groundwater

Within each GRA, specific remedial technology types are identified to achieve the remedial goal. For example, the remedial technology type identified for the ex-situ groundwater treatment GRA is physical treatment. For each technology type, one or more process options may be available. For example, gas phase stripping and carbon adsorption are two process options for the physical treatment technology.

The GRAs, remedial technologies and process options remaining after the preliminary screening are listed in Table 4.1. To further refine the list of candidate remedial technologies, a detailed description of each of the remaining technologies and their potential implementability at the BRAC property is provided in the discussion that follows. The remedial technologies that survived this more detailed screening process are identified as such in Table 4.1. These technologies will be used in the development of alternatives presented in Section 5.0.

## 4.4 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

This section evaluates in greater detail the process options considered applicable after the initial screening process. This more detailed evaluation allows representative process options to be selected for each technology type, and thus, simplifies the development and evaluation of alternatives. Based on the representative process options selected, performance guidelines can be developed during preliminary design; however, in keeping with the FFS process, the actual process option used to implement the remedial action will not be selected until the remedial design phase.

Three criteria are used to evaluate the process options that survived the initial screening. These criteria are effectiveness, implementability, and cost. The effectiveness evaluation considers:

- The potential effectiveness of each process option for meeting potential RAOs and for handling the volumes of contaminated media to be treated;

**Table 4.1**
**Evaluation of Process Options for Focused Feasibility Study**
**Former Carswell AFB, Texas**

| General Response Action | Process Option | Effectiveness | Implementability | Cost | Retained |
|---|---|---|---|---|---|
| Institutional Action | ICs | Effective in preventing exposure to contaminated groundwater. Does not reduce contaminant levels. | Easy to implement on-site. May be difficult to implement for off-site areas. | No capital and low O&M cost. | Yes |
| | Physical Barriers | Effective in preventing exposure to contaminated groundwater. Does not reduce contaminant levels. | Easy to moderate implementation. May be difficult to implement on public golf course. | Low capital and low to moderate O&M costs. | Yes |
| | Groundwater Monitoring | Not effective in reducing risks to receptors. Effective in determining toxicity levels and rate and extent of contaminant migration. | Easy to implement. Groundwater monitoring is already in progress at the site. | Low to moderate capital and high O&M cost. | Yes |
| Containment | Extraction Wells | Effective for containment of plume, not effective for remediating dissolved contaminants or source area. | Moderately easy to implement may require wells to be installed off-site. Can expand existing system of extraction wells | Moderate to high capital and O&M cost. | Yes |
| | Phytoremediation | Effective once plants have been established (5-10 yrs). Limited areas on site that could accommodate trees or grasses of that density. Not effective during the dormant season. Must be paired with other technology to ensure MCLs are met. | Moderately easy to implement. | Low capital and low O&M cost. | No |
| Discharge of Treated Groundwater | Surface Water Discharge | Effective for discharge of treated groundwater. | Easy to implement. Treated water would be discharged to surface ponds. Discharge must be in accordance with NPDES requirements. | Low capital and O&M cost. | Yes |
| | Discharge via Well Injection | Effective for discharge of treated groundwater. Better options are available. | Moderately easy to implement. Requires installation of injection wells. Requires permit. | Moderate capital and O&M cost. | No |

# Table 4.1 (continued)
## Evaluation of Process Options for Focused Feasibility Study
## Former Carswell AFB, Texas

| General Response Action | Process Option | Effectiveness | Implementability | Cost | Retained |
|---|---|---|---|---|---|
| Ex-Situ Groundwater Treatment | Air Stripping | Effective for treatment of chlorinated hydrocarbons from extracted groundwater as demonstrated by existing GWTS. | Easy to implement, however anti-scaling agents are necessary to reduce fouling. Existing GWTS will require expansion. | Moderate capital and O&M cost. | Yes |
| In-Situ Groundwater Treatment | Co-metabolic Biodegradation | Effective treatment provided good distribution of nutrients, oxygen, and a co-metabolite can be achieved. | Moderately difficult to implement since this option involves injection of methane, toluene, or other carbon source. | Moderate to high capital and O&M cost. | Yes |
| | Monitored Natural Attenuation | Effective only under favorable conditions. Historical site data indicates generally aerobic conditions and limited evidence of on-going natural attenuation. The PRB has enhanced this process in recent years. | Easy to implement | Low capital and O&M cost. | Yes |
| | Chemical Reaction Zone | Effective for treatment of chlorinated hydrocarbons. | Difficult to implement. | High capital and low O&M costs. | No |
| | Permeable Treatment Barrier | Short-term effectiveness has been demonstrated within a localized area downgradient of existing PRB. Long-term effectiveness for treatment of chlorinated hydrocarbons has not been demonstrated. May not treat entire plume. | Difficult to implement due to size of plume and presence of cultural features. | High capital and low O&M costs. | Yes |

- The effectiveness of each process option in eliminating, reducing, or controlling the current and potential risks;
- How proven and reliable each process option is with respect to the contaminants and conditions at the FFS area.

Technology types and process options that do not effectively protect human health and the environment, those that may pose significant adverse environmental effects, or those that offer very limited environmental benefit are screened out and not retained to formulate remedial alternatives.

The implementability evaluation includes both the technical and administrative feasibility of implementing each technology type and process option. Technical feasibility involves the ability to construct, reliably operate and meet technology-specific regulations for process options until the remedial action is complete. It also includes operation, maintenance, and monitoring of technical components of a process option, after implementation of the remedial action is complete. Because the process options have been screened for technical implementability, the implementability evaluation in this section places greater emphasis on administrative implementability. Examples of administrative implementability are factors such as permits, the availability and capacity of treatment, storage, and disposal facilities to dispose of waste materials.

The cost evaluation in this screening is limited to relative comparison of capital and operation and maintenance (O&M) costs rather than development of detailed cost estimates. The cost of each process option is based on engineering judgment (i.e., on the basis of past implementations and past experience at other sites) and identified as either high, moderate or low, relative to other process options for the same technology type.

For the BRAC property, process options retained as a result of the screening evaluation were evaluated based on the criteria presented above. Table 4.1 presents the GRAs, remedial technologies, and process options retained to formulate into remedial alternatives for each site along with the results of the effectiveness, implementability and cost evaluation. The following subsections summarize the evaluated GRAs and Process Options.

### 4.4.1 No Additional Action

For purposes of the technology screening process as applied to the FFS, the No Additional Action alternative will consist of maintaining the former BRAC property boundary (along Route 183) under governmental control. The planned transfer of BRAC property to local interests will not occur and all remediation systems currently operating on or near the FFS area will remain active. For all other action alternatives, the guiding assumption is that property transfer will occur and local interests will obtain control of the property.

### 4.4.2 Institutional Actions

Institutional Actions consist of ICs such as legal restrictions or advisories on property use, physical barriers to prevent unauthorized access, and groundwater monitoring to track changes in contaminant location and/or concentration. The following subsections present a more detailed description of the institutional actions available for implementation at the BRAC property. Institutional actions are appropriate for this site and were incorporated in several of the RAO alternatives presented in Sections 5.0 and 6.0 of this FFS. Institutional actions when applied to the site will be summarized in a LUC/IC plan. The ESD will list that LUCs are necessary until MCLs can be met. Appendix B details the required LUCs given the risks and receptors at the site.

#### 4.4.2.1 Institutional Controls

This subsection describes ICs that may be necessary for remedial alternatives that require a restricted land use in order to be protective of human health and the environment. In particular, ICs will be used to prevent an unanticipated change in land use that could result in unacceptable exposures to residual contamination, or, at a minimum, to alert future users to the residual risks and to monitor for any changes in use. ICs play a key role in ensuring long-term protection and should be evaluated and implemented with the same degree of care as is given to other elements of the remedy. There are five general categories of ICs: governmental controls; proprietary controls; enforcement and permit tools with IC components; informational devices; and physical barriers.

##### *4.4.2.1.1 Governmental Controls*

Governmental controls are usually designed, implemented and enforced by state and local governments. Typical governmental controls include zoning restrictions, statutes, building permits and other provisions that restrict land or resource use at a site. The effectiveness of these types of controls depends in most cases upon the willingness of the state or local governments to adopt them, and enforce them over the long term. Zoning can be used to restrict certain types of activities that could disturb certain aspects of a remedy (e.g., digging or removing soil from a landfill cap) or control certain exposures not otherwise protected by the remedy (e.g., prohibit drinking or fishing in contaminated waters). A site could be zoned for "industrial purposes only," thereby prohibiting the development of residential buildings. Local permits could place limitations on well drilling or building construction. Groundwater use restrictions could be directed at limiting or prohibiting certain uses of groundwater including limitations or prohibitions on well drilling. The ultimate governmental control is condemnation of property, in which title of the property would be taken over by the governmental entity through condemnation to prevent the site from being used.

##### *4.4.2.1.2 Proprietary Controls*

Proprietary controls involve legal instruments placed in the chain of title of the site or property. In Texas, pursuant to the TRRP, the use of deed notices or restrictive covenants are acceptable ICs in lieu of governmental ordnances or zoning. Deed notices do not restrict the use of property, but are intended to provide notice and information regarding the property to the owner of the property, prospective buyers and others. Restrictive covenants, on the other hand, do restrict use of the property and its resources. Restrictive covenants are used especially in cases involving innocent landowners where a person or entity purchases or owns land impacted by contamination migrating from an adjacent property. The landowner agrees not to perform activities that would create risk or exposure. The restrictive covenant would be drafted to be in favor of TCEQ and the State of Texas and would "run with the land". This means the covenant and the property are inseparable once the covenant is recorded. All subsequent transfers and successive owners will be subject to the covenant. The landowner is responsible for filing the deed notice and/or restrictive covenant in the real property records of the county in which the property is located.

Easements may also form a part of the proprietary control. Easements are property rights that are conveyed by a landowner to another party giving the second party rights to the first party's land. An affirmative easement allows the holder to enter upon or use another's property for a particular purpose such as entering the property for monitoring purposes. A negative easement imposes limits on how the landowner may use his/her property such as prohibiting the drilling of a well.

It should be noted that if the site is to remain federally owned, the use of covenants and easements are not, in general, available for use. Proprietary controls may not be an option because a deed does not exist or the landholding Federal agency lacks the authority to encumber the property. Rather, establishing, implementing, enforcing and monitoring ICs should be included in a Base Master Plan or a facility-wide land use plan. Language regarding regular monitoring of the effectiveness of Land Use Controls would be included in a ROD Amendment.

*4.4.2.1.3 Enforcement and Permit Tools with IC Components*

Under CERCLA §§104 and 106(a), EPA may issue unilateral administrative orders and administrative orders on consent to compel the landowner to limit certain site activities. Enforcement tools should include notice requirements that mandate the property owner to notify the EPA or state to obtain their approval prior to transferring the property, to ensure the ICs are enforceable with the new owner.

Texas Department of Licensing and Regulation (TDLR) requires all well drillers to be licensed under 16 TAC Chapter 76. A driller must submit a State Well Report within 60 days of the installation of a well. The TDLR does not maintain files or maps on known contaminated properties to compare State Well Reports against; however, although no well permits are required for installation of potable water wells on the BRAC property, the TCEQ would be required to be informed of any proposed BRAC area wells (Diehl, 2002). This would require the submittal of all proposed well plans and collection and analysis of groundwater samples after well installation. In addition, if a driller encounters "undesirable" water while drilling a well, he is obligated to inform the landowner within 24 hours, and within 30 days he must notify the TDLR that the landowner has been notified of the presence of "undesirable" water. The TDLR would then have responsibility to see that the landowner either had the well completed as a monitoring well or was abandoned. If the driller had previous knowledge that the water was contaminated and continued to drill a well, the TDLR could take action against the driller and have the well completed as a monitoring well or abandoned.

#### *4.4.2.1.4 Informational Devices*

Informational tools provide information or notification of the prohibited activities for a site. Examples of this type of tool include state registries of contaminated properties, and advisories. In Texas, the Texas Solid Waste Disposal Act, Texas Health and Safety Code, Chapter 361 requires TCEQ to publish the State Superfund Registry which identifies facilities which may constitute an imminent and substantial endangerment to public health and safety or to the environment due to a release or threatened release of hazardous substances into the environment. Advisories provide warnings to potential users of land, surface water or groundwater of some existing or impending risk associated with their use. Pictorial signage can be used to convey the message of no admittance, swimming, boating, fishing or digging at a site.

#### *4.4.2.1.5 Physical Barriers*

Physical barriers constitute an institutional action that does not rely on the legal system. Fences, gates, and signs would restrict personnel access to portions of the site. These barriers would be used to exclude people from directly contacting above-ground treatment systems.

### 4.4.2.2 Groundwater Monitoring

Monitoring is required for all RAOs to verify compliance with the stipulated groundwater concentrations. Existing monitoring wells would be sampled to monitor impacts of the alternatives on groundwater contamination at the site. The surface water near the site would also be monitored to determine if the surface water was affected by groundwater discharge. Monitoring would continue as necessary in support of ROD 5-year reviews.

## 4.4.3 Containment

The two technology process options for containment retained for further evaluation include extraction wells (pump-and-treat) and phytoremediation.

### 4.4.3.1 Extraction Wells (Pump-and-Treat)

Pump-and-treat systems for remediating groundwater came into wide use in the early to mid-1980s. By the early 1990s, evaluations by EPA (EPA, 1989; Haley et al, 1991) and others (Freeze and Cherry, 1989; Mackay and Cherry, 1989) called into question the performance of pump-and-treat systems. The general “failure” of the pump-and-treat approach was identified as its inability to achieve “restoration” (i.e., reduction of contaminants to levels required by health-based standards) in 5 to 10 years, as anticipated during the design phase of projects. Although a variety of factors contributed to this shortcoming, tailing and rebound (frequently caused by diffusion into and out of fine-grained sediments) represented the major barrier to achieving remediation goals (see Appendix C.2). Despite its questionable remediation effectiveness, pump-and-treat serves as an excellent technology for containment purposes.

By design, pump-and-treat systems capture contaminated groundwater and pump it to the surface for treatment. This process requires locating the groundwater contaminant plume in three-dimensional space, determining aquifer and chemical properties, designing a capture system, and installing extraction (and in some cases, injection) wells. Monitoring wells/ piezometers used to check the effectiveness of the pump-and-treat system are an integral component of the system. Injection wells may be used to enhance the extraction system by flushing contaminants toward extraction wells or drains. A pump-and-treat system may be used in combination with other remedial actions, such as low-permeability walls to limit the amount of clean water flowing to the extraction wells, thus reducing the volume of water to be treated and discharged.

Even though a major limitation of pump-and-treat technology is its questionable ability to achieve site clean-up objectives, that limitation is of lesser importance in the containment situation on the BRAC property. Regardless of the remedial action implemented on the BRAC property, contaminated groundwater will continue to flow onto the property until the plume cutoff from the EPL system at AFP 4 is completely remediated. Therefore, the purpose of the pump-and-treat system is not to extract and treat all contaminated water on-site, but to prevent the influx of contaminants. As long as the pump-and-treat system efficiently captures the incoming contaminated groundwater, the system would work effectively. Limitations with respect to effective containment include: (1) an inadequate design that allows continued migration of contaminants across the property boundary and (2) operational failures that allow the loss of containment. Typical operational problems stem from the failure(s) of surface equipment, electrical and mechanical control systems, and chemical precipitation that inhibits groundwater flow in wells, pumps, and surface plumbing.

The extracted groundwater must be treated before discharge. Therefore, this technology must be combined with an ex-situ treatment and discharge system.

Because of its ability to contain groundwater, pump-and-treat was retained for further consideration.

#### 4.4.3.2 Phytoremediation

Phytoremediation is an emerging technology for cleanup of contaminated groundwater. This technology involves the use of green plants and trees to remove, contain, or render harmless various organic and inorganic contaminants. While engineered wetlands have been used at various sites to aid in the removal of metals and in the transformation of explosives, a newer application uses trees or grasses to remove TCE from groundwater. The plant-based remediation system has been referred to as "a biological, solar-driven, pump-and-treat system with an extensive, self-extending uptake system (the root system)" (Hinchman and Negri, 1997). Phytoremediation utilizes the unique and selective uptake capabilities of the root systems of the plant, along with translocation, bioaccumulation, and contaminant storage/degradation abilities of the entire plant. Possible phytoremediation mechanisms include: transpiration, sorption to the root surface followed by diffusion into the root interior, translocation, phytodegradation, enhanced rhizosphere biodegradation, and phytovolatilization.

As described in Section 2.11.4, a phytoremediation area for a demonstration study was established along the northwestern boundary of the BRAC property. The trees are expected to achieve a closed canopy in 2007. It is estimated that, after closure of the canopy, the trees will remove 20 percent of the groundwater flowing across the area during the growing season. During the dormant season, no containment effect is anticipated. Because the trees would contain only a fraction of the incoming groundwater for only part of the year, this technology by itself would not provide containment that would allow attainment of the RAOs. Also there is limited space on the golf course and surrounding area to accommodate the density of trees required. For these reasons, this technology process option was not retained for further consideration.

### 4.4.4 Discharge of Treated Groundwater

Use of the pump-and-treat approach for groundwater containment requires ex-situ groundwater treatment. Disposal of the effluent could be achieved by one of two process options:

- Discharge to surface water
- Injection into wells

Descriptions and screening evaluations of these process options are presented in the following paragraphs.

**Surface Water Discharge.** Water could be discharged to a local stream after being treated to applicable surface water discharge criteria. The nearest stream is Farmers Branch Creek, which flows into the West Fork Trinity River.

With respect to permitting, the TCEQ manages the NPDES program, rather than EPA. According to the TCEQ, a TPDES industrial wastewater permit would be required for a remediation system that discharges as a point source to a creek (Dubnick, 2002). The TCEQ developed water quality standards (30 TAC Chapter 310) that provide the basis for the discharge limits. The human health protection values specified for TCE and VC are 200 $\mu$g/L and 5 $\mu$g/L, respectively, but the standards may be adjusted to accommodate site-specific conditions. The adjustments are based upon whether the receiving stream is perennial or intermittent, the volume of flow in the stream, the volume of treated groundwater to be discharged, the mixing zone in the receiving stream, and other such factors. If a stream has not been classified (Farmers Branch Creek was not listed as a classified stream), the TCEQ encourages the applicant to collect data to develop documentation concerning the general stream type and flows at the point of discharge. If Farmers Branch Creek were classified as an intermittent stream, then 48-hour acute toxicity testing of the effluent, with a 100 percent dilution factor would be required. If Farmers Branch Creek were classified as a perennial stream, then chronic and acute toxicity testing may be required depending on the ratio of the discharge to the flow of the stream. Regardless of the stream classification, samples of the discharge would be collected for chemical analyses, likely on a quarterly basis.

The application process for a permit requires the submittal of a technical report and an administrative report. The application instructions state that the technical report should be prepared by a Texas registered Professional Engineer (P.E.) or by a qualified, competent person with experience in the field to which the application relates. An administrative review of the application is performed to ensure that all the required information has been submitted and once the completeness has been determined, a technical review begins. The technical review may last as long as nine months. As part of the technical review, the TCEQ determines the discharge limits and files a notice of intent to discharge to the receiving stream. A draft permit is prepared and sent to the applicant, who is allowed 30 days to provide comments on the draft. The permit is filed with the Office of the Chief Clerk and a second notice of intent to discharge to the receiving stream is published. The public then has 30 days to comment on the permit, and EPA has 45 days to comment. A hearing request could be filed during the public comment period which would increase the time needed to obtain a permit. Based on the public and EPA comments, the permit may require modification or may be issued. Surface water discharge is a technically appropriate option provided that the substantive requirements of the discharge permit are met. This process option was retained for further evaluation.

**Discharge via Well Injection.** Discharge via well injection involves pumping groundwater out of the affected aquifer, treating the water to the applicable water quality standards, and re-injecting the effluent into the surficial deposits. The use of injection wells or infiltration galleries for the re-injection of water from groundwater treatment systems is regulated under 30 TAC Chapter 305 as a Subsurface Fluid Distribution System. According to the TCEQ, the use of injection wells or infiltration galleries must meet two requirements: (1) the water being injected must meet primary MCLs for the contaminants; and (2) no degradation of the aquifer into which the effluent is injected can occur (Eister, 2002). Therefore, even if the contaminant concentrations in the water to be injected are below the MCLs, it cannot be injected into a part of the aquifer that has contaminant concentrations less than MCLs.

Wells or galleries undergo "Approval by Rule"; no public comments, hearings, or notices are required. An Authorization Form (EPA Code 5X26) must be submitted. The approval time is usually one to two weeks after the form is received. Other than the natural limitations of the aquifer, there are no limits on the discharge rate of the wells or galleries. Because surface water discharge is less expensive and more easily implemented than well injection, this alternative will not be carried forward into the alternative development.

### 4.4.5 Ex-Situ Groundwater Treatment

#### 4.4.5.1 Air Stripping

Air stripping can be used as part of a pump-and-treat system to remove VOCs, such as TCE and its degradation products, from dilute aqueous waste streams. This technology takes advantage of the high volatility of certain chemicals to transfer them from the water to air. Air stripping is not appropriate for low volatility compounds, high solubility compounds, metals, or inorganics. A number of air stripper configurations are available. For example, a tower may be used in which the water trickles over media of various shapes (slats, rings, and spheres) designed to increase the area of the air-water interface. For low water flow rates, a tray system may be used in which the water is aerated by cascading over a series of trays. Removal efficiencies for air strippers range from 50 percent to greater than 99 percent. After the contaminants are transferred to the air stream, the air stream may require treatment to prevent an excessive release of the contaminants to the atmosphere. Based on prior operation of the air stripper system at the pump-and-treat system for Landfills 4 and 5, while an air permit would be obtained, treatment of the air stream and air sampling would not be required on the BRAC property.

Because air stripping is easily implemented and provides a proven means to cost-effectively remove TCE and its degradation products from aqueous waste streams, it was retained for further evaluation.

#### 4.4.5.2 Carbon Adsorption

Carbon adsorption is a process in which molecules are attracted to and then held at the surface of granular activated carbon as contaminated water is pumped through the carbon beds. This technology is able to effectively remove a variety of organic compounds, in particular those compounds that are hydrophobic. Because there are a finite number of sorption sites on the activated carbon, periodically the activated carbon must be replaced with clean activated carbon. Spent carbon may be disposed as a hazardous waste or shipped off site for regeneration. Activated carbon is a potentially effective option for the contaminated groundwater at the BRAC property, especially as a polishing step that would follow other treatment such as air stripping. Carbon units have been used effectively at many sites, including the upgradient AFP 4 site. Because of easy implementation and cost-effective contaminant removal, carbon adsorption will be retained for further evaluation.

### 4.4.6 In-Situ Groundwater Treatment

#### 4.4.6.1 Cometabolic Biodegradation

Biodegradation relies on microbial enzymes to transform a contaminant of concern to a less toxic form. Though some compounds can be degraded through direct metabolism by the microbes, other compounds do not provide enough energy to support their direct metabolism. Some of these latter compounds may be degraded through cometabolism. Cometabolism occurs when the microbial enzymes produced for primary substrate oxidation are capable of degrading the secondary substrate fortuitously, even though the secondary substrates do not afford sufficient energy to sustain the microbial population. To achieve cometabolism, a primary substrate (e.g., methane, toluene) is injected, either through air or water, into the groundwater. Depending on the groundwater quality, nutrients may be injected at the same time. Appendix C.2.3 provides a detailed description of the cometabolic processes.

Table C.2-4 in Appendix C lists the different mechanisms by which the three major COCs (TCE, *cis*-1,2-DCE and VC) on the BRAC property may be microbially degraded. Under aerobic conditions, *cis*-1,2-DCE and VC may be directly degraded by microbes, while TCE can be degraded only through cometabolism. Under anaerobic conditions, TCE, *cis*-1,2-DCE and VC can be degraded both directly and through cometabolism. There are some limitations associated with the anaerobic degradation of these COCs. The presence of PCE in the groundwater has been observed to inhibit the anaerobic degradation of VC (Tandol et al, 1994). PCE is present at low concentrations across portions of the groundwater plume. In addition, the preferential degradation of TCE under anaerobic conditions may result in the accumulation of *cis*-1,2-DCE and VC. Furthermore, the injection of methane and air has been successfully used at a variety of sites to stimulate the aerobic cometabolism of TCE (Travis and Rosenberg, 1997). Aerobic co-metabolism has the potential to remediate the contamination on the BRAC property to the groundwater concentrations required for unrestricted use. For this reason, aerobic cometabolism was selected for further evaluation.

#### 4.4.6.2 Monitored Natural Attenuation

The term "monitored natural attenuation" (MNA) refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. Other terms associated with natural attenuation in the literature include "intrinsic remediation," "intrinsic bioremediation," "passive bioremediation," "natural recovery," and "natural assimilation." The natural attenuation processes that are at work in such a remedial alternative include a variety of processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include aerobic and anaerobic biodegradation, dispersion, sorption and volatilization. These processes and their applicability to the conditions at the BRAC property are briefly described below. Additional details are provided in Appendix C.2.4 and in the 1999 Annual Groundwater Sampling Report for NAS Fort Worth JRB (HGL, 2000b).

*Biodegradation* - Soil is the natural habitat for large numbers of microorganisms, many of which can convert chlorinated organics to innocuous byproducts. As described for cometabolism, TCE cannot serve as a primary substrate for microbial growth. For aerobic degradation of this contaminant, a readily available source of organic carbon is required. The groundwater on the BRAC property has a low concentration of dissolved organic carbon. Thus, minimal degradation of TCE is likely to occur naturally without the addition of an organic carbon source.

*Adsorption* – Chlorinated VOCs in the subsurface may adhere to soil particles and resist further migration. For chlorinated organics, sorption is not expected to be a significant process. In addition, the solid matrix of the aquifer is a combination of sand and gravel; these coarse solids are typically associated with minimal adsorption. This process is expected to contribute minimally to natural attenuation at this site.

*Volatilization* - Chlorinated VOCs, like those reported at the BRAC property, can volatilize from the upper portion of the water table into the soil gas and then migrate upwards through the soil column to the ground surface. This mechanism is expected to play a role in natural attenuation at the BRAC property.

*Dispersion* - Dispersion refers to the contaminant dilution along the leading edge of the plume caused by diffusion, mixing and spatial variation in permeability (Cantor et al, 1988). The influx of rain water or irrigation (such as the type occurring regularly at the golf course) also will serve to dilute plume concentrations. Once the groundwater flowing onto the BRAC property is remediated (e.g., by the PRB along the upgradient property boundary), these natural dilution processes will, over time, reduce the concentration of contaminants currently observed in the middle of the BRAC property.

In short, the primary mechanisms by which natural attenuation is expected to remediate the on-site groundwater are dispersion and volatilization.

Application of this technology requires measurement of contaminant concentrations and water quality parameters in order to determine if the subsurface environment is conducive to the different natural attenuation processes. Water quality parameters that would require monitoring include DO, ORP, chloride, alkalinity, methane, $Fe^{+2}$ and manganese, and sulfate/ sulfite.

Although biodegradation and sorption would play only minor roles in the MNA process, this option was retained for further evaluation. This technology was evaluated for potential use to remediate the interior of the BRAC property in conjunction with a more aggressive technology to remediate the contaminated groundwater flowing onto the property. This approach is easy to implement and has a low cost and was carried forward in the development of RAO alternatives.

#### 4.4.6.3 Chemical Oxidation

In-situ chemical oxidation is rapidly emerging as a viable remediation technology for mass reduction in source areas as well as for plume treatment. The oxidants most commonly employed to date include peroxide, permanganate, and ozone, with subsurface delivery to groundwater by vertical or horizontal wells and to soil by lance injectors and hydraulic fracturing. The potential benefits of in-situ oxidation include the rapid and extensive reactions with various COCs, applicability to many biorecalcitrant organics and subsurface environments, and ability to tailor treatment to a site from locally available components and resources. Some potential limitations exist including: potential need for large quantities of reactive chemicals to be introduced due to the oxidant demand of the target organics and the unproductive oxidant consumption of the formation; resistance of some COCs to chemical oxidation; and potential for process-induced detrimental effects including gas evolution, permeability loss, and mobilization of redox sensitive and exchangeable sorbed metals.

Full-scale deployment of this remedial approach is accelerating, but caution is necessary to avoid poor performance and unforeseen adverse effects. Matching the oxidant and delivery system to the COCs and site conditions is the key to achieving performance goals. As presented in the discussion in Appendix C, however, there are a number of potential problems associated with chemical oxidation. Examples of these problems include: presence of metals that may have altered mobility and risk due to chemical oxidation; ability of chemical oxidation to achieve stringent cleanup goals (such as MCLs); regulatory permitting requirements and constraints; and health and safety precautions during chemical handling. These concerns, along with the others listed in Appendix C, in conjunction with the high costs have precluded this technology from further consideration.

#### 4.4.6.4 Permeable Reactive Barrier

This technology, patented by ETI, consists of a PRB containing ZVI or a funnel and gate system with a ZVI reactive cell. The PRB would be installed as a permanent unit across the flow path of the contaminant plume and the natural gradient will transport contaminants to and through the treatment media. The chlorinated VOCs are degraded by dehalogenation as they migrate through the wall, and chlorine atoms are stripped from the chlorinated hydrocarbon using electrons supplied by the oxidation of iron. If there is adequate residence time within the reactive zone, the chlorinated VOCs ultimately are degraded to ethane and ethene. These end products are innocuous and may be readily degraded by naturally-occurring microbes. Details of the reaction are presented in Appendix C.2. The iron is dissolved during the dehalogenation process, but the metal degrades so slowly that the remediation barrier, barring other factors such as plugging, remains effective for many years.

This technology is emerging but a number of other full-scale systems have been installed in recent years. Although considerable design details have been developed through pilot-scale and full-scale applications, some critical issues (e.g., establishing tested and proven design procedures, determination of an appropriate design safety factor, improving construction technologies, documenting long-term performance, and evaluating synergy with other groundwater remediation technologies) are still in need of refinement. Little data concerning the long-term performance of this technology are available. Two major issues related to the longevity of the PRB are iron loss and the clogging of the reactive media through the formation of chemical precipitates and/or bio-fouling. Monitoring of the existing systems and ongoing laboratory studies are designed to address these issues and to facilitate wider implementation of this technology.

PRBs potentially have several advantages over conventional pump-and-treat methods for groundwater remediation. Reactive barriers can degrade or immobilize contaminants in-situ without any need to transport the contaminants to the surface. PRBs do not require continuous input of energy because the natural gradient of groundwater flow is used to carry contaminants through the reaction zone. Operational and routine maintenance requirements are minimal; therefore the associated costs tend to be low. The technical and regulatory problems related to ultimate discharge requirements of effluents from pump-and-treat systems are avoided with this technology. In addition, once a PRB is installed, its presence has minimal visual impact on the property.

As with any remediation technology, PRBs do have some disadvantages. Because the PRB relies on the natural hydraulic gradient to move groundwater through the treatment zone, if the hydraulic conductivity of the PRB is less than the surrounding aquifer, the groundwater may bypass the reactive media. The hydraulic characteristics of the proposed PRB location must be thoroughly investigated in order to ensure that the alignment of the PRB and the reactive media selected do not result in bypass. In addition, the groundwater quality should be evaluated with respect to its propensity to form chemical precipitates within the reactive media. If excess chemical precipitates form in the pore spaces, the resulting loss in hydraulic conductivity may create hydraulic bypass of the PRB. Because the treatment efficiency is directly related to the residence time, it is critical to ensure that the wall is thick enough to allow for degradation of the chlorinated compound and any intermediate products. Therefore, accurate modeling is required to obtain reliable degradation rates. Typically, degradation rates are estimated based on a treatability study performed with the site groundwater. Although many PRBs have been successfully installed in the field, there are uncertainties associated with the estimation of the reaction rates. Finally, the degradation reaction consumes iron. Based on laboratory data and field installations, it is estimated that the iron in the PRB installed along the western property boundary should last on the order of several decades (ETI, 2001). Because of similarity in groundwater characteristics, it is likely that another PRB installed on the BRAC property would have a similar expected longevity.

To support application of this technology, monitoring wells would be installed on both sides (upgradient and downgradient) of the treatment zone in order to obtain information about the long-term performance of the technology. Aside from groundwater monitoring, the only long-term maintenance requirement would be periodic iron rejuvenation (removal of chemical precipitates).

This technology option was retained for further evaluation because of its low O&M costs and requirements. In addition, much of the site characterization work, including the treatability study, has already been performed at the BRAC property for the PRB installed along the western property boundary in April and May 2002.

#### 4.4.6.5 Chemical Reaction Zone

This technology is another approach that relies on the reductive dehalogenation reactions used in the ZVI PRB described above. An alternative method to the PRB for achieving the same chemical reaction is to inject and disperse into the contaminated area a highly reactive ZVI powder. This process was developed by ARS Technologies and has been implemented effectively on a number of sites. With this technology, there is uncertainty involved with calculating the exact quantity of iron powder required for effective remediation and uncertainty concerning the ability of the installation technique to evenly disperse the iron powder through the entire contaminated zone. This technique tends to have a higher cost than the PRB described above, and does not appear to have operational advantages over the PRB. The primary advantage of this technology over a conventional PRB is the lack of the requirement to perform large-scale excavations to emplace the reactive media and the relative ease in avoiding buried obstacles such as utilities and building foundations. However, the added cost over a conventional PRB and the difficulty in assuring adequate subsurface distribution of the reactive media precluded this technique from further evaluation.

## 4.5 SUMMARY OF TECHNOLOGY SCREENING RESULTS

Appendix C presents the results of a preliminary technology screening and provides a more thorough description of each technology presented in this Section. Table 4.1 summarizes the results from the screening process presented in this section. The table includes a description of the processes and screening comments are included about whether the technology or process option is being retained for inclusion in the remedial action alternatives presented in Section 5.0.

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# 5.0 DEVELOPMENT OF ALTERNATIVES

Remedial technologies and associated process options were identified and qualitatively evaluated in Section 4.0. During this preliminary screening process, remedial alternatives and process options were eliminated or retained based on cost, effectiveness, and implementability. At the end of the technology screening process, representative process options were selected for inclusion into remedial alternatives for the BRAC property. As part of the alternative development process, process options were combined in order to achieve the three RAOs that are described in Section 3.0. The remedial technologies and technology process options that passed the preliminary screening and subsequent evaluation in Section 4.0 are as follows:

| Medium | General Response Actions | Remedial Technologies | Technology Process Options |
|---|---|---|---|
| Groundwater | No Action/Institutional Actions: | No Action/Institutional Options | |
| | - No action | - Deed Restrictions | |
| | - Monitoring | - Fencing | |
| | Containment Actions: | Containment Technologies | groundwater pumping |
| | - Containment | | |
| | Collection/Treatment Actions: | Extraction Technologies | groundwater pumping |
| | - collection/treatment discharge | | |
| | | Treatment Technologies | |
| | | - Physical-chemical | air stripping |
| | | | carbon adsorption |
| | | - In-situ | monitored natural attenuation |
| | | | cometabolic biosparging |
| | | | permeable reactive barrier |
| | | Disposal Technologies | |
| | | - Discharge to surface water after treatment | |

During the remedial alternative development process, the representative process options selected during the technology screening (Section 4.0) were assembled into remedial alternatives for the BRAC property. Acceptable engineering practices, as related to site-specific conditions, were considered during the development of the remedial action alternatives. Guidance for the development of these alternatives was obtained from the following sources:

- 40 CFR 300 National Contingency Plan (NCP)
- Section 121 of the 1986 Superfund Amendments and Reauthorization Act (SARA)
- Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (EPA, 1988).

Four remedial action alternatives, presented in Table 5.1, were developed from the representative technology process options identified above. These four alternatives are:

Alternative 1 – No Additional Action
Alternative 2 – MNA with LUCs
Alternative 3 – Pump-and-Treat and Cometabolic Biosparging
Alternative 4 – ZVI Permeable Reactive Barriers and MNA

**Table 5.1**
**Remedial Action Alternatives**

| Property Not Transferred | Property Transferred |
|---|---|
| **Alternative 1** | **Alternative 2** |
| **No Federal Boundary Change**<br>• Maintain PRB<br>• Long Term Monitoring<br>• Land Use Controls | **Federal Boundary Change**<br>• Monitored Natural Attenuation<br>• Land Use Controls (LUCs) restricting residences and potable waste/groundwater supply wells until MCLs are achieved |
| | **Alternative 3** |
| | **Federal Boundary Change**<br>• Pump-and-Treat<br>• Cometabolic Biosparging<br>• LUCs restricting residences and potable water/groundwater supply wells until MCLs are achieved |
| | **Alternative 4** |
| | **Federal Boundary Change**<br>• Additional PRBs<br>• Monitored Natural Attenuation<br>• LUCs restricting residences and potable water/groundwater supply wells until MCLs are achieved |

For each alternative, engineering design variables were estimated based on simple calculations, experience at the former Carswell AFB and similar sites, and best engineering judgment. Examples of engineering design variables that were estimated during alternative development process include the number of extraction and monitoring wells to be used; and the quantity of materials such as nutrients, iron, and activated carbon needed. The approximations were used to estimate the costs for each alternative. More accurate estimates will be required during the remedial design phase. The detailed analysis and comparative analysis presented in Section 6.0 are based on the remedial action alternatives described in this section.

## 5.1 RAO 1 - NO ADDITIONAL ACTION

Under RAO 1, one remedial alternative has been developed. As required by the NCP, the no action alternative provides a comparative baseline against which other alternatives can be evaluated. Under this alternative, all source units, surface water, and groundwater would be left "as is", without implementing any additional containment, removal, treatment, or other mitigating actions. For the purposes of this FFS, however, Alternative 1 (Figure 5.1) is modified from the typical "no action" required by the NCP to "no additional action" because there are already several remedial technologies that have been installed within or upgradient of the BRAC property, and these remedies will continue to operate. This modification will make the comparative analysis of the various alternatives more meaningful and will provide a sound basis for the cost comparisons presented in Section 6.0.

RAO 1 assumes that, at a minimum, the requirements of the existing AFP 4 ROD are met, that the property is not transferred, and that the current land use does not change. The ROD states that MCLs must be achieved at the federal property boundary. Currently, these remediation levels are being met.

### 5.1.1 Alternative 1 – Detailed Description

Alternative 1 provides a baseline condition against which the other alternatives may be compared. Alternative 1 consists of the following three components; (1) a PRB located along the western boundary of the BRAC property; (2) a LTM program that involves sampling 3 wells semi-annually for the first 8 years, and then annually for 22 years; and (3) an area of active phytoremediation located along the northwestern boundary of the BRAC property (Figure 5.1). The PRB and phytoremediation area were installed on the BRAC property as part of two separate technology demonstration studies. Because of their in-situ nature and the fact that they will continue to operate, the PRB and the phytoremediation area were included as part of each alternative action being considered. Each component of Alternative 1 is discussed in greater detail below.

<u>Permeable Reactive Barrier</u>

Under this alternative (and all the other alternatives) the existing PRB will be maintained. The PRB is 1,126 feet long, 2 feet thick, and is composed of ZVI and sand (50 percent each by weight). The base of the PRB is keyed into the bedrock, while the top of the reactive media is located at 599 feet above mean sea level (msl) or higher. The PRB is located along the western boundary of the BRAC property.

Fifty-two and 23 monitoring wells were sampled during May and October 2004, respectively, for the constituents listed in Table 5.2. It is assumed that only six wells will be monitored on a semi-annual basis for the next 8 years, and then annually for the next 22 years. The number of monitoring wells and monitoring frequency, however, may be further reduced if the PRB is meeting expected performance goals. It is assumed that the iron in the wall will be rejuvenated (in-place reduction of iron) every 10 years.

**Table 5.2**
**PRB Monitoring and Sampling Program**

| Parameter | Monitoring Frequency |
|---|---|
| *Field Parameters*<br>• Water Level<br>• pH<br>• Groundwater Temperature<br>• Redox Potential<br>• Dissolved Oxygen<br>• Specific Conductance<br>• Turbidity | Semi-annually for the next 8 years, and annually thereafter. The frequency may be reduced based on operational stability. |
| *Organic Analytes*<br>• VOCs<br>• Methane, ethane, ethane<br>• Total Organic Carbon | Semi-annually for the next 8 years, and annually thereafter. The frequency may be reduced based on operational stability. |
| *Inorganic Analytes*<br>• Alkalinity<br>• Calcium*<br>• Iron, Total*<br>• Magnesium*<br>• Potassium*<br>• Silica, Reactive*<br>• Sodium*<br>• Nitrate<br>• Chloride<br>• Sulfate | Semi-annually for the next 8 years, and annually thereafter. The frequency may be reduced based on operational stability. |

Note: * Metals were not sampled during October 2004.

<u>Long-Term Monitoring</u>

The objectives for monitoring the AFP 4 groundwater plume (established in the AFP 4 ROD) require monitoring the downgradient extent of the regional TCE plume, particularly at the DoD boundaries along Route 183, the West Fork Trinity River, and Lake Worth (Rust Geotech, 1995). The data quality objectives (DQOs) correspond to the critical groundwater exposure pathway evaluation objectives listed for the project. The DQOs are to collect data of sufficient quality to assess (1) potential exposure to groundwater sources used for drinking water; and (2) potential on site and off site exposures to contaminated surface water. The COCs for AFP 4 include TCE and TCE-related compounds, mainly *cis*-1,2-DCE, but also *trans*-1,2 DCE, VC, and PCE. Three wells located at the former Carswell AFB will likely be sampled for PCE, TCE, *cis*-1,2-DCE, and VC on a semi-annual basis for the next ten years and annually for 20 years thereafter. In accordance with the LTM plan, eight surface water samples also will be collected on the same schedule, including two samples from Farmers Branch Creek on the former Carswell AFB.

<u>Phytoremediation</u>

As discussed in Section 2.11, a field-scale demonstration of phytoremediation was established along the northwestern section of the BRAC property. The trees were planted in 1996 and are expected to mature in 2007. For the FFS cost analysis, it is assumed that, while the trees would be left in place, the phytoremediation area would not be maintained for the duration of the cost analysis (30 years).

## 5.2 RAO 2 – PROPERTY TRANSFERRED

RAO 2 transfers the property with interim institutional actions that will limit the exposure pathways and thus ensure protection of human health until MCLs are met. ICs will prevent the exposure of on-site residents to groundwater contaminants through the soil gas inhalation pathway and the potable water pathway. Under this RAO, the only exposure to groundwater contaminants will be to construction workers working in excavations for new buildings and new utilities, and industrial/commercial workers in a building located above the plume as detailed in Appendix B. Land use controls will be developed to ensure protection of construction workers. Risks to industrial/commercial workers from the vapor intrusion pathway were calculated to be less than or within the EPA target risk range (Appendix B). The institutional actions that preclude construction of houses will also ensure that the potable and process water for a commercial/industrial building is obtained from a municipal source.

Alternatives 2 through 4 include the use of ICs to prevent exposure of an on-site resident to groundwater contaminants until MCLs are achieved. For all of these alternatives, a restrictive covenant would be applied to the property transfer to prevent the installation of potable water wells and process water wells in the Terrace Alluvium on the site, and the construction of residential buildings directly above the plume. The use of restrictive covenants is described in detail in Section 4.4.2.1.2. Once MCLs have been met, institutional actions will be lifted.

In addition, Alternatives 2 and 4 incorporate MNA as shown in Figures 5.2 and 5.4. As described in Section 4.4.6.2 and Appendix C, this process option relies on a number of natural mechanisms, such as volatilization and dispersion, to reduce contaminant levels to the specified goals. For Alternative 2, no additional means are used to promote the natural processes unless warranted during the Five-Year Review. To monitor the progress of MNA, 5 LTM wells will be sampled for natural attenuation parameters in addition to VOCs. These wells will be sampled on a semi-annual basis until MCLs have been achieved.

### 5.2.1 Alternative 2 – Detailed Description

Alternative 2 consists of MNA combined with land use controls until MCLs are achieved. The timeframe calculated to reach MCLs is between 20 and 50 years as described in Appendix E. Optimization of the existing PRB or other treatment systems may be required in order to reach MCLs. This will be determined by Five-Year Reviews, starting with the 2012 ROD review (since the next ROD review will not provide enough data/time to properly evaluate the MNA). As described above, Alternative 2 would rely on restrictive covenants to ensure that receptors are not exposed to groundwater contaminants either directly, through installation of a drinking water well in the Terrace Alluvium, or indirectly, through the soil gas pathway. In addition, restrictive covenants would be used to ensure protection of construction workers.

As described for Alternative 1, the existing PRB and phytoremediation area will continue to provide in-situ treatment of the groundwater flowing on to the BRAC property (Section 5.1.1). This alternative relies on the EPL system containing the source areas contributing to the southern lobe TCE plume. In addition, the LTM program monitoring described in Section 5.1.1 will be continued at the BRAC property.

### 5.2.2 Alternative 3 – Detailed Description

Alternative 3 consists of pump-and-treat along the western and northwestern boundaries, and biosparging within the plume to promote aerobic co-metabolism of the TCE (Figure 5.3). Restrictive covenants will be used to ensure protection of human health until MCLs are achieved. The co-metabolic biosparging and pump-and-treat systems are discussed in greater detail below.

*Cometabolic Biosparging*

A detailed description of cometabolic biosparging is provided in Section 4.4.6.1 and Appendix C.2.3 of this FFS. The biosparge system proposed as part of this alternative would inject methane and air to support aerobic co-metabolism of TCE. Although a number of organic constituents could have been used to initiate cometabolic biosparging, methane was selected because of its relatively low costs and ease of delivery through horizontal wells. Methane will be injected at 2 percent of the volumetric airflow rate for 20 percent of the time for the first 6 months. It is assumed that this methane addition will sufficiently raise the available carbon levels to allow significant biological activity. After the initial 6-month methane injection period, air will be injected at three-week intervals followed by one-week intervals of methane injection. This injection cycle will be maintained for five years. The volume of air/methane to be injected is based upon equivalent vertical wells at 10 cfm and 50-foot radius of influence. Therefore, the horizontal wells will be spaced at 100-foot intervals.

The biosparging system at the BRAC property consists of two separate systems, one for the portion of the plume north of Farmers Branch Creek (but still on the BRAC property), and one for the main portion of the plume (Figure 5.5). The system north of Farmers Branch Creek consists of 8 horizontal wells with a combined total length of 4,900 feet. The horizontal wells will be placed around the phytoremediation area so as to not damage the trees. The southern portion system consists of 12 horizontal wells with a combined total length of 6,800 feet. The wells will be stainless steel pipe because plastic would not have sufficient tensile strength.

*Pump-and-Treat*

For Alternative 3, a pump-and-treat system consisting of four wells each operating at 20 gpm will be placed along the western boundary. The depth to bedrock in this area is approximately 38 feet. The wells will be 6 inches in diameter, constructed of PVC, and screened across the entire saturated thickness. A second pump-and-treat system consisting of four wells each operating at 10 gpm will be installed along the northwestern property boundary. The depth to bedrock in this area is approximately 7 to 10 feet. These wells will be 6 inches in diameter, constructed of PVC, and screened across the entire saturated thickness.

The groundwater water extracted from the western boundary wells will be treated via a combined tray air stripper and carbon adsorption unit to concentrations below MCLs. The carbon will be recycled (replaced) twice a year. Following treatment, water will be discharged to the golf course pond, which discharges to Farmers Branch Creek. Monthly TPDES monitoring will be performed. The previous pump-and-treat system discharged to the pond with no adverse effects. The system is assumed to operate for 30 years. The water pumped from the wells along the northwestern boundary will be treated to MCLs by a tray air stripper and carbon adsorption system. As with the pump-and-treat system along the western boundary, the carbon will be recycled (replaced) twice a year. Following treatment, water will be discharged to the golf course pond which discharges to Farmers Branch Creek. Monthly TPDES monitoring may be performed as well as quarterly bio-monitoring on the golf pond. CERCLA sites may be able to waive the monthly monitorings. The system is assumed to operate for 30 years.

As described for Alternative 1, the existing PRB and phytoremediation area will continue to provide in-situ treatment of the groundwater flowing onto the BRAC property (Section 5.1.1) and the EPL system is assumed to contain the source areas contributing to the Southern Lobe TCE plume. In addition, the LTM program and PRB monitoring described in Section 5.1.1 will be continued at the BRAC property.

### 5.2.3 Alternative 4 – Detailed Description

Alternative 4 consists of PRBs along the western and northwestern boundaries (in addition to the existing PRB) to treat the groundwater coming onto the site to MCLs. MNA processes would be relied on to remediate existing groundwater contamination underlying the BRAC property. As described for Alternative 2, LUCs will be used to ensure protection of human health until MCLs are achieved. The Alternative 4 remedial configuration is shown in Figure 5.4, and each component is discussed in greater detail below.

*Permeable Reactive Barrier*

<u>Western Property Boundary</u>

The PRB along the western boundary will be installed upgradient and parallel to the baseline PRB, and will be approximately 1600 feet. The performance monitoring data for the existing PRB were combined with the results of the treatability study completed prior to construction of the existing PRB to estimate the PRB thickness necessary to achieve MCLs along the western boundary. Based on the effluent vinyl chloride concentrations, it is estimated that an additional 1.6 feet of PRB (an additional 19 hours of residence time) is required to achieve MCLs along the southern part of the existing PRB. Because of the depth to bedrock, the construction technique that would be used to install the reactive media is the biopolymer slurry technique. With this construction method, the minimum reactive media thickness is 2 feet. Therefore, for this alternative it is assumed that a 2-foot thick PRB would be installed parallel to the existing PRB. Because of the existing PRB, a safety factor was not applied to this PRB.

To the north of the existing PRB, TCE and vinyl chloride are flowing onto the site at concentrations of approximately 800 ppb and 40-50 ppb, respectively. Based on the treatability study results, it is estimated that, with a safety factor of 2, the PRB thickness north of the PRB should be 5.6 feet thick. The bottom of the wall will be keyed into the bedrock, which is approximately 28 to 40 feet below surface throughout this area. Due to the depth to bedrock, this PRB would be installed using the biopolymer slurry wall method.

Eight wells would be installed along the western boundary for maintenance monitoring of the PRB. These wells will be monitored quarterly for the first two years. Three of these wells will be monitored semi-annually for another eight years and yearly for the following 20 years. Monitoring frequency may be decreased if the PRB is meeting expected performance goals. The samples will be analyzed for the same compounds as the baseline PRB. It is assumed that the iron in the wall will be rejuvenated (in-place reduction of iron) every 10 years.

To treat incoming groundwater along the northwestern boundary of the BRAC property, a 900-foot PRB will be placed along this border in a north-south orientation before shifting to the northeast toward Taxiway Charlie (Figure 5.4). The results of the treatability study for the existing PRB were used to estimate the residence time required to attain MCLs if the influent TCE concentration were 370 $\mu$g/L and the influent *cis*-1,2-DCE concentration were 38 $\mu$g/L. With a safety factor of 2, the design thickness for a PRB along the northwestern boundary will be 2.2 feet. The bottom of the wall will be keyed into the bedrock which is approximately 7-10 feet over this area. It is assumed that the PRB along the northwestern BRAC property boundary will be installed with a continuous one-pass trencher.

Twelve wells will be installed along the northwestern boundary for maintenance monitoring of the PRB. Fourteen of these wells will be monitored quarterly for the first 2 years, followed by semi-annually until year 10, and annually thereafter, up to 30 years. Monitoring frequency, however, may be decreased if the PRB is meeting expected performance goals. The samples will be analyzed for the same compounds as the baseline PRB. It is assumed that the iron in the wall will be rejuvenated (in-place reduction of iron) every 10 years.

*Monitored Natural Attenuation*

Alternative 4 relies on MNA to remediate the plume within the BRAC property to MCLs within a reasonable timeframe. To monitor the progress of MNA, the eight wells sampled for the LTM program will also be sampled for natural attenuation parameters.

As described for Alternative 1, the existing PRB and phytoremediation area will continue to provide in-situ treatment of the groundwater flowing on to the BRAC property (Section 5.1.1) and the EPL system is assumed to contain the source areas contributing to the Southern Lobe TCE plume. In addition, the LTM program and PRB sampling described in Section 5.1.1 will be continued at the BRAC property.

# 6.0 DETAILED ANALYSIS OF ALTERNATIVES

This section presents a detailed analysis of the remedial action alternatives for the BRAC property. The objective of the detailed analysis is to present and interpret relevant information necessary to select the most appropriate remedy. The four alternatives that were developed in Section 5.0 are summarized below as follows:

Alternative 1 – No Additional Action
Alternative 2 – Monitored Natural Attenuation with Land Use Controls
Alternative 3 – Pump-and-Treat and Cometabolic Biosparging
Alternative 4 – Permeable Iron Reactive Barriers and Monitored Natural Attenuation

The detailed analysis, which presents an in-depth evaluation of the 4 remedial alternatives, provides the basis for selecting an alternative and preparing a proposed plan. The costs for several technology options, such as the cometabolic biosparging, were based on the conceptual-level design developed based on existing site data. For these technology process options, pilot-scale tests may be required prior to full-scale field implementation to more accurately estimate costs. These tests would be designed to provide information to support a detailed design and to refine the cost assumptions. Nonetheless the costs are thought to be accurate to within -30 to +50 percent.

Section 6.1 discusses the evaluation criteria, and Sections 6.2 through 6.6 present the individual analyses for each alternative.

## 6.1 EVALUATION CRITERIA

Section 121 of CERCLA, as amended, specifies statutory requirements for remedial actions. These requirements include protection of human health and the environment, compliance with ARARs, a preference for permanent solutions that incorporate treatment as a principal element to the maximum extent practicable. To assess whether alternatives meet the requirements, EPA has identified nine criteria in the NCP (EPA 1988) that must be evaluated for each alternative retained through the screening stage [Sect. 300.430(e)(9)(iii)]:

- overall protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, and volume through treatment;
- short-term effectiveness;
- implementability;
- cost;
- state acceptance; and
- community acceptance.

Of the nine criteria listed above, the first two – overall protection of human health and the environment, and compliance with ARARs – are considered to be threshold criteria. The remedial action alternative selected must meet these two requirements. The next five criteria discussed in this report (long-term effectiveness and permanence; reduction of toxicity, mobility and volume reduction through treatment; short-term effectiveness; implementability; and cost) are balancing criteria. The final two criteria, state acceptance and community acceptance, are modifying criteria. Section 6.2 summarizes the evaluation of alternatives against the threshold criteria and balancing criteria. The modifying criteria of state and community acceptance will be considered following public comment on the proposed plan. The threshold and balancing criteria are briefly described in the following paragraphs.

### 6.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion assesses whether the alternative achieves and maintains adequate protection of human health and the environment in accordance with the RAOs established in Section 3.0. Because the scope of this criterion is broad, it also reflects the discussions of the subsequent criteria, including long-term effectiveness, permanence, and short-term effectiveness. Evaluation of this criterion describes how risks associated with each exposure pathway are eliminated, reduced, or mitigated through treatment, engineering, or ICs. This criterion also evaluates impacts to the site environment resulting from the action itself. The results of the HHRA (Section 2.0) were used to delineate those areas and media requiring remediation as summarized below:

- Groundwater – The results of the Baseline HHRA indicated that contaminants in the groundwater would pose an unacceptable carcinogenic and non-cancer health threat to future residents who use the Terrace Alluvium Aquifer as a potable water source. In addition, the Baseline HHRA indicated that, under very conservative exposure assumptions, the contaminants in the groundwater also posed unacceptable health threats to the construction worker. Also, the site must meet the MCL ARAR. In order to be considered protective of human health, the remedial action alternative must either prevent a receptor's exposure to the groundwater or reduce COC concentrations to MCLs.

  Although the groundwater concentrations protective of exposure by residents and/or construction workers may be applied to the entire BRAC property, only a portion of the BRAC property is actually affected by the groundwater contaminants. The groundwater plume is located in the northwestern section of the BRAC property. The plume does not extend far south of White Settlement Road. In addition, the plume has not affected the groundwater beneath the existing residential area.

  Ecological receptors are not exposed directly to groundwater. In addition, the results of the Baseline ERA indicate that ecological communities in surface water are not adversely affected by groundwater contaminants discharging into surface water.

- Surface Water – All cancer risks and noncancer hazards associated with exposure to surface water are below EPA target values. Current conditions are considered protective of human health. In addition, the Baseline ERA indicates that current surface water quality should not have an adverse effect on ecological communities. Therefore, current surface water conditions are considered protective of the environment.

- Sediment – All cancer risks and noncancer hazards associated with exposure to sediment are below EPA target values. Current conditions are considered protective of human health. As with the surface water, the Baseline ERA concludes that contaminant concentrations in the sediment should not adversely affect ecological communities. Therefore, current sediment conditions are considered protective of the environment.

### 6.1.2 Compliance with ARARs

ARARs are not applicable to the no action alternative.

Section 3.0 identifies the potential ARARs for the BRAC property. The approach adopted by this FFS is to focus the evaluation of alternatives on compliance with ARARs that are critical to meeting this threshold criterion.

### 6.1.3 Long-Term Effectiveness and Permanence

This criterion evaluates the extent to which an alternative achieves an overall reduction in risk to human health and the environment after the RAOs have been met. It also considers the degree to which the alternative provides sufficient long-term controls and reliability to prevent exposures that exceed protective levels to human and environmental receptors. Alternatives that offer the highest degrees of long-term effectiveness and permanence are those that leave little or no waste at the site, thus eliminating long-term maintenance and monitoring and minimizing reliance on ICs.

The principal factors addressed by this criterion include magnitude of residual risk and the adequacy and reliability of controls to address such risk. These two factors are described further below. This criterion of effectiveness and permanence also evaluates the potential long-term environmental effects of the alternative on biotic resources, wetlands, and floodplains.

The evaluation of adequacy and reliability of controls assesses the effectiveness of any treatment, containment, or institutional measures that are part of the alternative. Factors considered include performance characteristics, maintenance requirements, and expected durability. Information and data from past performance and similar technology applications are incorporated appropriately into the evaluation. ICs are considered where they potentially improve the effectiveness of engineered measures.

### 6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion reflects the statutory preference for remedial alternatives that substantially reduce toxicity, mobility, or volume of hazardous substances through treatment. The evaluation of alternatives against this criterion considers the extent to which alternative technologies can effectively and permanently fix, render harmless, immobilize, or reduce the volume of waste materials and contaminated media.

### 6.1.5 Short-Term Effectiveness

This criterion addresses the effects of the construction and implementation phases of the alternative until RAOs are achieved. The evaluation of alternatives against this criterion considers the effects on human health and the environment posed by operations conducted during the remedial action phases. Both the potential impacts and associated mitigation measures are examined for maintaining protectiveness for the community, remediation workers, and environmental receptors throughout the duration of activities.

Potential short-term risks to the public include inhalation of constituents that may be released during waste removal and treatment operations, and contaminant exposure and physical injury during waste transport off site.

Potential short-term risks to workers include direct contact and exposure during construction, waste handling, and transportation; physical injury or death during construction and transportation activities; and non-remediation worker exposures to airborne contaminants during waste and soil removal operations. This analysis also includes a description of mitigation measures, such as engineering and ICs, that are expected to minimize potential risks to the public and workers.

Short-term environmental effects and mitigation measures are assessed in a qualitative manner. The assessment evaluates the impacts on environmental media and potentially sensitive resources (e.g., wetlands and floodplains); short-term effects on socioeconomics and cultural resources; and cumulative impacts of remedial construction and other activities occurring in the area.

### 6.1.6 Implementability

This criterion examines the technical and administrative factors affecting implementation of an alternative and considers the availability of services and materials required during implementation. Technical factors to be assessed include the ease and reliability of initiating construction and operations, the prospects for implementing any required future actions, and the adequacy of monitoring systems to detect failures. Administrative factors include permitting and coordination requirements among the lead agency and regulatory agencies. Service and material considerations include treatment, storage, and disposal capacities; equipment and operator availability; and applicability or development requirements of prospective technology.

The assessment of technical feasibility examines the performance history of the technologies in direct applications or considers the expected performance for similar applications. Any uncertainties associated with construction, operation, and performance monitoring are also addressed. In developing the alternatives presented in this FFS, an effort was made to select standard construction methods and to avoid techniques that would present problems during implementation.

The evaluation of administrative feasibility includes a discussion of those actions required to coordinate with regulatory agencies to establish the framework for complying with any key substantive technical requirements that must be met by an alternative. If a permit is required, then the analysis should consider the ease of obtaining the permit and the sampling requirements to demonstrate compliance with the permit. Other factors to consider are the likelihood of violating a permit through system malfunction and the associated repercussions.

Implementability also takes into account the availability of the materials and services required to install and operate a remedial action alternative's technology process option(s). For example, the analysis considers whether the remedial action uses materials that are locally available or specialized materials produced by a limited number of suppliers. Generally, an off-the-shelf system should have ready availability of replacement parts and operating supplies. The evaluation also examines the technical skill required to construct, operate and maintain the system. For example, it might be difficult to locate a contractor capable of installing an emerging technology.

The selection of standard construction methods provides administrative benefits and enhances the availability of services and materials. Well understood approaches are generally easier to contract and manage than special activities or emerging technologies. Cost estimates and schedules should be more accurate for standard construction methods, and contracts and permits more straightforward.

### 6.1.7 Cost

The lifecycle cost of a remedial action alternative is an important factor to consider. The capital, O&M costs for each remedial action alternative were estimated in accordance with EPA guidance (EPA, 2000). Because only a preliminary design was performed for the remedial technologies, the costs have a significant level of uncertainty. After selection of a remedial action alternative, the actual costs will be better defined through the design process. At the FFS stage, the purpose of the cost estimation is to allow comparison of budget requirements among the various alternatives. Due to funding limits, this comparison is extremely important. An aggressive remedial action approach does not provide effective protection of human health and the environment if the funding agency can afford to build only half the treatment system.

The cost tables for each alternative are provided in Appendix D. The methodology and major assumptions are presented in the discussion below. Section 7.0 provides a comparison of the capital costs and net present worth for the O&M of each alternative.

#### 6.1.7.1 Cost Estimate Accuracy

At the FFS stage, the design for each remedial action alternative is conceptual, and therefore, the cost estimate for each alternative is considered to be a rough approximation of the actual costs. The cost estimator must make assumptions regarding the detailed design in order to prepare the cost estimate. These assumptions include parameters, such as the length of piping to the discharge point and the amount of granular activated carbon required, that will not be defined until the preliminary or detailed design stage. Cost sources which are typically used to estimate remedial alternatives include cost curves, generic unit costs, vendor information, standard cost estimating guides, historical cost data, and estimates from similar projects. For this FFS, most of the costs were obtained from 1999 R.S. means with the appropriate escalation factors for 2002. For the PRB technology process option, the costs were estimated from recent other costs obtained for the construction of a PRB that runs along the western portion of the BRAC property. Other costs, such as the air stripper cost, were obtained from vendors.

At this stage, the expected accuracy of the cost estimates ranges from -30 to +50 percent.

#### 6.1.7.2 Cost Estimate Components

Cost estimate components for remedial action alternatives include capital and annual O&M costs. Capital costs include both direct and indirect costs. Direct capital costs include well installation, purchase and installation of major equipment contingencies to address changes in scope or bid items during construction, professional/technical services for remedial design, project management and construction management. Indirect capital costs include the contractor overhead and contractor profit.

Annual O&M costs include the post-construction costs necessary to ensure the continued effectiveness of a remedial action, such as operating/monitoring costs, maintenance materials, purchased services, residue disposal, chemical analysis of samples, and utilities. As with capital costs, a contingency factor is applied to address unforeseen costs or conditions. Periodic costs include the O&M costs that occur only once every few years, such as a five-year review of remedial action effectiveness and equipment replacement. To address unforeseen conditions, a contingency factor is applied to all periodic costs.

#### 6.1.7.3 Present Value Analysis

Because each remedial alternative includes costs that are expended at both the beginning of the project (e.g., capital costs) and in subsequent years (e.g., O&M and periodic costs), a Present Value analysis was performed. This analysis estimates the present value of costs incurred in future years. This approach permits comparison of different remedial alternatives on the basis of a single cost figure for each alternative. This single cost figure, referred to as the Present Value, is the amount needed to be set aside at the initial point in time (base year) to assure that funds will be available in the future as they are needed, assuming certain economic conditions.

Several assumptions must be made to determine the Present Value for the remedial alternatives. These assumptions include the period of analysis and the discount rate. The EPA guidance (EPA, 2000) states: "In general, the period of analysis should be equivalent to the project duration, resulting in a complete life cycle cost estimate for implementing the remedial alternative." The guidance also permits the use of a period of analysis that is shorter than the project duration. Under this scenario, specific justification should be provided for the period of analysis selected. For the analysis in this FFS, a period of 30 years was assumed. Because the sources of contaminated groundwater are upgradient of the BRAC property, all remedial measures must be maintained until the plume that is being cut off or contained by the EPL system has been remediated. It is assumed than the plume emanating from AFP4 and being cutoff by the EPL will require between 20 and 50 years to reach MCLs as described in Appendix E. Costs beyond 30 years have not been calculated.

The discount rate, which is similar to an interest rate, is used to calculate the time value of money and discounting reflects the productivity of capital. EPA policy on the use of discount rates for remedial investigation/feasibility study (RI/FS) cost analysis for federal facilities requires the use of real discount rates from Appendix C of the Office and Management Budget Circular A-94. The policy also requires using the same discount rate for each remedial alternative, regardless of the period of analysis. The latest update at the time of this costing effort to Appendix C, dated February 6, 2002, identifies the real discount rate for projects greater than 30 years to be 3.9 percent. Therefore, the Present Value analysis for each remedial alternative utilizes a discount rate of 3.9 percent.

The baseline costs for Alternative 1 are not included in the Present Value cost analysis.

#### 6.1.7.4 Cost Development Assumptions

To aid in the development of the remedial alternative cost estimates, several general assumptions were used to provide consistency between the alternatives. These assumptions are listed below. Unless otherwise stated, the general assumptions are based upon EPA guidance (EPA, 2000). Alternative specific assumptions are discussed Section 6.2.

**Excluded Costs**

- Award/Incentive Fees for Consultants and Subcontractors
- Procurement Costs
- Insurance, licensing, taxes, or permitting costs
- Performance and Payment Bond costs

**Capital Costs**

- Prime Contractor Overhead based on 15 percent of subtotal of Direct Capital Costs
- Prime Contractor Profit based on 10 percent of subtotal of Direct Capital Costs plus Prime Contractor Overhead

- Project management, remedial design and construction management costs determined using EPA guidance (EPA, 2000)
- Capital contingency, including Scope and Bid contingencies, costs are based on 30 percent of Total Direct Capital Costs

**Operation and Maintenance Costs**

- Labor costs include costs for system monitoring, general maintenance, and sampling
- Analytical costs are based upon historical costs
- Project management costs determined using EPA guidance (EPA, 2000)
- O&M contingency costs based on 20 percent of Total Direct O&M Costs

**Periodic Costs**

- Alternatives will be re-evaluated for effectiveness every five years beginning in year six
- Project Management costs based on 5 percent of Total Periodic Costs
- Contingency based on 20 percent of Total Periodic Costs

**Present Value Analysis**

- Discount Rate based on 3.9 percent, per Appendix C of Circular A-94
- Project duration based on 30 years
- All costs are round off to the nearest $1,000

## 6.2 ALTERNATIVE 1 – NO ADDITIONAL ACTION

The no additional action alternative consists of maintaining the PRB and phytoremediation sites described in Section 2.11 and continued monitoring of groundwater. Under this alternative the BRAC property would remain under federal control and not be transferred to the public.

### 6.2.1 Overall Protection of Human Health and the Environment – Alternative 1

The no-further action alternative does not significantly reduce the risk to human health or the environment. Current on-site residents are not exposed to the contaminated groundwater. Under retained Federal ownership of the land, residential use of the property will not change. Therefore, Alternative 1 is protective of the on-site resident. Under Alternative 1, construction activities are limited to repair of existing subsurface utilities. This limited exposure scenario was not evaluated in the baseline HHRA. To evaluate whether Alternative 1 was protective of the utility worker, risk calculations were performed (Appendix B.1). Two scenarios were considered. In the first scenario, the utility worker repairs utilities in areas where the groundwater is too deep to intersect a utility trench. On the BRAC property, the deep groundwater is located in the vicinity of the PRB. Based on pre-PRB data, historically high groundwater concentrations in the deep groundwater do not pose a threat to utility workers. Near Farmers Branch Creek and in the northwestern part of the property, the groundwater becomes shallow enough to potentially intersect a utility trench. Concentrations protective of the utility worker performing repairs in a trench that intersects the water table are calculated in Appendix B.1. The results indicate that current groundwater conditions are not protective of the utility worker if the worker performs repairs as frequently as assumed for the risk calculations. To ensure protection of utility repair workers under Alternative 1, it will be necessary to establish administrative controls to limit exposure.

Migration of contaminants downgradient and off-site appears unlikely because the plume has retracted over 600 feet in the past two years (Appendix A.4). Therefore, Alternative 1 is protective of off-site residents.

No critical habitats for threatened or endangered species have been identified on the BRAC property (Section 2.8). The results of the Baseline ERA indicate that current conditions do not pose an unacceptable threat to ecological receptors in natural (Farmers Branch Creek) and manmade (golf course pond) surface water bodies on the BRAC property. Therefore, maintenance of current conditions would be protective of the environment.

### 6.2.2 Compliance with ARARs

ARARs are not applicable to the no action alternative.

### 6.2.3 Long-Term Effectiveness and Permanence

The existing PRB will decrease VOC concentrations substantially as discussed in Section 2.11.3. Although the PRB does not currently span the entire width of the TCE plume, the PRB is effectively degrading VOC contaminants in the groundwater that flows through it. This degradation along with the effects of natural attenuation and the ongoing remedial actions at AFP 4 will continue to reduce contaminant levels in groundwater underlying the BRAC property. The phytoremediation area should continue to reduce the migration of contaminants along the northwestern property boundary during the growing season. One objective under RAO 1 is to prevent off-site migration of contaminants exceeding MCLs. The existing PRB and monitoring program should ensure that this goal is met. Long-term monitoring will identify any changes in contaminant concentrations and plume extent. Under RAO 1, it will be necessary to perform long-term monitoring, to maintain the PRB, and to retain federal government control of the property until the groundwater is remediated through natural attenuation.

With Alternative 1, careful monitoring and maintenance of the PRB would be required. Changes in the flow velocities through the PRB must be monitored to ensure that mineral precipitation is not clogging the pore spaces and, therefore reducing the effectiveness of the PRB. In addition, the federal government must retain control of the property in order to ensure that residences are not built above the plume and to limit excavation activities. These ICs will be effective if the Air Force maintains periodic inspections and continued oversight of activities. Because this alternative would leave hazardous materials on-site, a review would be conducted at least every five years to ensure that the remedy continues to provide adequate protection of human health and the environment in accordance with CERCLA121(c).

### 6.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Because of the continued maintenance of the existing PRB and the presence of the phytoremediation area, current reductions in the toxicity, mobility, or volume of contamination would continue under implementation of the no additional action alternative. Both the baseline PRB and the phytoremediation area decrease the mass of contaminants. Long-term monitoring of the groundwater would allow initiation of contingent actions if significant changes in contaminant concentrations or plume boundaries threatened off-site groundwater quality.

### 6.2.5 Short-Term Effectiveness

In the short term, retained federal government control would be effective in protecting the hypothetical utility worker. Because the remedial actions and land use actions are currently in place, implementation of Alternative 1 would not create short-term environmental impacts.

### 6.2.6 Implementability

Implementation of Alternative 1 involves maintenance of the existing PRB, performance monitoring for the PRB, continued oversight of the experimental phytoremediation project, continued long-term monitoring of groundwater and surface water, and continued site restrictions. With the exception of maintenance on the existing PRB, all other activities are currently performed on the BRAC property without administrative or technical difficulties. The maintenance of the phytoremediation plot, PRB performance monitoring, and LTM rely on conventional, proven techniques and equipment. Because the federal government will retain control of the BRAC property under Alternative 1, current site restrictions can easily be continued. Maintenance of the existing PRB will likely be more difficult to implement than the other ongoing activities. Several techniques are available to maintain or rejuvenate a PRB. These include:

- Using ultrasound to break-up the precipitate;
- Using pressure pulse technology to break-up the precipitate;
- Jetting the upgradient face of the PRB with water under high pressure; and
- Using solid-stem augers to agitate the upgradient face of the PRB.

These technologies are not well tested, due to the relative immaturity of PRB technology; consequently, it is difficult to foresee whether these methods can be easily implemented. All of these maintenance methods require invasive activities at the site, which may conflict with or disrupt future land use activities.

### 6.2.7 Cost

The costs of maintaining the existing PRB include semi-annual monitoring simultaneous with LTM monitorings of 6 wells for 8 years, followed by annual sampling for another 22 years for the constituents listed in Table 5.2. Monitoring frequency, however, may be decreased if the PRB is meeting expected performance goals. Also included in the costs is a rejuvenation of the reactive media. It is assumed that the PRB will require chemical treatment (such as in-place reduction of the iron or acid washing to remove build-up of iron carbonate) every ten years over the period of performance. The costs for the monitoring are based upon current actual unit costs for the sampling, analysis and reporting for the site.

An experimental phytoremediation project is also ongoing along the northwestern boundary of the BRAC property. Because the trees are relatively mature, additional costs are expected to be minimal; consequently, the costs associated with phytoremediation are not included in the cost estimate.

The greatest uncertainty in costs is associated with the level of maintenance that the PRB will require over the 30-year period of performance. In the event the PRB does not perform satisfactorily, the media rejuvenation may have to be performed more frequently than once every ten years. As noted above, the costs for chemically treating the wall three times over the period of performance have been included in the analysis. Current data on PRBs in similar environments indicate that this type of effort is more likely to be required after 15 years or longer. The ten-year timeframe was chosen to be conservative.

The Present Value cost of Alternative 1 is $2,988,000.

## 6.3 ALTERNATIVE 2 - MONITORED NATURAL ATTENUATION WITH LAND USE CONTROLS

Alternative 2 relies on ICs to limit exposure to receptors until remediation levels (MCLs) are achieved through MNA. Based on groundwater modeling, it is estimated that MNA will result in attainment of MCLs in 20 to 50 years. Alternative 2 is shown in Figure 5.2.

### 6.3.1 Overall Protection of Human Health and the Environment

Alternative 2 is designed to meet all the elements of RAO 2 (Section 3.0), which assumes that the BRAC property will be transferred for eventual unrestricted use. If the conditions of RAO 2 are met, then the remedial actions would protect human health and the environment. This alternative relies on MNA processes to reduce on-site groundwater concentrations over an extended period of time. With proper implementation and enforcement of the ICs, this alternative will be protective of human health. Because current conditions on the BRAC property do not pose an unacceptable threat to ecological receptors, this alternative is protective of the environment.

### 6.3.2 Compliance with ARARs

For Alternative 2, implementation of land use controls or MNA would not trigger location-specific or action-specific ARARs. ARARs associated with the SDWA primary and secondary drinking water standards (MCLs or SMCLs) (40 CFR 141), or the Texas Drinking Water Standards (30 TAC §290), if such standards are more stringent than those under the SDWA, will need to be complied with for the groundwater that flows off-site. Current data indicate that the leading edge of the plume is not posing a threat to groundwater quality along the downgradient property boundary.

### 6.3.3 Long-Term Effectiveness and Permanence

Land use controls will not decrease any contaminants at the site; these institutional controls will, however, limit or prevent exposure to contaminants by construction workers and by any potential future residents. By eliminating or restricting contact with contaminants, health risk is reduced. Specifically, Alternative 2 will prevent the use of the groundwater as a potable water source, eliminate the potential for construction of residences above the groundwater plume, and control construction worker exposure until MCLs are met. The long-term effectiveness of these institutional controls depends on the willingness and ability of the local government to enforce the controls.

The existing remedies (PRB, phytoremediation and natural attenuation) described in Alternative 1 as well as the continued operation of the EPL system will continue to reduce risk at the site. Institutional controls aimed at limiting exposures to the construction worker will be required until the MCLs are achieved.

The long-term monitoring will identify changes in contaminant concentrations and the extent of the contaminant plume. Further remedial action may become necessary if these changes appear to present additional risks or hazards not apparent at this time.

### 6.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 2 will achieve the same degree of reduction in the toxicity, mobility, and volume of contamination as Alternative 1.

### 6.3.5 Short-Term Effectiveness

Under Alternative 2, no construction will occur, and therefore, there will be no short-term increase in risk. Land use controls will require a minimal amount of time to implement, and will be effective immediately.

### 6.3.6 Implementability

Land use controls and MNA are easily implemented at the site. A Land Use Implementation Plan must be developed, and the appropriate proprietary controls (e.g., restrictive covenants) must be initiated. Additional natural attenuation parameters can be easily added to the existing LTM program.

Because Alternative 2 consists of only institutional controls and MNA, it should be the easiest alternative to implement under RAO 2.

### 6.3.7 Cost

The costs for land use controls and MNA have been incorporated into the total costs for all three alternatives under RAO 2. Costs for warning signs, implementation plans, deed restrictions, and annual site visits have been projected for the land use controls. The costs for MNA include only the additional analyses; the costs do not include the analyses currently performed for the LTM. It is assumed that all the sampling can be conducted at the same time as the LTM sampling, and no additional labor hours are required.

The present value cost of Alternative 2 is $1,199,000. This is in addition to the costs already incurred under Alternative 1.

## 6.4 ALTERNATIVE 3 – PUMP & TREAT AND COMETABOLIC BIOSPARGING

Alternative 3 is the most aggressive and costly alternative. This alternative is intended to reduce contaminant concentrations on site to levels that would allow unrestricted use of the land within 5 years. It consists of pump-and-treat along the western and northwestern boundaries to prevent the influx of upgradient contaminants onto the BRAC property, and cometabolic biodegradation to remediate contamination already present on the property. The Alternative 3 remediation scheme is shown in Figure 5.3.

### 6.4.1 Overall Protection of Human Health and the Environment

Alternative 3 is designed to meet MCLs in a relatively short time frame. This alternative includes reducing contaminant concentrations in groundwater to levels that are protective of residents who may use groundwater as their primary source of drinking water. By preventing off-site contaminants from migrating onto the property and by implementing aggressive on-site groundwater remediation, on-site groundwater is estimated to reach MCLs within 5 years. During the actual remediation, ICs will be used to prevent or restrict exposure to groundwater contaminants. The air stripping will result in the release of VOCs to the air, but no increased risk associated with inhalation is anticipated due to dispersion in the ambient air. Therefore, this alternative will be protective of human health.

Because Alternative 3 would result in the discharge of treated groundwater to Farmers Branch Creek, this alternative will affect the local hydrology. The expected combined flow through both pump-and-treat systems of 120 gallons per minute should not adversely affect Farmers Branch Creek, and may even provide a beneficial effect during periods of low flow. The contaminants in the groundwater would be treated to below the discharge requirements specified by TCEQ. In addition, the effluent will be monitored monthly. This treatment and monitoring will ensure that the effluent does not adversely affect the quality of water in Farmers Branch Creek. In addition, the Baseline ERA indicated that the current conditions at the BRAC property will not adversely affect ecological communities. Therefore, Alternative 3 would be protective of the environment.

### 6.4.2 Compliance with ARARs

Installation of a pump-and-treat system triggers action-specific ARARs. The discharge of treated groundwater would be in compliance with the TPDES requirements for discharge to surface water. These requirements are established in the Texas Water Code, Title 2, Chapter 26, Subchapters D and G, as well as the Water Quality Certification requirements in 30 TAC §§307 and 279. Air emissions from the system would be in compliance with NESHAPs (40 CFR 61), and the Texas Administrative Code requirements contained in Specific Air Emission Requirements for Hazardous or Solid Waste Management Facilities (30 TAC Subchapter L).

Compliance with chemical-specific ARARs should be as follows: where groundwater from the site discharges to surface water, the ARARs to be complied with include those established from the CWA requirements regarding toxic pollutant effluent standards (40 CFR 129) and the protection of surface water quality (40 CFR 130, 131). ARARs associated with the SDWA primary and secondary drinking water standards (MCLs or SMCLs) (40 CFR 141), or the Texas Drinking Water Standards (30 TAC §290), if such standards are more stringent than those under the SDWA, will need to be complied with for any groundwater from the site that is a source of drinking water.

Depending upon the extent of contamination associated with the drill cuttings from the installation of the biosparging system and pump and treat systems, the management and disposal of the cuttings will be in compliance with RCRA requirements contained in 40 CFR Parts 241, 260, 264, and 268, as well as the requirements contained in the Texas Solid Waste Disposal Act and the Texas Industrial Solid Waste and Municipal Hazardous Waste Regulations (30 TAC §335). Because spoils from the existing PRB were not classified as hazardous waste, it is expected that drill cuttings from Alternative 3 would also not be classified as hazardous waste.

### 6.4.3 Long-Term Effectiveness and Permanence

As described for Alternative 2, it is estimated that the residual upgradient contamination flowing onto the BRAC property will not attain MCLs for between 20 and 50 years. After remediation of the on-site groundwater with the co-metabolic biosparging, it will be necessary to maintain the pump-and-treat systems to prevent the influx of groundwater with concentrations above the MCL. If hydraulic control of the influent contamination is not maintained, then it may be necessary to continue to co-metabolic biosparging for longer than 5 years.

Methane injection to enhance cometabolic microbial activity is a new technology that was tested in a five-year demonstration pilot at the Savannah River Site. Based on the results of this demonstration study, it is estimated that the groundwater on the BRAC property should be remediated to concentrations at or less than MCLs in five years, provided that the influx of contaminants is eliminated. There are a number of uncertainties with respect to the cometabolic component of this alternative including:

- whether the methane can be delivered to all of the contaminated media;

- whether the nutrient concentrations are sufficient to allow degradation; and
- whether the microbial populations are ubiquitous in the subsurface;

If this alternative is selected, then pilot scale testing will be performed to obtain site-specific data on the methane and nutrient requirements and the microbial populations present in the aquifer. These data should address some of the uncertainties identified above.

As with the previous Alternatives the remedial actions in Alternative 3 do not provide a permanent solution as long as the upgradient sources exist. The existing PRB will require periodic maintenance and operation of the pump-and-treat systems will need to continue until the residual upgradient AFP 4 plume cutoff by the EPL system is remediated.

### 6.4.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Treatment of the groundwater extracted by the containment system will transfer most of the contaminants from the groundwater to the ambient air and some of the contaminants to the granular activated carbon. The latter process immobilizes the contaminants (at least temporarily depending on whether the carbon is disposed or re-generated). By transferring the VOCs to the ambient air, treatment by the air stripper would enhance the mobility of the contaminants. The premise behind this treatment approach is that the VOC emissions are so slight relative to the ambient air volume that the VOCs are diluted to negligible concentrations. This component of Alternative 3 does not reduce contaminant toxicity, except through dilution, or contaminant volume. In addition, the VOCs will be more mobile in the ambient air than in the groundwater. The cometabolic biosparge system will reduce contaminant toxicity, mobility and volume via complete biotic degradation.

### 6.4.5 Short-Term Effectiveness

Hydraulic containment of contamination will be achieved shortly after groundwater extraction begins. The bioremediation initiated by methane injection may require up to six months to attain microbial populations at sufficient levels to noticeably degrade the contaminants. During this time, with the influx of groundwater contaminants substantially reduced, natural attenuation processes may begin to reduce on-site contaminant concentrations.

During construction for Alternative 3, dust may be generated. Monitoring of dust levels and use of dust control measures, such as wetting the ground surface, would ensure that the dust does not pose a threat to the general public. Except for the capped landfill, on which no construction may occur, contamination in the surface soil or subsurface soil is not present on the BRAC property. Therefore potential exposure to soil contamination by construction workers is not an issue. Only minimal excavation would be required to install the treatment plants, including the compressors for the biosparge system, and piping. No direct contact with groundwater is anticipated during installation of these components of the remedial action. During well installation, all work would be performed in accordance with OSHA requirements for hazardous waste sites; these requirements are protective of worker health and safety. Because horizontal drilling would be used, installation of the methane/air injection lines would not require excavation. Therefore, risks from inhaling groundwater contaminants that have volatilized into a trench or excavation should be minimal. Regardless, as required by OSHA, the worker breathing zones would be monitored and protective measures taken if breathing zone concentrations exceeded applicable threshold values.

As with any construction site, physical hazards would exist. The potential impacts of these hazards would be controlled through standard construction safety procedures. The construction area would also be cordoned off from access by the general public. It is expected that installation of the pump-and-treat systems and the cometabolic biosparge system would have minimal impacts on worker and public health and safety.

Construction practices, such as the use of silt fencing, would ensure that the environment is protected during installation of Alternative 3. Although small amounts of clearing and excavation would be necessary, the affected area would be on the edge of and in the middle of a golf course. These activities would not affect habitat native to the Fort Worth area, but would affect areas that resemble lawns. Installation of the treatment systems for Alternative 3 should not adversely affect the environment.

### 6.4.6 Implementability

The materials, equipment and skilled labor needed to install, operate and maintain both pump and treat systems should be readily available in the Fort Worth area. This alternative, however, will require considerable coordination with the Westworth Redevelopment Authority.

Design and contractor selection are estimated to require approximately eight months. Construction of the pump and treat systems will take another three months. Standard construction techniques would be used. After construction, these systems will require a high level of oversight to ensure that the groundwater treatment system functions correctly and is in compliance with an NPDES permit. Although it will be necessary to obtain a discharge permit for the treated groundwater, it is assumed that the emissions from the air strippers will not require a permit. This assumption is based on the former operation of the pump and treat system for Landfills 4 and 5, adjacent to the existing PRB.

As discussed in Section 4.0, an NPDES permit may be required in order for the treated groundwater to be discharged into Farmers Branch, although waivers can be obtained for CERCLA sites. The application process for a permit requires the submittal of a technical report and an administrative report. The application fee for a new minor facility is $350 and for a new major facility the fee is $2,050; the combined groundwater effluent from the treatment systems of Alternative 3 should be considered a minor facility. An administrative review of the application is performed to ensure that all the required information has been submitted and, once the completeness has been determined, a technical review begins. The technical review can take up to nine months. A draft permit is prepared and sent to the permittee, who is allowed 30 days to provide comments on the draft. The permit is then filed with the Office of the Chief Clerk and a second notice of intent to discharge to the receiving stream is published. The public then has 30 days and EPA has 45 days to comment on the permit. Based on the public and EPA comments, the permit may then require modification or may then be issued. Based on these timeframes, the permitting process could require more than one year to complete.

Before design and installation of the full-scale cometabolic biosparge system, a pilot-scale study should be performed. With design, installation and performance of the pilot system, review of the data, and then design and installation of the full-scale system, it could take several years before the cometabolic biosparging begins operation. In light of the emerging nature of this technology, the design approach will have more uncertainty than would be associated with an established technology such as pump and treat. Although horizontal injection wells would be utilized to minimize the impact on the golf course, it is likely that portions of the golf course would be off limits to the public during well installation and during high pressure injection. The horizontal well drilling will require a specialty contractor, but there are many companies nationwide capable of horizontal drilling. The other components of the biosparge system, such as the compressors, would be installed with standard construction techniques.

Between the permitting requirements for the pump and treat systems, and the pilot-scale study for the cometabolic biosparge system, Alternative 3 could take a relatively long time to implement.

### 6.4.7 Cost

A pump and treat system along the western property boundary would consist of four wells each operating at 20 gpm. A second pump and treat system north of Farmers Branch Creek along the northwestern property boundary would consist of four wells each operating at 10 gpm. The cost estimate for the pump and treat systems includes installation of wells, air strippers, granular activated carbon units, carbon replacement, system maintenance, system operator, electricity, TPDES permit and performance monitoring, and reporting. Both air strippers would be off-the-shelf tray units. The system is assumed to operate for 30 years. The wells will be installed to 34 feet below surface on average and completed with six-inch PVC well materials. It is assumed that soil cuttings are collected and disposed at a hazardous waste disposal facility. For O&M costs, it is assumed that the carbon is recycled twice a year, and that a system operator works 32 hours a week to maintain both systems.

For the cometabolic biosparging, there would be two separate systems: one for the portion of the plume north of Farmers Branch (in the northwestern past of the BRAC property), and one for the plume in the vicinity of White Settlement Road. The locations of the horizontal wells are shown in Figure 5.3. The predominant costs are the installation of the horizontal wells and O&M costs. The northwestern system consists of eight wells (placed around the phytoremediation site) that total approximately 4900 feet of length, and the southern portion consists of 11 wells totaling approximately 6800 feet. Costs for stainless steel pipe were assumed because plastic would not have sufficient tensile strength to be pulled those distances through the borehole. The volume of air/methane to be injected is based upon equivalent vertical wells at 10 cfm and 50-foot radius of influence. Therefore, the horizontal wells are spaced at 100-foot intervals. The costs for the methane blending system was an engineering estimate based upon the cost of programmable logic controllers, electronically driven proportioning valves, on-line methane detectors and associated piping. This rough estimate for the methane blending system has little effect on the overall current cost of this alternative, because the cost is dominated by horizontal well installation, electricity and methane costs.

Methane was assumed to be injected at 2 percent for 20 percent of the time for the first six months. It is assumed that this injection rate will sufficiently raise the available carbon levels. After the initial 6-month methane injection period, air will be injected at three-week intervals followed by one-week intervals of methane injection. This injection cycle will be maintained for five years. The methane volume percentages are comparable to those used at the Savannah River Site demonstration project. Results from that project indicated that methane persisted in the groundwater for a substantial period of time after the methane was injected.

There is a relatively high degree of uncertainty associated with this cost estimate. In particular, the costs could increase substantially based on subsurface conditions encountered during horizontal drilling and the length of time required to achieve remediation of on-site groundwater. As mentioned previously, if the containment system for Alternative 3 does not effectively prevent on-site migration of contaminated groundwater, it might be necessary to operate the biosparge system sporadically for longer than 5 years. In this situation, O&M costs could substantially increase.

The Present Value cost of Alternative 3 is $19,351,000. This is in addition to the costs already incurred under Alternative 1.

## 6.5 ALTERNATIVE 4 – PERMEABLE IRON REACTIVE BARRIERS AND MONITORED NATURAL ATTENUATION

This alternative consists of a PRB along the western boundary, in addition to the existing PRB, and a third PRB along the northwestern boundary to treat the groundwater coming onto the site to MCLs. MNA would be used to remediate the plume currently on the BRAC property. Alternative 4 is shown in Figure 5.4.

### 6.5.1 Overall Protection of Human Health and the Environment

Alternative 4 is designed to meet MCLs over a longer timeframe than Alternative 3 but a shorter timeframe than Alternative 2. MCLs will be met by treating the upgradient groundwater along the property boundary with the PRBs, and by relying on natural attenuation processes to reduce the groundwater contamination currently on the BRAC property.

By reducing contaminant concentrations on the property to MCLs, Alternative 4 will be protective of human health under unrestricted land use conditions for both on-site and off-site receptors. Alternative 4 will not affect surface waters or critical habitats. Alternative 4 will be protective of the environment.

### 6.5.2 Compliance with ARARs

Depending upon the extent of contamination, if any, associated with soil that is excavated during installation of the PRBs, the management and disposal of the soil will be in compliance with RCRA requirements contained in 40 CFR Parts 241, 260, 264, and 268, as well as the requirements contained in the Texas Solid Waste Disposal Act and the Texas Industrial Solid Waste and Municipal Hazardous Waste Regulations (30 TAC §335). The PRB that was installed on the western boundary in May 2002 did not require off-site disposal of soils. TCLP samples from the spoils piles passed all requirements for leaving the soil at the site. Based on this site history, it is expected that spoils associated with Alternative 4 will be able to remain on site.

ARARs associated with the SDWA primary and secondary drinking water standards (MCLs or SMCLs) (40 CFR 141), or the Texas Drinking Water Standards (30 TAC §290), if such standards are more stringent than those under the SDWA, will need to be complied with for any groundwater from the site that is a source of drinking water.

### 6.5.3 Long-Term Effectiveness and Permanence

The primary VOCs present, TCE and *cis*-1,2-DCE, have been successfully treated using PRB technology; and the inorganic chemistry of the plume at the BRAC property appears to pose no significant impediments to technology application (ETI, 2001). In addition, the treatability studies performed for the PRB have shown that treatment with reactive iron is effective in removing VOCs in groundwater through permanent destruction of the contaminants. Although the PRB is an emerging technology with limited long-term performance data, the available information suggests that the PRB may be effective in substantially reducing the influx of contaminants to the BRAC property for decades. Because the PRB does not having moving parts to maintain, the PRB should provide more reliable reduction in contaminant concentrations than the pump and treat approach. Regular monitoring of the groundwater quality upgradient and downgradient of the PRB is important to ensure that the periodic maintenance for the PRB is performed before its effectiveness is significantly reduced. For this FFS, it was assumed that iron rejuvenation or maintenance would be required once every ten years, but this maintenance may actually be required less frequently.

The long-term performance of the PRB may be adversely affected by groundwater mounding upgradient of the PRB followed by by-pass around the PRB. This problem should be prevented by careful design, installation and maintenance of the PRB to ensure that the hydraulic conductivity of the media within the PRB is higher than that of the surrounding subsurface environment.

By nearly eliminating the mass of contaminants flowing onto the site, the PRB will allow natural attenuation to reduce on-site contamination to concentrations meet MCLs. This approach will likely require more time than the aggressive cometabolic system in Alternative 3.

### 6.5.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Through abiotic degradation of the chlorinated hydrocarbons, installation of the PRBs will result in contaminant toxicity and volume reduction. These reductions require adequate residence time for the abiotic reactions to go to completion. If the residence time is not adequate, excess levels of intermediate by-products (*cis*-1,2-DCE, VC) may be in the PRB effluent. Use of reliable treatability study data and modeling should minimize the potential for this situation. The use of the PRB across the entire plume has the greatest potential of all the alternatives to reduce contaminant toxicity and volume.

The use of monitored natural attenuation within the BRAC property will decrease contaminant toxicity primarily by decreasing its concentration through dispersion. Because the natural groundwater conditions do not favor biodegradation, this component of Alternative 4 will have only minimal effect on contaminant mass.

### 6.5.5 Short-Term Effectiveness

This alternative will be effective in the short term by treating the contamination before it can migrate onto the BRAC property. However, the use of natural attenuation would require more time to meet MCLs compared to Alternative 3, which would actively remediate the on-site contamination.

It was assumed that the PRB along the western property boundary would be installed using the biopolymer slurry approach and the PRB along the northwestern boundary would be installed with one-pass trenching. Both of these techniques allow installation of the reactive media without requiring workers to enter an excavation. Aside from the reactive media mixing operations, minimal dust would be generated. Water is added during reactive media mixing; this water serves to minimize dust generation. All work would be performed in accordance with the OSHA regulations governing work at hazardous waste sites. These regulations ensure worker health and safety. The construction area would be cordoned off from access by the general public.

Construction practices, such as the use of silt fencing, would ensure that the environment is protected during installation of the PRB. Although the PRBs will require small amounts of clearing, the affected areas are on the edge of a golf course.

Based on experience with installation of the existing PRB, it is expected that installation of the PRB extension would have minimal impact on worker and public health and safety and the environment.

### 6.5.6 Implementability

Because the treatability study results for the existing PRB would be applied to the design of these PRBs, a treatability study would not be required for Alternative 4. Installation of the PRB requires specialized equipment and experience that most local contractors do not possess. Although a specialty geotechnical construction firm must be used, there are several qualified ones in this country. The procurement of a qualified PRB contractor should not pose difficulties for implementing Alternative 4.

Installation of the PRBs will require coordination with the Westworth Redevelopment Authority. Approximately 10 months will be required for design and implementation. Because no permits are required, minimal coordination with regulatory agencies would be required for PRB installation and operation. The lack of permit requirements also means that less frequent monitoring is needed as compared to Alternative 3. Aside from groundwater monitoring, the PRB would require only periodic maintenance and a relatively low level of operational supervision.

Alternative 4 should be easier and require less time to implement than Alternative 3.

### 6.5.7 Cost

The PRB along the western boundary will parallel the existing PRB and then will extend beyond the northern terminus of the existing PRB by 400 feet. Based on simulations of contaminant degradation used for the design of the existing PRB and on recent performance monitoring data, the PRB would be 2 feet thick where it parallels the existing PRB and 5.6 feet thick to the north of the existing PRB.

To treat groundwater along the northwestern boundary a 900-foot PRB would be placed along the northwestern border in a north-south orientation prior to shifting to the northeast towards Taxiway Charlie. The estimated thickness of the PRB required to meet MCLs was based upon TCE and *cis*-1,2-DCE influent concentrations of 370 and 58 $\mu$g/L, respectively. It was assumed that contaminant degradation along the northwestern boundary could be modeled with the same rate constants as used for the PRBs near the western boundary. The groundwater velocity is lower in this area ~0.03 ft/day. Based upon the modeling results using the low velocity and low influent concentrations, the required PRB thickness would be nominal. The minimum width for the one-pass trench is 1.5 feet so that width would be used.

Both PRBs would use a reactive media composed of 50 percent ZVI and 50 percent sand by dry weight. For both PRBs, it is assumed that chemical treatment (such as in-place reduction of the iron or acid washing to remove build-up of iron carbonate) will be required every ten years over the period of performance. Fifteen monitoring wells will be installed and sampled on a quarterly basis for the compounds listed in Table 5.2. After two years, the monitoring frequency will be reduced to semi-annual and only four wells will be sampled. After 10 years, the four wells will be sampled annually. Treatment of the iron will be conducted every 10 years as well. Maintenance of the existing PRB will likely be more difficult to implement than the other ongoing activities. Several techniques are available to maintain or rejuvenate a PRB. These include:

- Using ultrasound to break-up the precipitate;
- Using pressure pulse technology to break-up the precipitate;
- Jetting the upgradient face of the PRB with water under high pressure; and

- Using solid-stem augers to agitate the upgradient face of the PRB.

These technologies are not well tested, due to the relative immaturity of PRB technology; consequently, it is difficult to foresee whether these methods can be easily implemented. All of these maintenance methods require invasive activities at the site, which may conflict with or disrupt future land use activities.

The in-situ iron injection technology is a patented process that will require a patent fee from the patent owner, EnviroMetal Technologies Inc. This cost was included in the cost estimate.

The costs for MNA include only the additional chemical analyses; the costs do not include the analyses currently performed for the LTM. It is assumed that all the sampling can be conducted at the same time as the LTM sampling, and no additional labor hours are required.

The Present Value cost of Alternative 4 is $16,455,000. This is in addition to the costs already incurred under Alternative 1.

# 7.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

This section provides a comparative analysis of the alternatives for the BRAC property relative to the criteria presented in Section 6.0 and describes the relative advantages and disadvantages of the alternatives. A summary of the ability of each alternative to meet each of the seven criteria as explained in Chapter 6 is presented in Table 7.1.

## 7.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Alternatives 2 through 4 are expected to reduce risk to acceptable levels for the corresponding land use scenario via MNA combined with active treatment (except Alternative 2 [MNA and land use controls only]). Under Alternative 1, the no additional action or baseline situation, the existing PRB and phytoremediation will continue to treat contamination from flowing onto the property while the dispersion and volatilization components of natural attenuation will decrease downgradient groundwater concentrations.

A 30-year duration was used in this evaluation because it is likely that, after 30 years, the treatment systems would require either replacement or major renovations in order to operate until the upgradient source is eliminated.

It is anticipated that Alternatives 3 and 4 and potentially Alternative 2will achieve the groundwater concentrations for RAO 2 within 30 years. Therefore, the ICs protecting construction workers would have to be maintained for a minimum of 30 years.

It is anticipated that Alternative 3 will reduce the groundwater concentrations on the BRAC property to unrestricted use levels in 5 years. It is expected that Alternative 2 will reach MCLs on the BRAC property within 20 to 50 years. Alternative 4's timeframe to reach MCLs is estimated at 10 to 15 years.

## 7.2 COMPLIANCE WITH ARARS

All alternatives can meet action-specific ARARs. Chemical-specific ARARs are met through natural attenuation and the treatment technologies proposed in each alternative. No location-specific ARARs were identified for any of the alternatives.

## Table 7.1
## Individual Evaluation of Final Alternatives

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Human Health Protection | No reduction in risk beyond that achieved by the existing PRB and natural attenuation; protective of human health due to controls maintained by the Federal government | Reduction of risk through remediation of groundwater to MCLs; protective of human health in the interim via LUCs. | See Alternative 2 | See Alternative 2 |
| Environmental Protection | There is no current risk to ecological communities. Ecological receptors will continue to be protected. | There is no current risk to ecological communities. Ecological receptors will continue to be protected. | See Alternative 2 | See Alternative 2 |
| Compliance with ARARs | Not applicable. | All ARARs will be achieved. Future optimizations/5 Year Reviews will ensure MCLs are obtained. | See Alternative 2 | See Alternative 2 |
| Magnitude of Residual Risk | The continued operation of the existing PRB is expected to attenuate residual contamination, resulting in risk reduction; maintenance of Federal control over the property will protect human health through elimination of exposure pathways | Risk reduced to acceptable levels through reduction in contaminant concentrations. | See Alternative 2 | See Alternative 2 |
| Adequacy and Reliability of Controls | Existing PRB will continue to reduce contaminant concentrations flowing onto the BRAC property. PRB will not affect contamination flowing onto the property in the area north of the PRB's northern terminus. Maintenance of Federal ownership of the land will ensure reliable control of future land use. | Existing PRB will continue to reduce contaminant concentrations flowing onto the BRAC property. PRB will not affect contamination flowing onto the property in the area north of the PRB's northern terminus. Reliability of this alternative also depends on ability to maintain effective operation of the AFP 4 East Parking Lot Pump and Treat System so it continues to contain the TCE plume for as long as the continuing source term is present. May require additional optimization to be adequate. Reliability of institutional controls depends on effective site monitoring. | System will provide adequate control of contaminants flowing onto the BRAC property and degradation of residual contamination currently present on the BRAC property. Pump-and-treat system must be maintained as long as source is present. Reliability of this approach depends on ability to maintain effective hydraulic control of contamination from NAS Fort Worth JRB until MCLs are achieved and maintained upgradient of the property boundary. | Additional PRBs will provide adequate control of contaminants flowing onto the BRAC property. MNA will reduce residual concentrations on the BRAC property, but will take longer to achieve MCLs than Alternative 3 and has less reliability than Alternative 3 in achieving MCLs. Reliability of this alternative also depends on ability to maintain effective operation of the AFP 4 East Parking Lot Pump and Treat System so it continues to contain the TCE plume for as long as the continuing source term is present. |

## Table 7.1 (continued)
## Individual Evaluation of Final Alternatives

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Need for 5 year review | Review would be required to ensure adequate protection of human health and the environment. | See Alternative 1 | See Alternative 1 | See Alternative 1 |
| Community Protection | No increase in risk to community from present level. Current land use and conditions are protective of human health. | The community will be protected provided that LUCs are maintained and effectively monitored until MCLs are met. | Most effective alternative in the short-term due to active removal of residual contamination on the BRAC property. Long-term effectiveness depends on maintenance of the hydraulic controls over the groundwater flowing onto the BRAC property. Ensures protection of the community by remediating groundwater on BRAC property to MCLs, thereby eliminating the need to prevent future use of the shallow groundwater. LUCs will ensure protectiveness in interim. | This alternative will effectively contain contaminated groundwater from moving onto the BRAC property immediately after completion of the PRB installation. The time frame to meet MCLs on the BRAC property by MNA will be longer than for the cometabolic processes (Alternative 3). Long-term effectiveness depends on maintenance of the PRBs that treat the groundwater flowing onto the BRAC property. Ensures protection of the community by remediating groundwater on BRAC property to MCLs, thereby eliminating the need to prevent future use of the shallow groundwater. LUCs will ensure protectiveness in interim. |
| Worker Protection | No additional risk to workers. | See Alternative 1 | Limited worker exposure during pump-and-treat well and pipeline installation. Some level of dermal protection from groundwater contact will be required. Protection from air stripper discharge and methane gas may be required. | Limited worker exposure during trenching activities. Dermal protection from groundwater and excavated soil contact will be required. |
| Environmental Impacts | Environmental impacts unchanged from existing conditions | See Alternative 1 | Impact to the environment would be minimal. The volume of groundwater pumped will not significantly impact surface water levels. | Trenching for PRB installation will have minimal impact on the environment. |

**Table 7.1 (continued)**
**Individual Evaluation of Final Alternatives**

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Time until Action Complete | NA | One year for establishment of land use controls. Land use controls and existing PRB must be maintained until MCLs are met which is expected to be between 20 and 50 years. Optimization efforts (if required) could reduce time until action is complete. | 5 years to achieve MCLs on the BRAC property. Hydraulic control of the upgradient groundwater must be maintained until MCLs are achieved and maintained (through EPL system containment) upgradient of the property. MCLs are ancipated to be achieved between 20 and 50 years. | Between 10-15 years to achieve MCLs on the BRAC property. Effective treatment of the groundwater flowing onto the BRAC property must be maintained until remediation or continued containment of the continuing source at AFP-4. MCLs are ancipated to be achieved between 20 and 50 years. |
| Amount destroyed or treated | No treatment of contaminants beyond that currently achieved by the existing PRB and natural attenuation. | This alternative will partially contain the contaminants flowing on the BRAC property. Residual contamination will be destroyed through MNA or an optimization of the current remedy. | This alternative will treat the residual contaminants on the BRAC property and contain/treat contaminants flowing onto the BRAC property. | See Alternative 2 |
| Reduction of Toxicity, Mobility, or Volume | Reduction of toxicity and contaminant mobility in vicinity of existing PRB, and downgradient of PRB through natural attenuation. | Reduction of toxicity and contaminant mobility in vicinity of existing PRB, and downgradient of PRB through natural attenuation. Additional optimization may be required to reduce volume. | Complete reduction in toxicity of groundwater on the BRAC property. Hydraulic controls will prevent future migration of contaminants onto the BRAC property. | Complete reduction in toxicity of groundwater on the BRAC property. PRBs will reduce toxicity of groundwater flowing onto the BRAC property. |
| Irreversible Treatment | Contaminant treatment provided by the existing PRB is irreversible. | Contaminant treatment provided by the existing PRB and MNA are irreversible. LUCs are reversible. | Destruction of contaminants by cometabolic processes is irreversible. Contaminants will not be destroyed by the pump-and-treat system, but will be transferred to the ambient air through air stripping. | Destruction of contaminants by natural attenuation and abiotic zero valent iron (ZVI) reactions is irreversible. |

## Table 7.1 (continued)
## Individual Evaluation of Final Alternatives

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Ability to Construct and Operate | With the exception of groundwater monitoring, no construction or operation is necessary. Maintenance on the PRB may be necessary every 10 years. The methods and effectiveness of this maintenance is not well documented and may be difficult. | See Alternative 1 | Pump-and-treat and methane injection require relatively simple operations. Construction of both systems is relatively straightforward. | PRBs require no operation. Construction is moderately difficult due to large trenching requirement. Maintenance on the PRB may be necessary every 10 years. The methods and effectiveness of this maintenance is not well documented and may be difficult. |
| Ease of Doing More Action if Needed | Activities currently conducted under the No Additional Action Alternatives can be easily modified. | Land use controls could be easily enhanced with other technologies, process options etc. | Simple to extend pump-and-treat or methane injection system if necessary. | The materials and services to extend the PRBs are available from several firms. |
| Ability to monitor Effectiveness | Present monitoring will provide adequate notice of potential exposure. | See Alternative 1 | Existing and proposed monitoring network will provide adequate notice of potential exposure, and sufficient information to evaluate the remedial effectiveness. | See Alternative 3 |
| Ability to Obtain Approvals and Coordinate with Other Agencies | None required | Requires the filing of deed restrictions. | May requires an injection permit and an NPDES discharge permit (a waiver can be obtained for a CERCLA site). Requires coordination with Westworth Redevelopment Authority. | Requires coordination with Westworth Redevelopment Authority. |
| Availability of Services and Capacities | No additional services or capacities required | See Alternative 1 | Requires delivery of methane used for cometabolic injection. Suppliers are available in the local area. Qualified drillers are readily available in the state. Qualified plumbers are readily available in the state. | Requires specialized geotechnical construction capability. Several qualified geotechnical contractors operate within the U.S. |
| Availability of Equipment, Specialists, and Materials | None required | None required | Pump-and-treat systems are readily available from multiple suppliers. Components for cometabolic injection of methane are locally available. Specialists to operate and maintain cometabolic and pump-and-treat systems are readily available. | Suppliers of ZVI are available. Equipment for PRB installation is readily available. No specialists are required for PRB operation |

**Table 7.1 (continued)**
**Individual Evaluation of Final Alternatives**

| Criteria | Alternative 1- [1]No Additional Action | [2]Alternative 2- MNA with Land Use Controls | [3]Alternative 3 Pump-and-Treat and Cometabolic Processes | [3]Alternative 4 2 Additional PRBs and MNA |
|---|---|---|---|---|
| Availability of Technologies | None required | None required | Pump-and-treat technologies readily available. Cometabolic technology will require pilot testing. | PRB technology is readily available and an operating PRB is already in-place. |
| Capital Cost | $0 | $36,000 | $11,080,000 | $5,736,000 |
| Present Value of O&M | $2,198,000 | $1,122,000 | $8,198,000 | $2,676,000 |
| Present Value of Periodic Costs | $790,000 | $41,000 | $73,000 | $1,980,000 |
| Total Present Value Costs | $2,988,000 | $1,199,000 [1,4] | $19,351,000[1] | $16,455,000[1] |

[1] Implementation of the no-additional action alternative for the BRAC property involves the implementation of a baseline PRB and the execution of long-term monitoring. Alternatives 2, 3, and 4's costs are in addition to the costs for Alternative 1 (which will be required for any of the 3 alternatives).

[2] Alternative 2 may also include optimization of the existing remedial technologies at the site.

[3] Alternatives 3 and 4 include the technologies in Alternative 2.

[4] Costs do not include any additional optimization costs which could be required if MNA is determined to be ineffective in reaching MCLs.

BLRA – Baseline Risk Assessment

## 7.3 LONG-TERM EFFECTIVNESS AND PERMANENCE

Alternatives 3 and 4 will decrease on-site contamination below the levels expected to result from the existing PRB and phtyoremediation area.

The long-term effectiveness of Alternative 2 is dependent on continued enforcement of the land use controls until MCLs are met. For Alternatives 2 through 4, the long-term effectiveness depends on uninterrupted operation of the EPL pump-and-treat systems, and for Alternative 3 and 4 on the ability of the new pump and treat systems to capture the upgradient groundwater and maintain operation. For Alternative 4, the long-term performance depends on continued monitoring and maintenance of the PRBs. To ensure protection of human health until the upgradient groundwater is remediated, all alternatives require long-term monitoring.

## 7.4 REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Additional active treatment is not a component of Alternative 2; however, the existing PRB, as well as upgradient source remediation efforts and passive treatment of groundwater by natural attenuation is expected to reduce groundwater toxicity and the volume of contamination to levels. Of the two alternatives that include active treatment, Alternative 3 provides for the least reduction in toxicity, mobility and volume. Because the technologies used in Alternative 3 do not degrade the contaminants, but simply transfer them from water to air or water to granular activated carbon, toxicity reductions are not achieved. Indeed, by transferring most of the volatiles to air, Alternative 3 might enhance contaminant mobility while substantially increasing contaminant dilution. Compounds sorbed to granular activated carbon would have reduced mobility. Because of the biodegradation component of Alternative 4, this alternative will result in additional reductions in contaminant toxicity and volume. Alternative 4 will provide for additional contaminant degradation through the extension of the PRB. Alternative 4 would have greater reductions in contaminants toxicity and volume than Alternative 3.

## 7.5 SHORT-TERM EFFECTIVENESS

Alternatives 1 and 2 are not effective in the short-term or long-term, but they also do not result in additional environmental impact. The remaining alternatives pose some potential risks to workers due to fugitive dust emissions and dermal contact with groundwater during drilling activities and/or excavation activities. Short-term risk to workers is also associated with these alternatives during groundwater sampling; a slight risk to the community is associated with Alternatives 3 and 4 during construction of remediation systems. The time required to achieve cleanup goals range from between 20 and 50 years for Alternative 2 and 5 years for Alternative 3.

## 7.6 IMPLEMENTABILITY

This criterion is not applicable to Alternative 1. The land use controls and MNA associated with Alternative 2 are easily implementable. Construction activities associated with

Alternatives 3 and 4 are common techniques and are implementable. However, the implementation of alternatives may impact golf course operations and traffic at the site during construction. Because Alternative 3 may require permits, this alternatives will likely require more time to implement than the others.

## 7.7 COSTS

Costs associated with implementation of each alternatives are summarized in Table 7.1. The cost for Alternative 1 ($2,988,000) will be required in addition to each alternative. The alternatives rank in the following descending order relevant to net present worth:

- Alternative 2 $1,199,000
- Alternative 4 $16,455,000
- Alternative 3 $19,351,000

Results of the cost analysis are presented in more detail in Appendix D.

## 7.8 SUMMARY

The results of the comparative analysis are summarized in Table 7.1. All of the alternatives provide protection of human health and the environment considering the land use option and compliance with ARARs. Alternatives 3 and 4 will be more reliable since they do not rely on land use controls for as long a period as Alternative 2. The ease of implementation for Alternatives 3 and 4 is similar, with Alternative 2 being the easiest.

Alternatives 2 through 4 reduce toxicity and volume through treatment with time frames ranging from 5 to up to 50 years. The most expensive alternative is Alternative 3 ($19 million), while the least expensive is Alternative 2 ($1.2 million).

The decision regarding which alternative will be implemented depends primarily on balancing cost against length of time to reach MCLs, Alternative 2 is significantly less costly than Alternatives 3 and 4. The success of Alternatives 3 and 4 depends on the effectiveness of their designs and the implementation of the designs. It is expected that Alternative 4 would be more effective than Alternative 2 and 3. Alternative 3 is the most costly and most aggressive approach, estimated to achieve groundwater concentrations for unrestricted use in 5 years.

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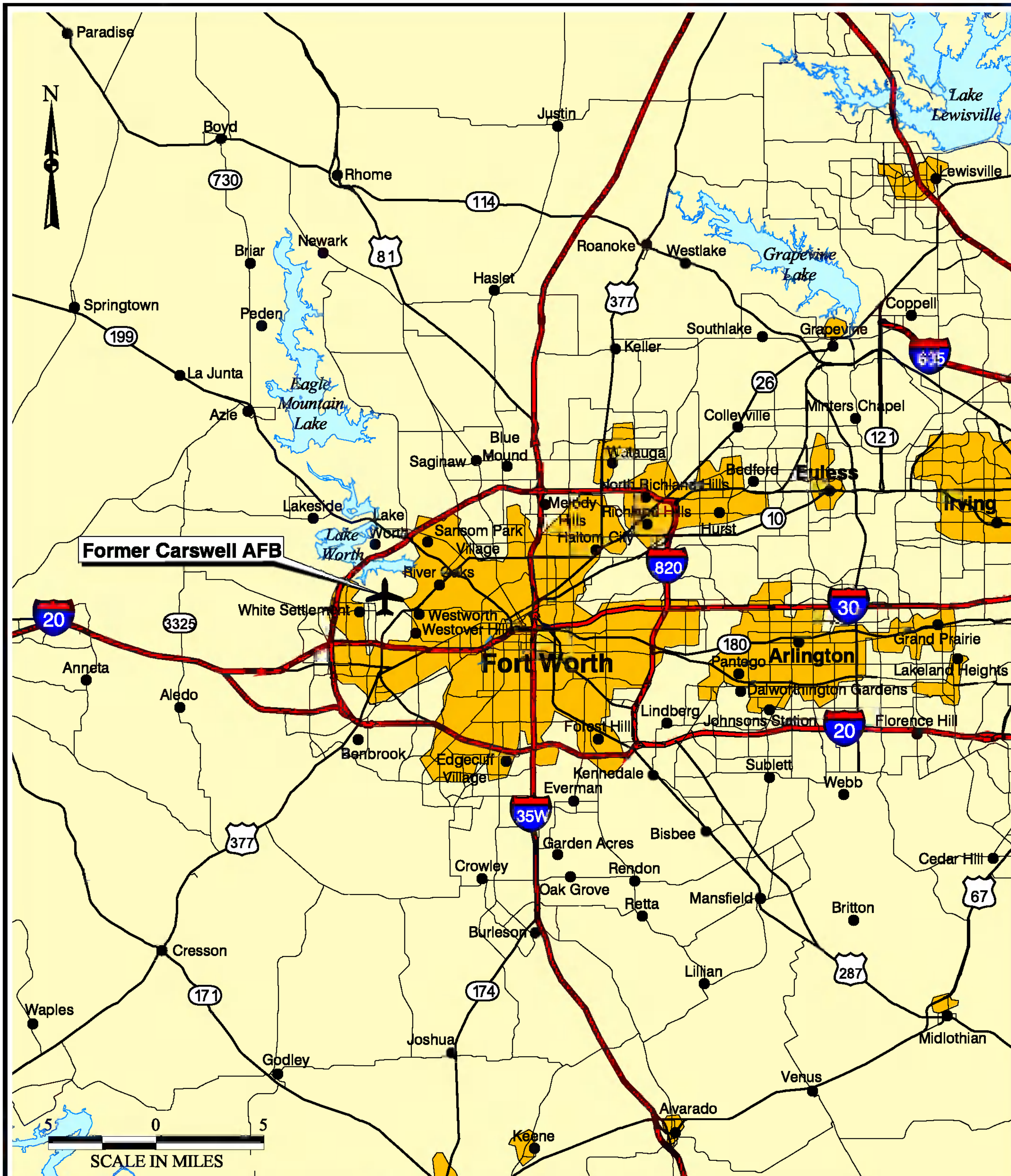


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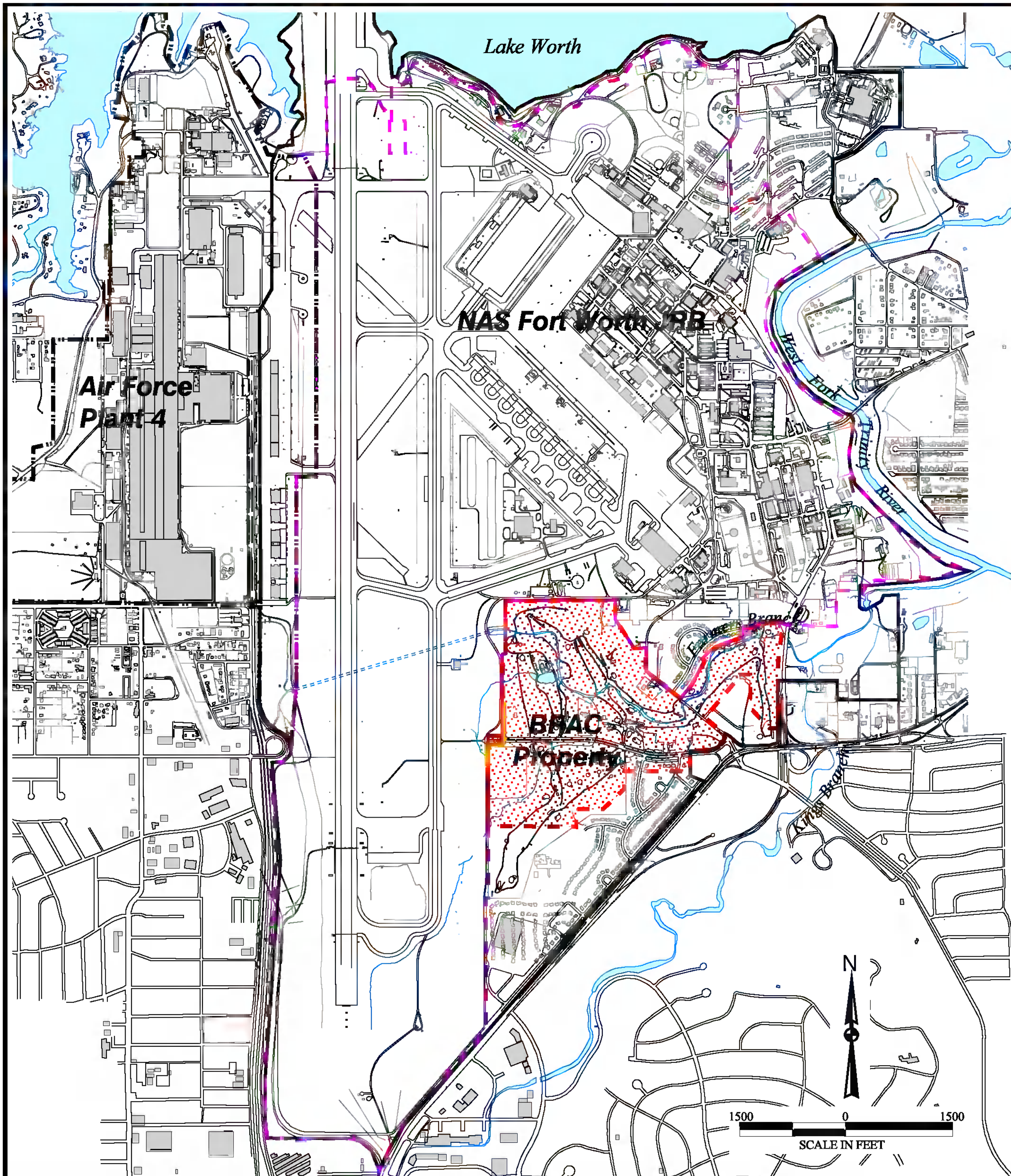
*Project: GSA002-007-06-07-02*
*Revised: 05/26/05 tbraswell*
*Source: ArcGIS 8.2, ESRI Data & Maps, 2002*


**Figure 1.1**

**Site Location Map**
**Former Carswell AFB, Texas**

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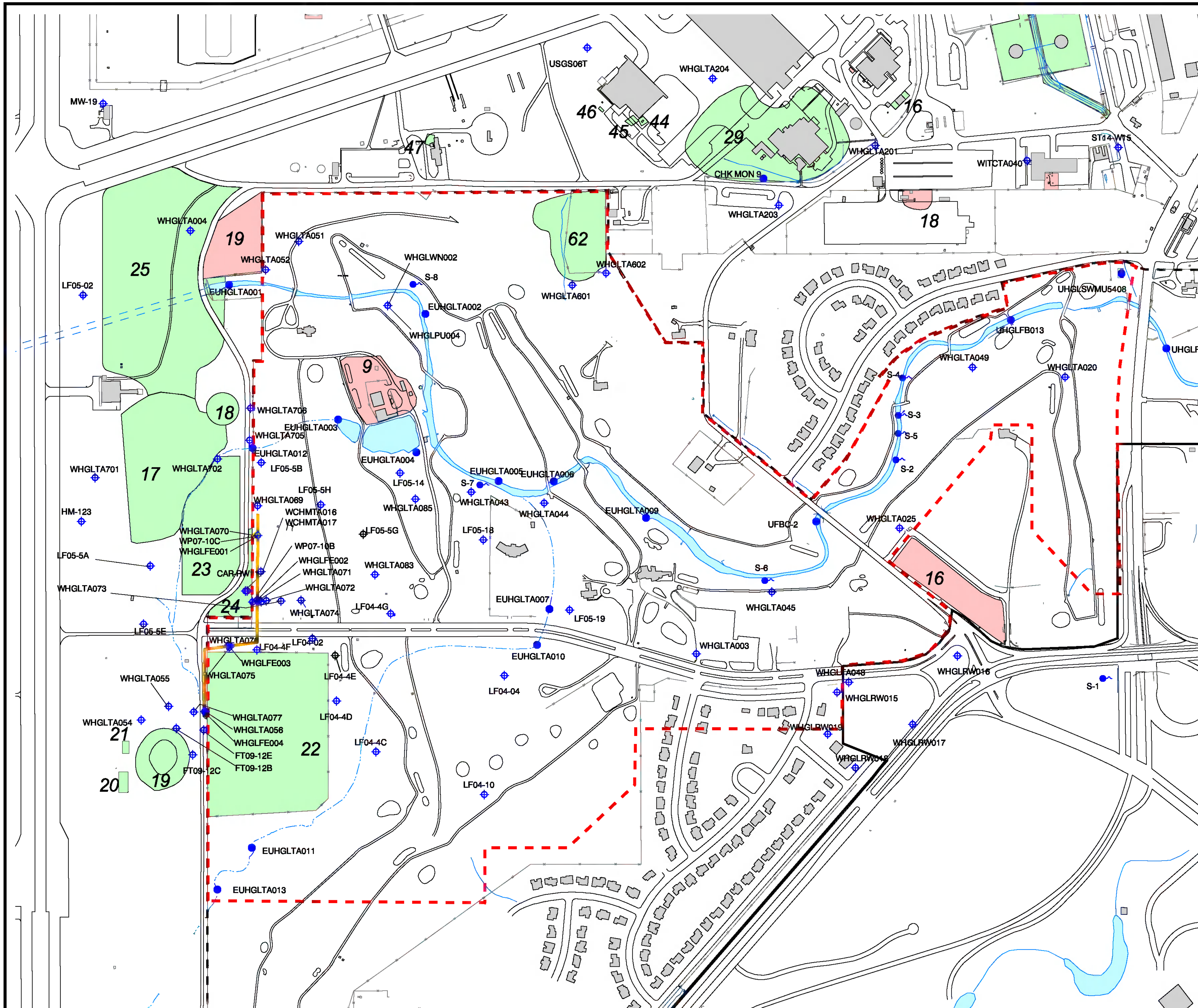
*Revised: 06/17/05 TBraswell*
*Source: HydroGeoLogic, Inc—GIS Database*

**Legend**

- NAS Fort Worth JRB Boundary
- Former Carswell AFB Boundary
- Air Force Plant 4 Boundary
- Risk Assessment/FFS Area
- Permeable Reactive Barrier (PRB)

**Figure 1.2
Area Covered by
Risk Assessment and
Focused Feasibility Study**




*HydroGeoLogic, Inc.—Focused Feasibility Study*
*Former Carswell AFB, Texas*

# Figure 1.3

# Site Map

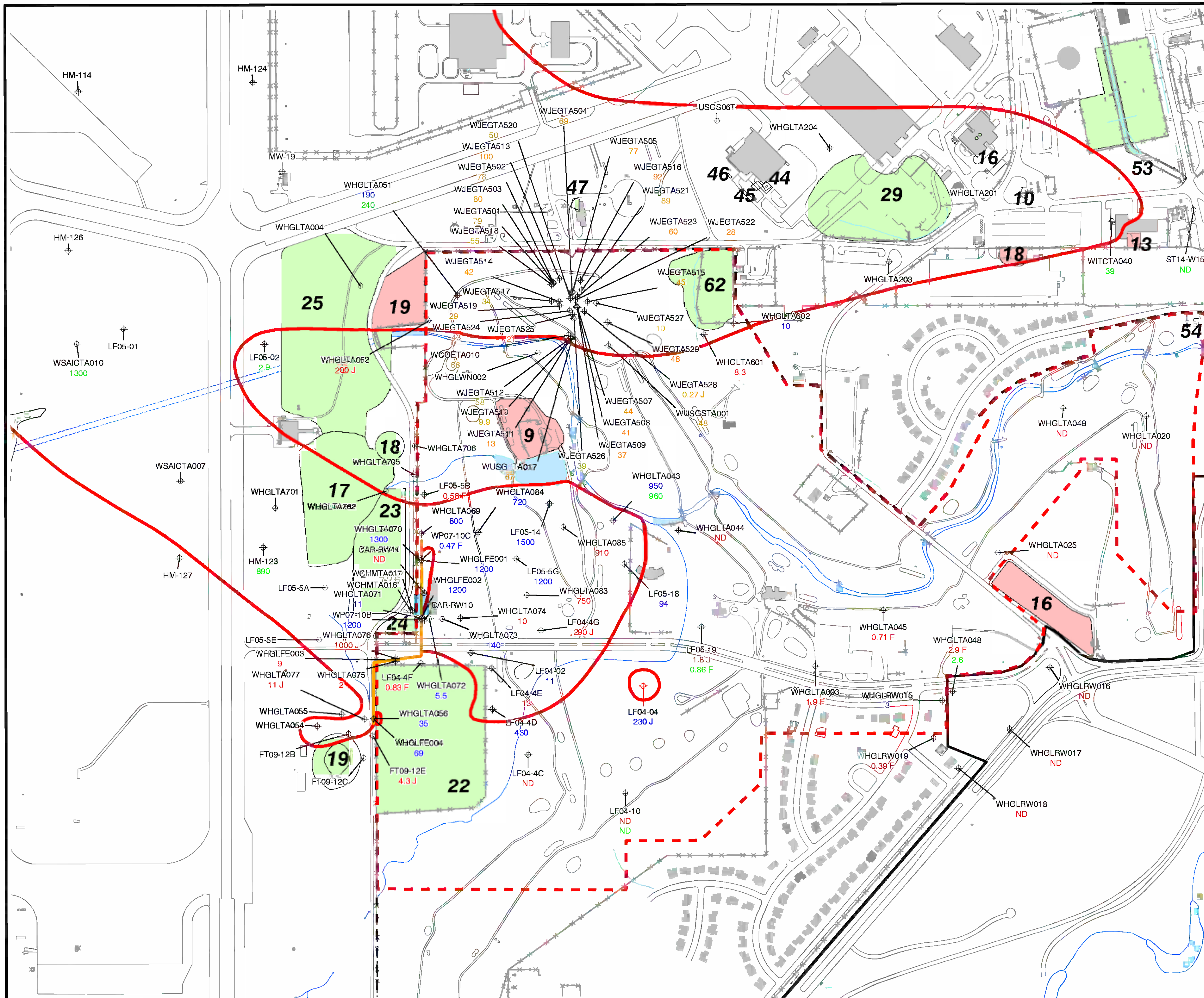
## Legend

- NAS Fort Worth JRB (Carswell Field)
- Former Carswell Air Force Base
- Risk Assessment/FFS Area
- Permeable Reactive Barrier
- Monitoring Wells
- Surface Water and Sediment Sampling Location
- Seep Sample Location
- Area of Concern
- Solid Waste Management Unit

*Filename: X:\GSA002\Maps\ffs_s_lobe_tce_gw_plume \site_map.apr*
*Project: GSA002-007-06-07-03*
*Revised: 06/17/05 tbraswell*
*Map Source: HydroGeoLogic, Inc. ArcView GIS Database 2002*

HydroGeoLogic, Inc. *Focused Feasibility Study*
*Former Carswell AFB, Texas*

# Figure 1.4
# Southern Lobe
# Trichloroethene Concentrations
# Terrace Alluvium
# April - October 2004



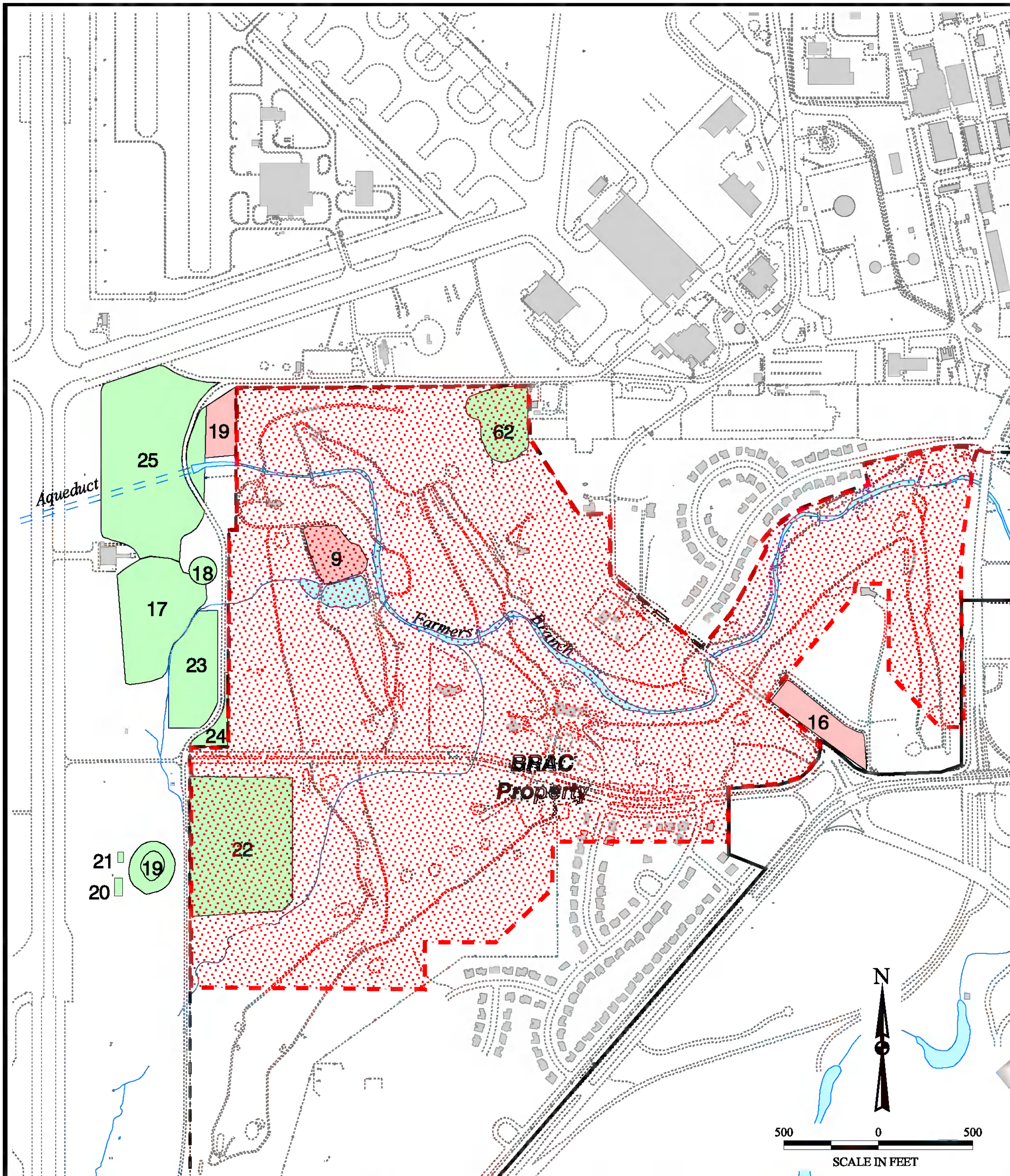

## Legend

| | |
|---|---|
| - - - | NAS Fort Worth JRB (Carswell Field) |
| ——— | Former Carswell Air Force Base |
| ——— | TCE Concentration Contour (5 µg/L) |
| - - - | Risk Assessment/FFS Area |
| ——— | Permeable Reactive Barrier Location |
| | Solid Waste Management Unit |
| | Area of Concern |
| | Building/Structure |
| ⌖ | Monitoring Well |
| 13 | PRB Semi-Annual Sampling Well (May 2004) |
| 66 | USGS Phytoremediation Sampling Well (July 2004) |
| 94 | PRB Semi-Annual Sampling Well (October 2004) |
| 2.6 | AFP 4 LTM Sampling Well (April 2004) |
| LF05-01 | Other Monitoring Well |
| F | The analyte was positively identified, but the associated value is below the PQL. |
| J | The analyte was positively identified, the quantitation is an estimation. |
| ND | Not detected at laboratory MDL of 0.5 µg/L. |

N

0 200 400 800
SCALE IN FEET

*Filename: X:/GSA002/DO 007/MAPS/ffs s lobe_tce_gw_plume/ TCE 2004.mxd*
*Revised: 06/15/05 tbraswell*
*Project: GSA002-007-06-07-03*
*Map Source: HydroGeoLogic, Inc. GIS Database*

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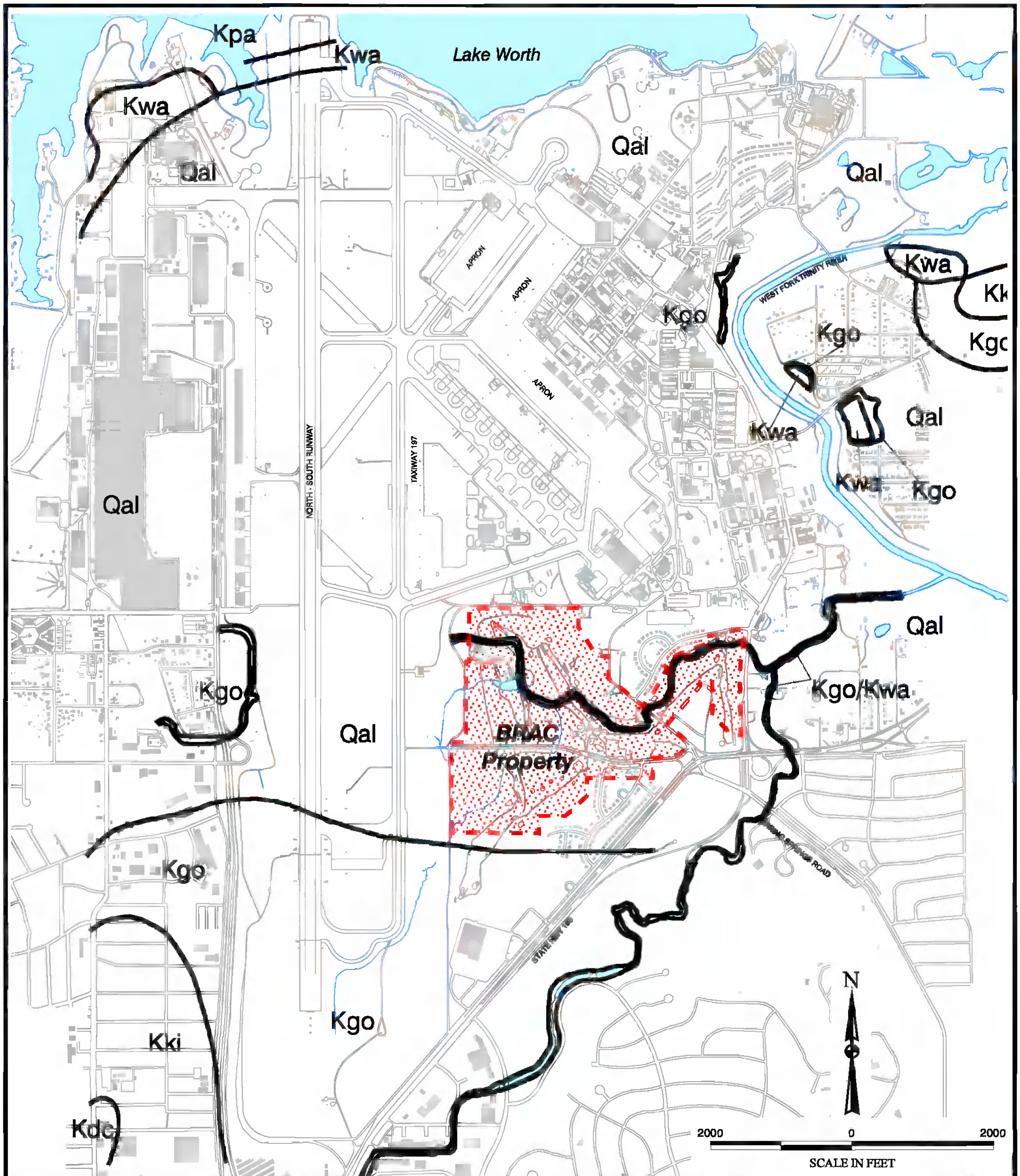
Project: GSA002-007-06-07-03
Revised: 06/17/05 tbraswell
Source: HydroGeoLogic, Inc.
ArcView GIS Database, 2002

**Legend**

- Risk Assesment / FFS Area
- NAS Fort Worth JRB Boundary
- Former Carswell AFB Boundary
- SWMU
- AOC

**Figure 2.1**
**Locations of SWMUs and AOCs near BRAC Property**

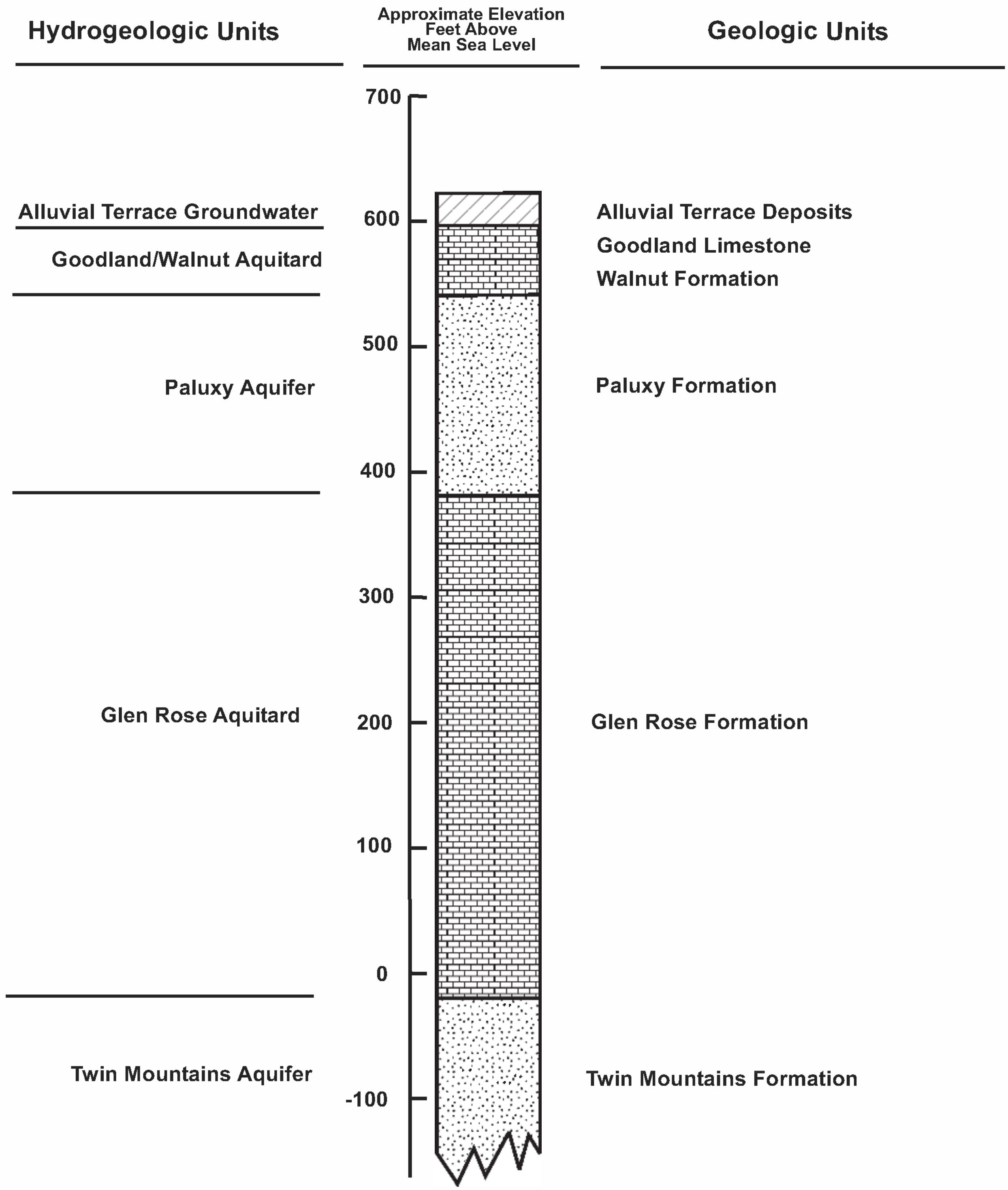



Filename: X:\GSA002\DO_007\MAPS\ffs_s_lobe_tce_gw_plume\areal_distr.apr
Project: GSA002-007-06-07-02
Revised: 06/17/05 tbraswell
Source: HydroGeoLogic GIS Database, 2002
Radian, 1989

**Legend**

| Symbol: | Geologic Unit: |
|---|---|
| Qal | Quaternary Alluvium |
| Kdc | Duck Creek Formation |
| Kki | Kiamichi Formation |
| Kgo | Goodland Limestone |
| Kwa | Walnut Formation |
| Kpa | Paluxy Formation |

**Figure 2.2**
**Areal Distribution of Geologic Units of Former Carswell AFB, Texas**

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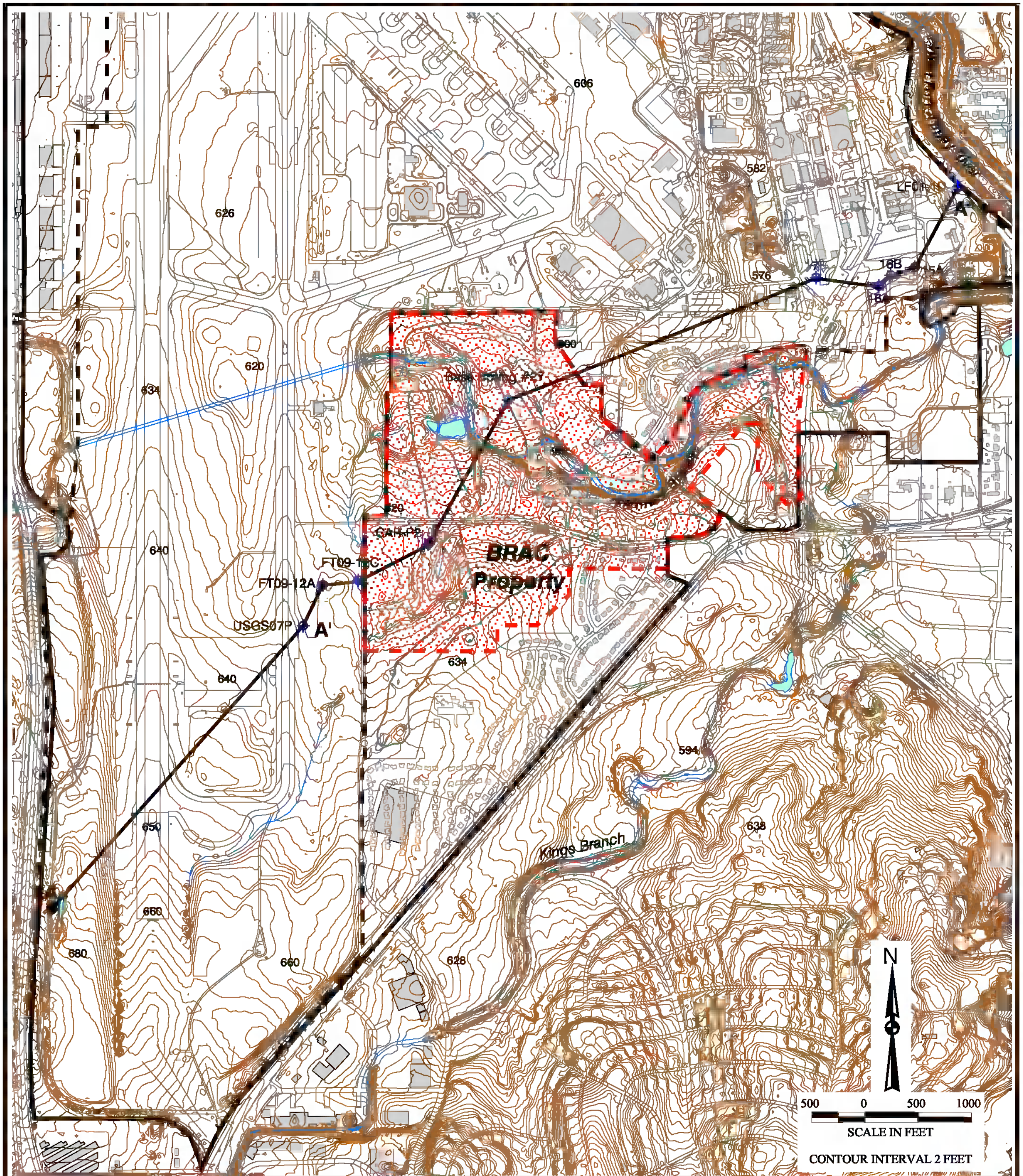
*Project: GSA002-007-06-07-02*
*Revised: 06/02/05 tbraswell*
*Source: Radian, 1989*

**Figure 2.3**

**Stratigraphic Column Correlating Hydrogeologic Units and Geologic Units**

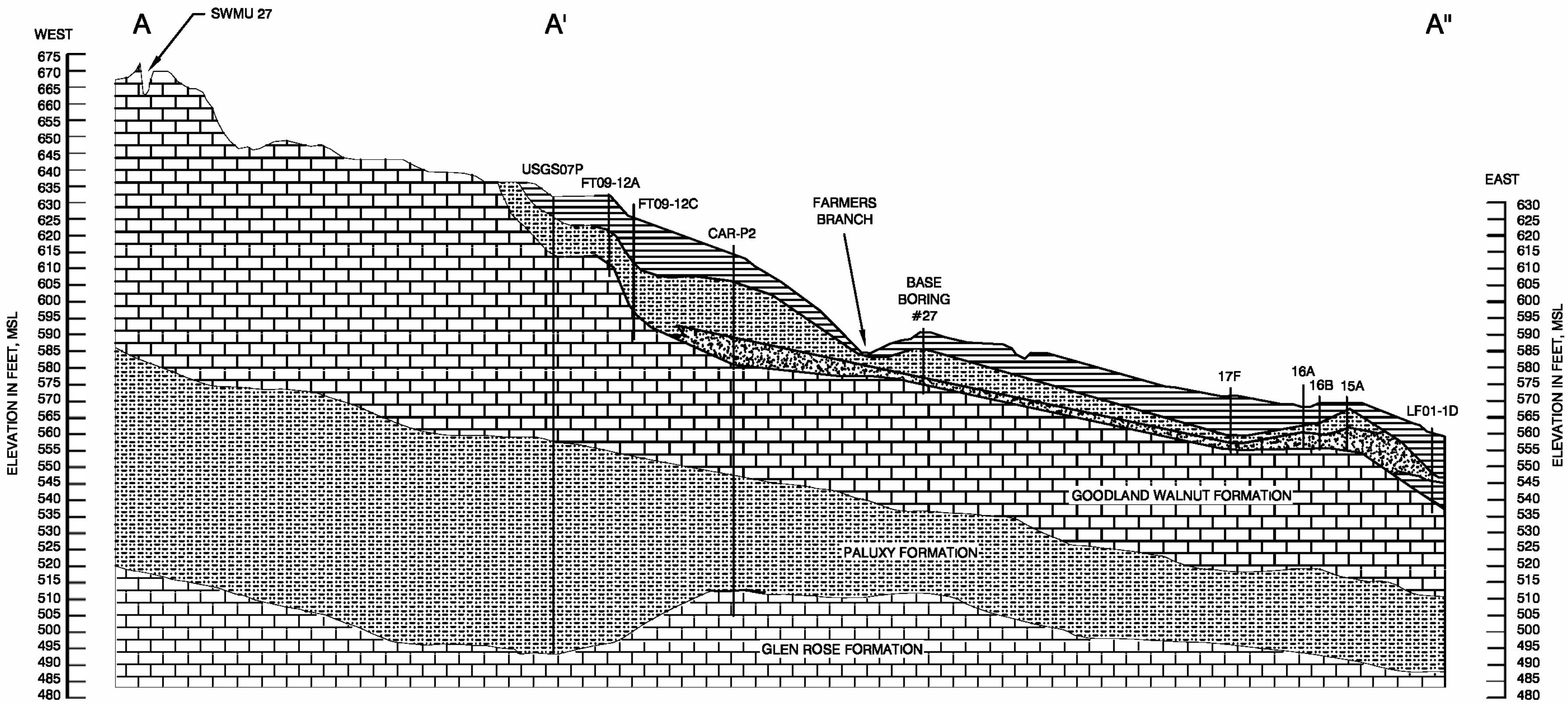



*Filename: X:\GSA002\DO_007\Maps\ffs_s_lobe_tce_gw_plume \x-section_a_a.apr*
*Project: GSA002-007-06-07-02*
*Revised: 06/17/05 tb*
*Source: HydroGeoLogic, Inc—GIS Database*

**Legend**

- NAS Fort Worth JRB Boundary
- Former Carswell AFB Boundary
- Risk Assessment/FFS Area
- 660 Topographic Contour

**Figure 2.4**
**Cross Section Location**
**A-A'-A"**




800 400 0 800

HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION = 15X

NOTES:

1. STRATIGRAPHIC CONDITIONS ARE KNOWN ONLY AT THE MONITORING WELLS AND BORINGS; CONTACTS ARE INTERPOLATED BETWEEN CONTROL POINTS.

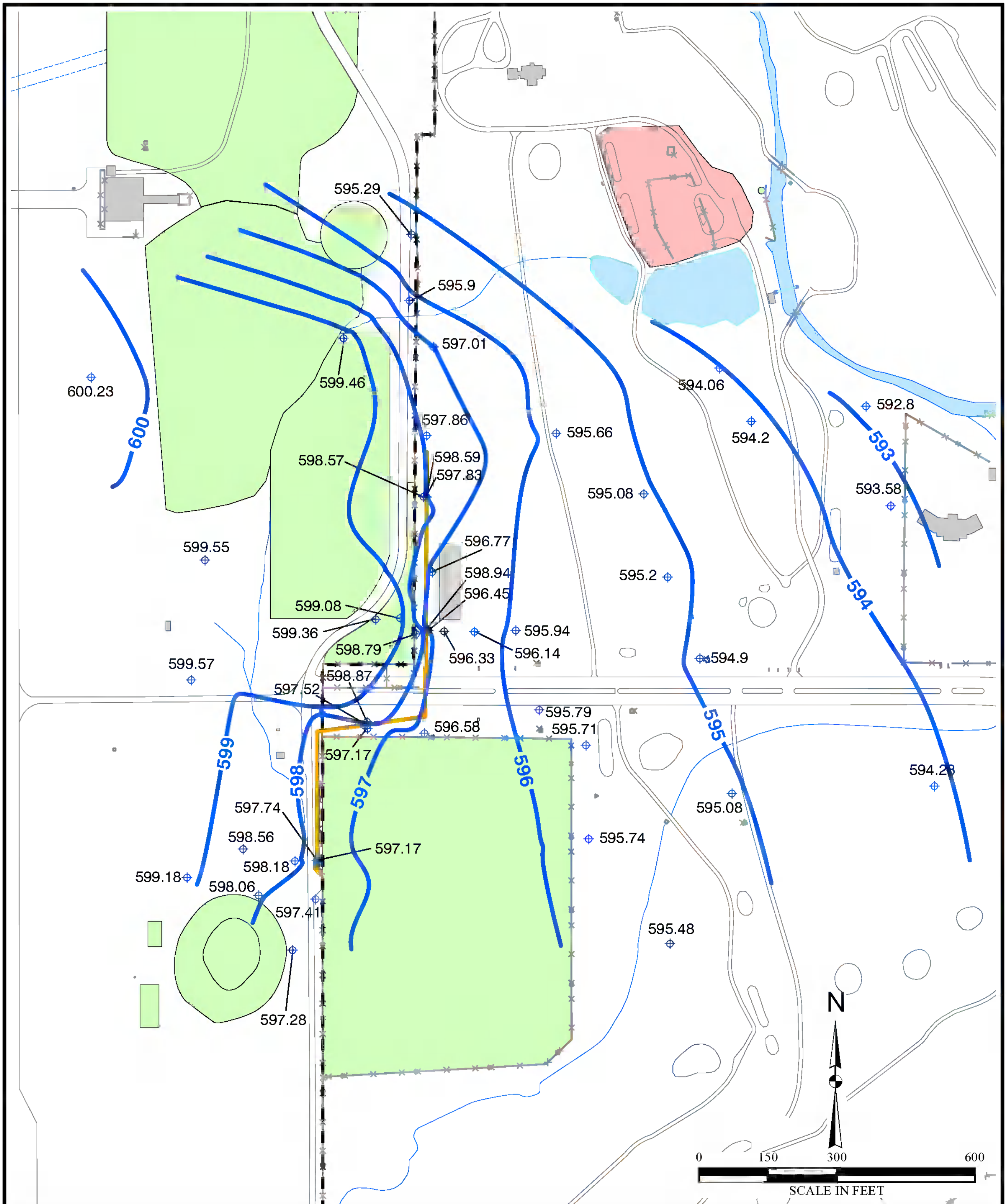
2. WITH THE EXCEPTION OF THE AREA BETWEEN USGS07P AND CAR-P2, THE CONTACT BETWEEN THE GOODLAND WALNUT AND PALUXY FORMATIONS DISPLAYS THE REGIONAL DIP OF 35-40 FEET PER MILE.

*Filename: X:\GSA002\DO_007\MAPS\ffs_s_lobe_tce_gw_plume\x-section.dwg*
*Revised: 06/02/05 tbraswell*
*Project: GSA002-007-06-07-02*
*Source: Radian, 1986; HGL, 1999*

**Legend**

- Clay and Fill Material
- Gravel
- Sand
- Limestone and Shale

**Figure 2.5**
**Generalized Geologic Cross Section A-A'-A"**

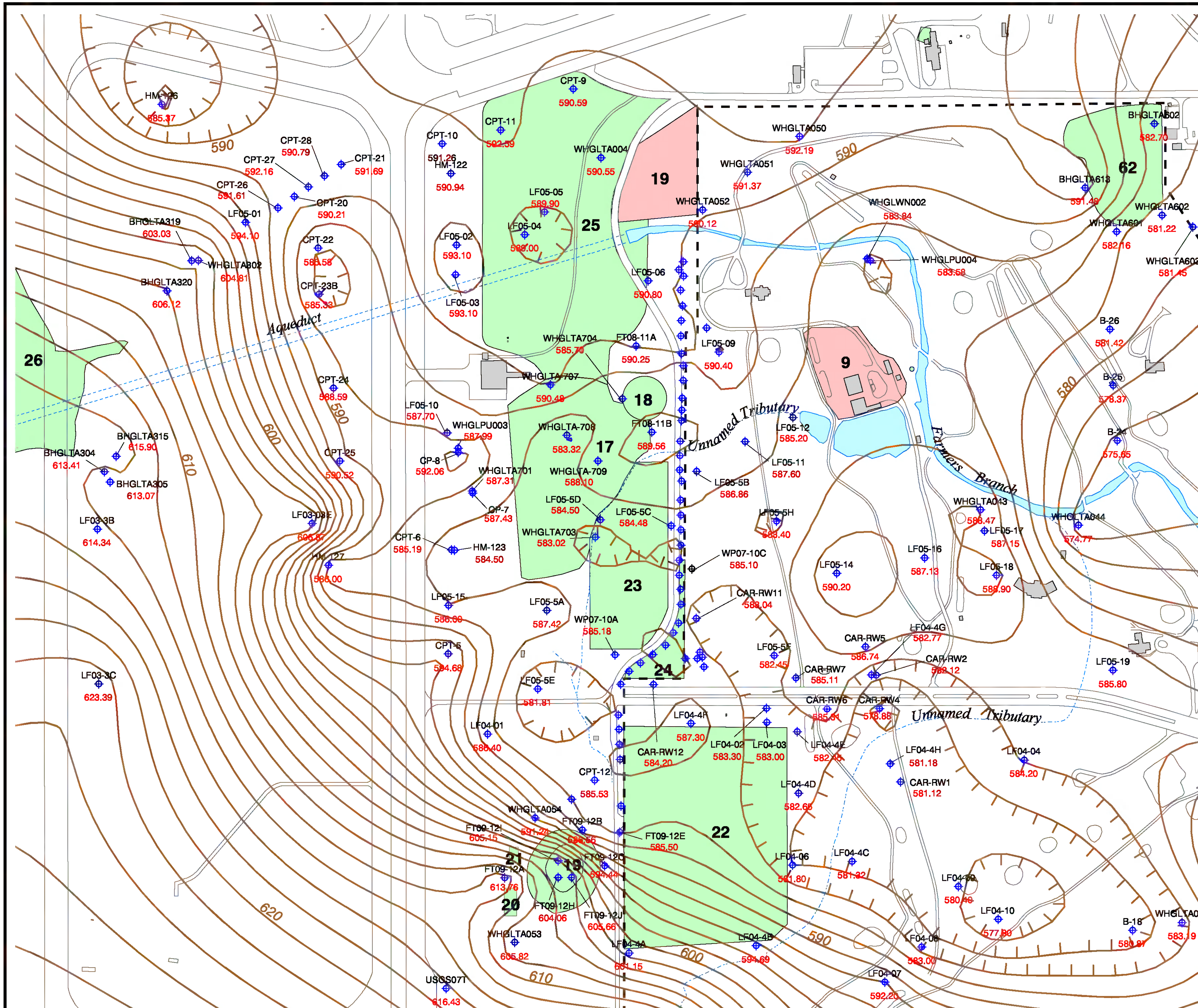



*Filename: X:/GSA002/DO_007/MAPS/ ffs_s_lobe_tce_gw_plume/PRB_GWE_Oct04.mxd*
*Revised: 06/02/05 tbraswell*
*Project: GSA002-007-06-07-03*
*Map Source: HydroGeoLogic, Inc. GIS Database*

**Legend**

- NAS Fort Worth JRB (Carswell Field)
- Permeable Reactive Barrier
- 588 Groundwater Elevation Contour
- Solid Waste Management Unit
- Area of Concern
- Building/Structure
- Monitoring Well

**Figure 2.6**
**Southern Lobe**
**Groundwater Elevations**
**October 2004**






# Figure 2.7

# Bedrock Elevation Map

## Legend

- - - NAS Fort Worth JRB (Carswell Field)

Bedrock Contours (ft msl)

Solid Waste Management Unit

Area of Concern

LF05-17 Monitoring Well Location

587.15 Bedrock Elevation (ft msl)

Note: Bedrock contour interval is 2 feet.

N

200 0 200 400

SCALE IN FEET

*Filename: X:\GSA002\DO_007\MAPS\FFS_S_Lobe_TCE_GW_Plume\ bedrock elevation.apr*
*Project: GSA002-007-06-07-02*
*Revised: 06/06/05 tbraswell*
*Map Source: HydroGeoLogic, Inc., ArcView GIS Database 2001*

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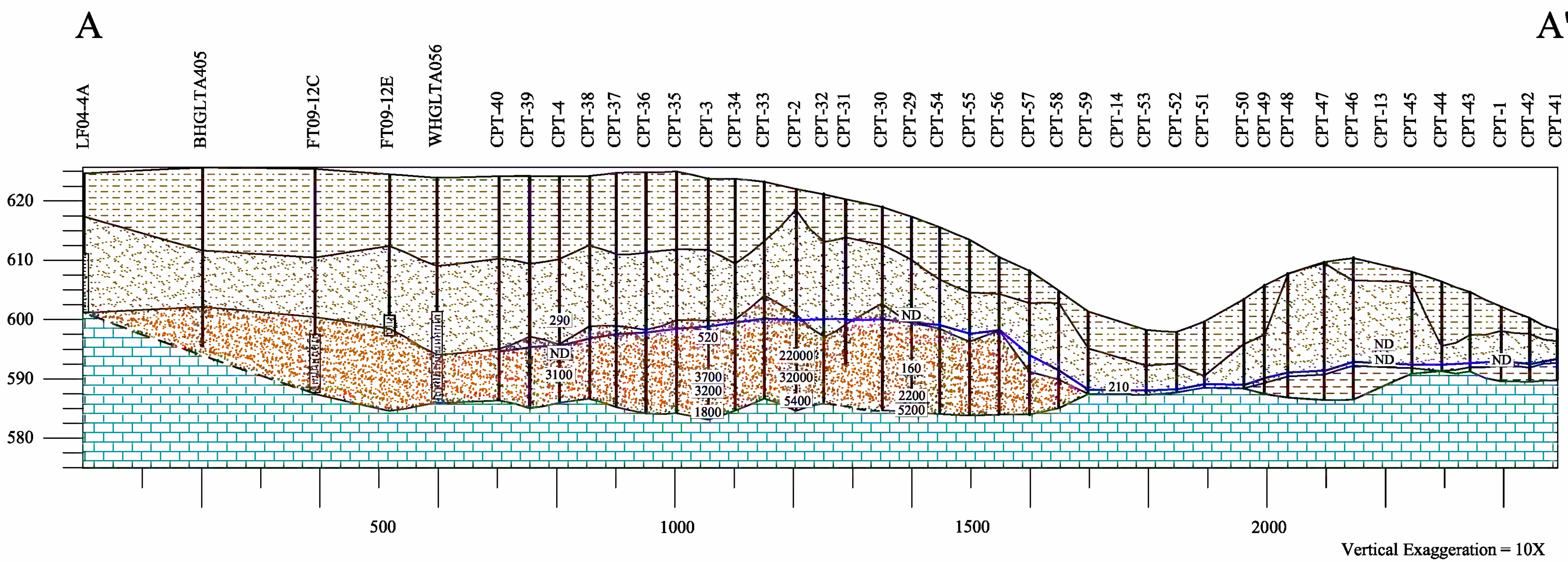
*Former Carswell AFB, Texas*

## Figure 2.8

## Cross Section A-A'

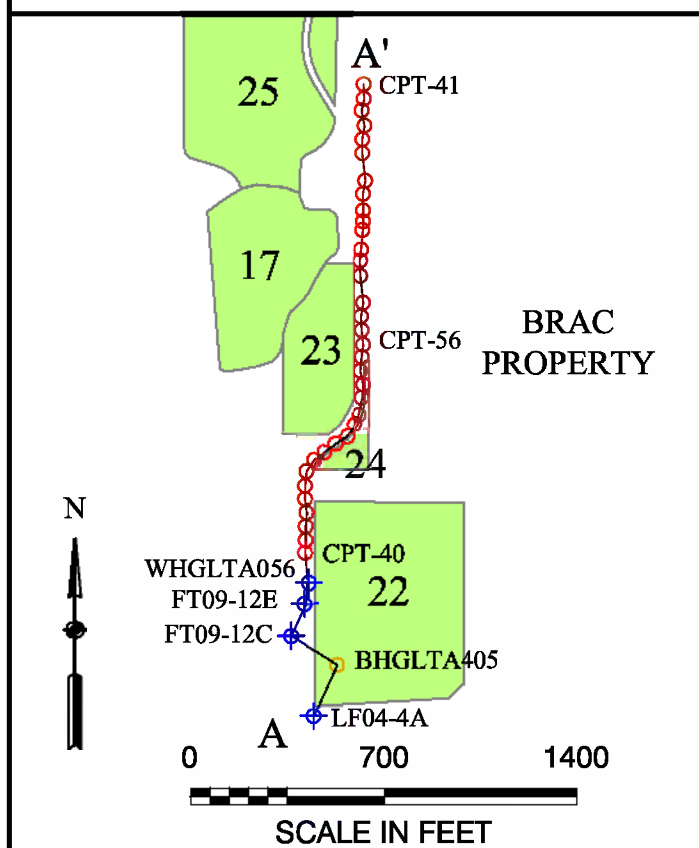



Notes:

290 - TCE concentrations (µg/L) are depicted at the vertical intervals sampled by the MIP and hydrosparge probes.

**Legend**

| | |
|---|---|
| Silt & Clay | Estimated Bedrock Depth |
| Sand | Water Table |
| Clay | Well Screen |
| Sand & Gravel | CPT Boring Location |
| Limestone | DPT Boring Location |
| SWMU | Monitoring Well |

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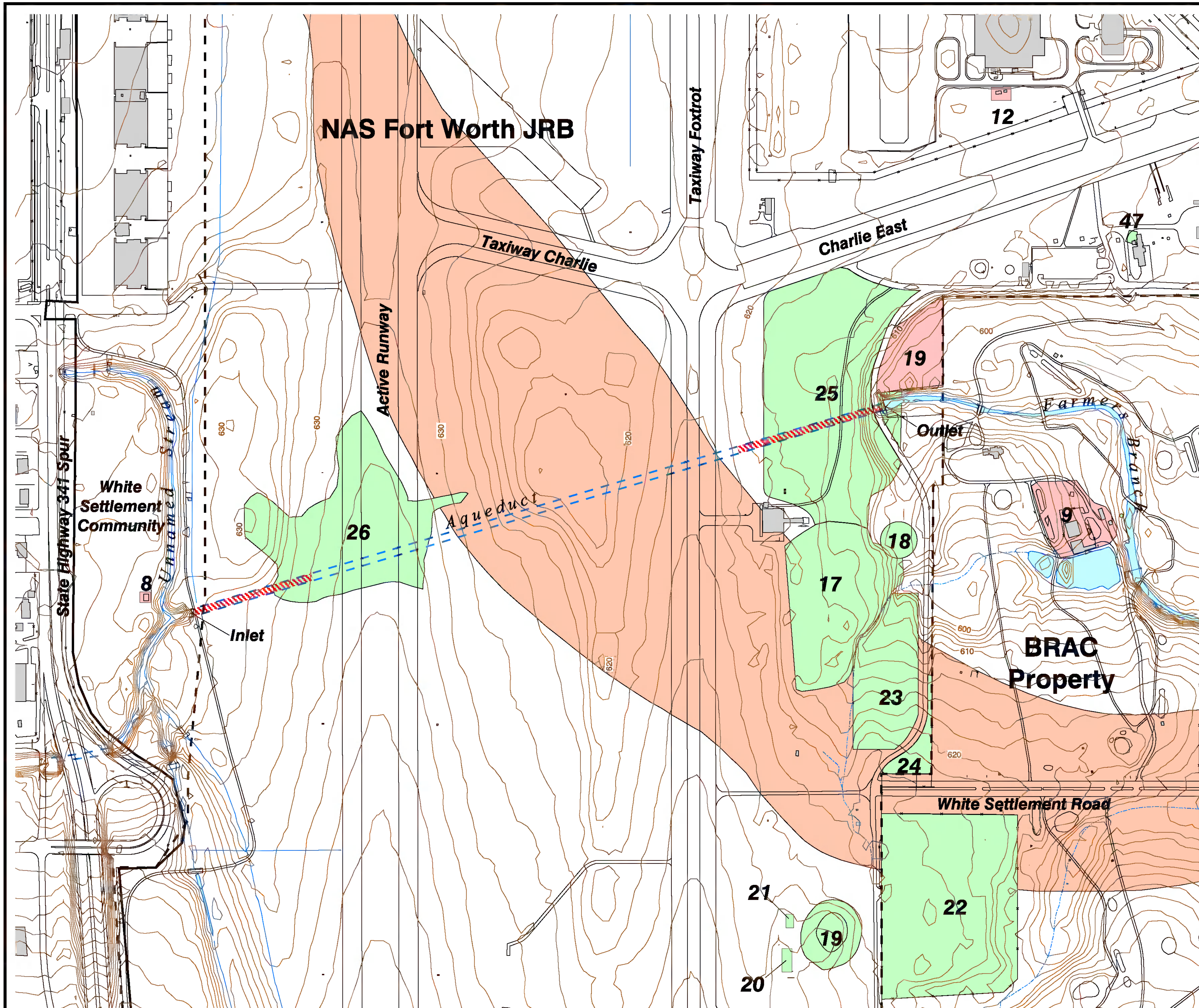
*Revised: 06/06/05 tbraswell*
*Map Source: HydroGeoLogic, Inc. GIS Database*




# Figure 2.9

## Aqueduct Location
## Former Carswell AFB

### Legend

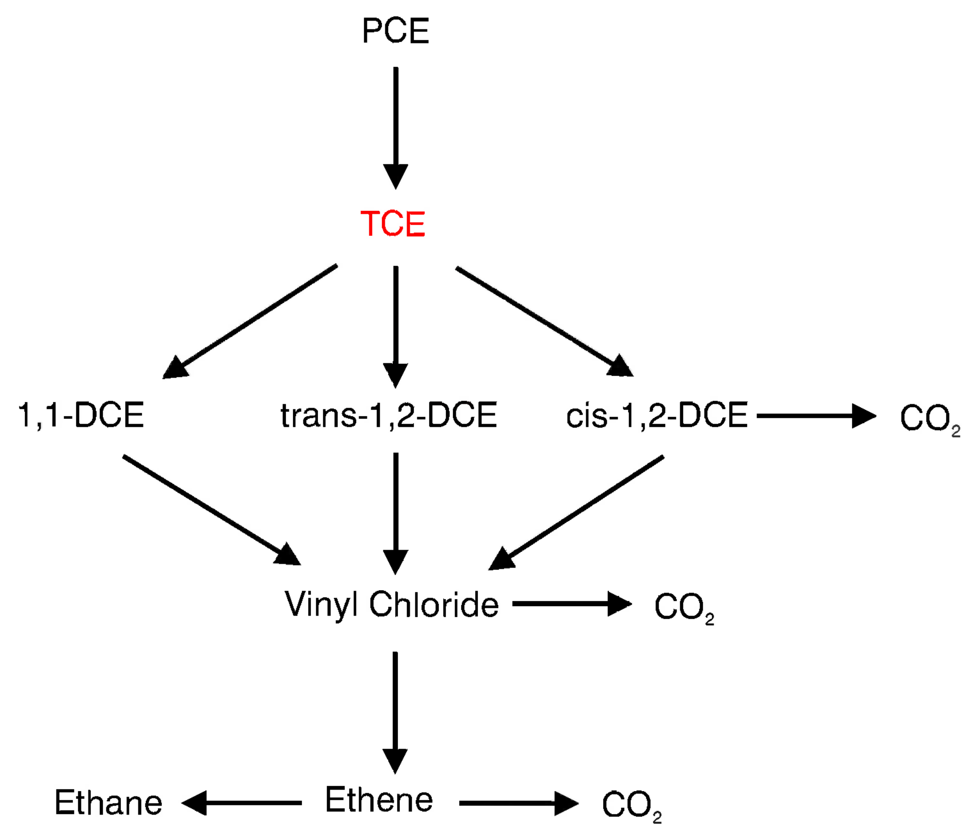
- NAS Fort Worth JRB Boundary (Carswell Field)
- Former Carswell Air Force Base Boundary
- Elevation Contour (2ft. Contour) (Source: IT Corp.)
- Portion of Aqueduct set on bedrock
- Paleochannel (Source: Parsons 1998, HGL 2000a)
- Area of Concern
  - 8 Aerospace Museum
  - 9 Golf Course Maintenance Yard
  - 12 Oil/Water Separator
  - 19 Suspected Former Fire Training Area
- Solid Waste Management Unit
  - 17 Landfill No. 7
  - 18 Fire Training Area No. 1
  - 19 Fire Training Area No. 2
  - 20 Waste Fuel Storage Area
  - 21 Waste Oil Tank
  - 22 Landfill No. 4
  - 23 Landfill No. 5
  - 24 Waste Burial Area
  - 25 Landfill No. 8
  - 26 Landfill No. 3
  - 47 Building 1015 Jet Engine Test Cell Oil/Water Separator

N

300 0 300 600

SCALE IN FEET

*Filename: X:\GSA002\DO_007\MAPS\ffs_s_lobe_tce_gw_plume\aqueduct.apr*
*Project: GSA002-007-06-07-02*
*Revised: 06/27/05 TH*
*Map Source: HGL ArcView GIS Database*




*Filename: X:\GSA002\DO_007\MAPS\FFS_S_Lobe_TCE_GW_Plume\TCE_Degradation.cdr*
*Project: GSA002-007-06-07-02*
*Revised: 06/27/05 TH*
*Source:*

**Figure 2.10**
**Degradation of PCE, TCE, and Daughter Products**

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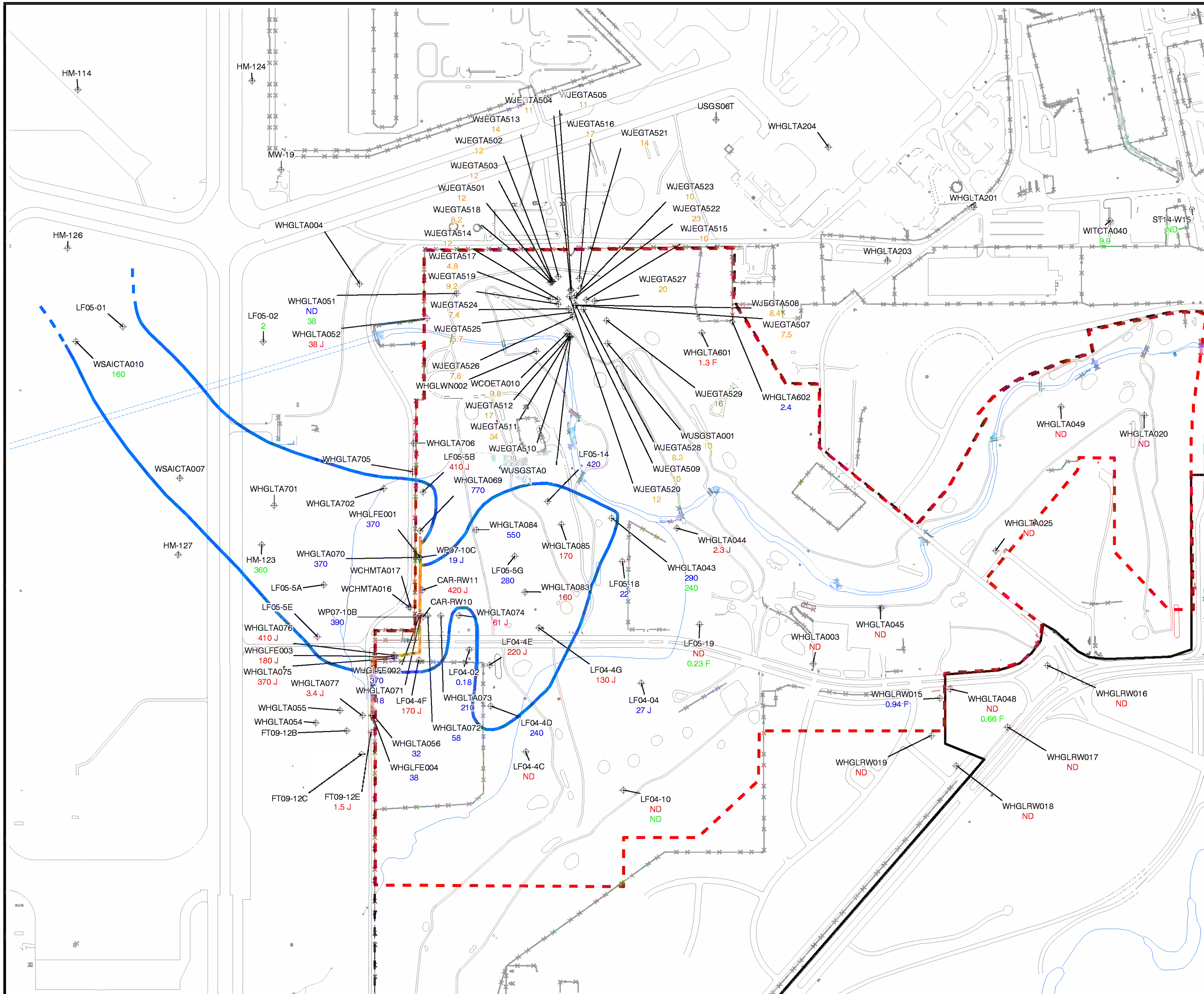
*Former Carswell AFB, Texas*

# Figure 2.11 Southern Lobe *cis*-1,2-Dichloroethene Concentrations, Terrace Alluvium April - October 2004




## Legend

| | |
|---|---|
| (black dashed line) | NAS Fort Worth JRB (Carswell Field) |
| (black solid line) | Former Carswell Air Force Base |
| (blue line) | *cis*-1,2-DCE Concentration Contour (70 µg/L) |
| (red dashed line) | Risk Assessment/FFS Area |
| (orange line) | Permeable Reactive Barrier Location |
| (oval) | Solid Waste Management Unit |
| (shaded oval) | Area of Concern |
| (shaded box) | Building/Structure |
| ⌖ | Monitoring Well |
| 160 | PRB Semi-Annual Sampling Well (May 2004) |
| 7.5 | USGS Phytoremediation Sampling Well (July 2004) |
| 0.18 | PRB Semi-Annual Sampling Well (October 2004) |
| 240 | AFP 4 LTM Sampling Well (April 2004) |
| LF05-01 | Other Monitoring Well |
| F | The analyte was positively identified, but the associated value is below the PQL. |
| J | The analyte was positively identified, the quantitation is an estimation. |
| ND | Not detected at laboratory MDL of 0.5 µg/L. |

N

0 200 400 800
SCALE IN FEET

*Filename: X:/GSA002/DO_007/MAPS/ffs_s_lobe_tce_gw_plume/cisDCE_2004.mxd*
*Revised: 06/27/05 tbraswell*
*Project: GSA002-007-06-07-03*
*Map Source: HydroGeoLogic, Inc. GIS Database*

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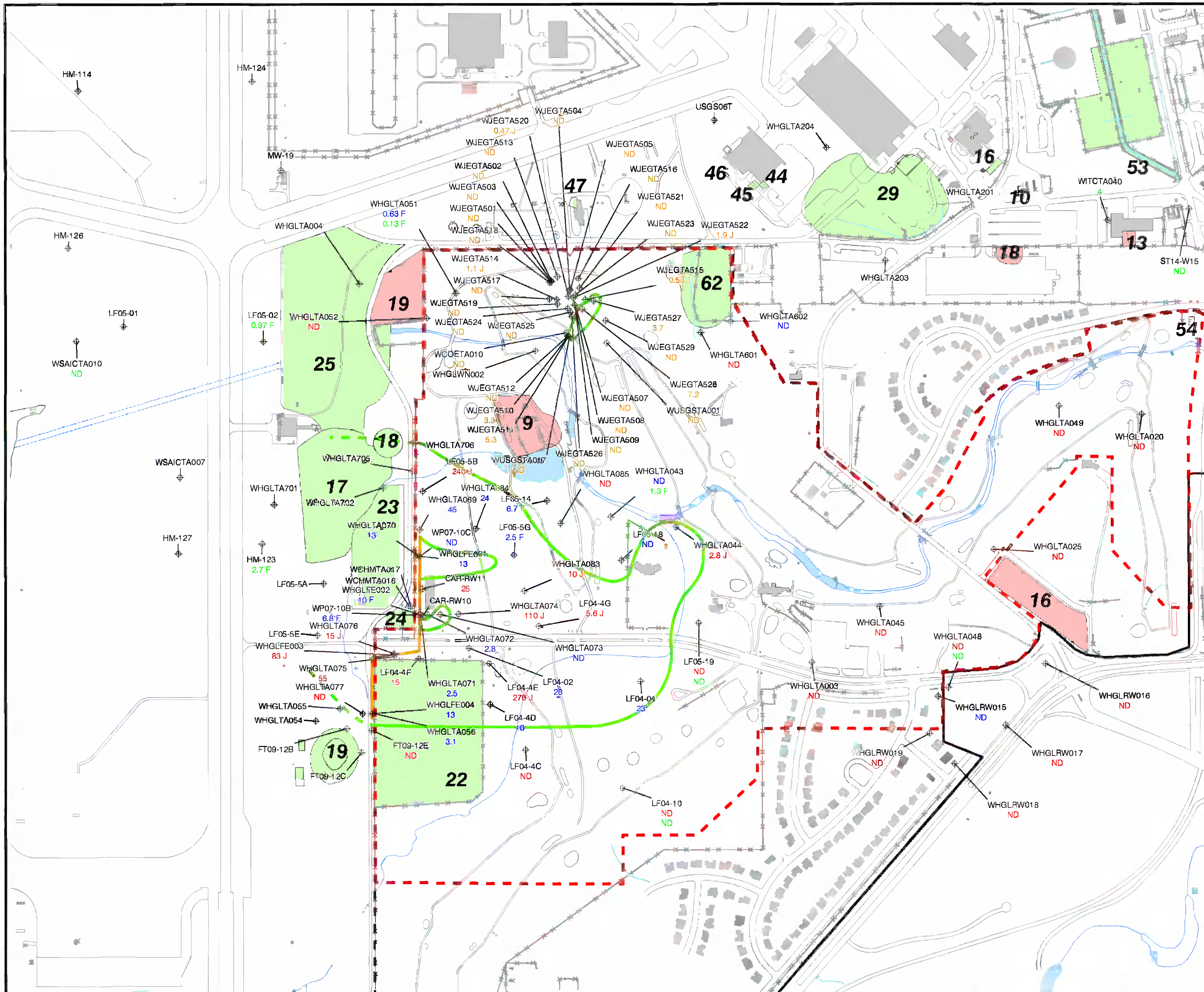
# Figure 2.12
# Southern Lobe
# Vinyl Chloride Concentrations
# Terrace Alluvium
# April - October 2004




## Legend

| | |
|---|---|
| - - - | NAS Fort Worth JRB (Carswell Field) |
| ——— | Former Carswell Air Force Base |
| ——— (green) | Vinyl Chloride Concentration Contour (2 µg/L) |
| - - - (red) | Risk Assessment/FFS Area |
| ——— (orange) | Permeable Reactive Barrier Location |
| (outline) | Solid Waste Management Unit |
| (shaded) | Area of Concern |
| (shaded) | Building/Structure |
| ⌖ | Monitoring Well |
| 25 | PRB Semi-Annual Sampling Well (May 2004) |
| 5.3 | USGS Phytoremediation Sampling Well (July 2004) |
| 3.1 | PRB Semi-Annual Sampling Well (October 2004) |
| 1.3 F | AFP 4 LTM Sampling Well (April 2004) |
| LF05-01 | Other Monitoring Well |
| F | The analyte was positively identified, but the associated value is below the PQL. |
| J | The analyte was positively identified, the quantitation is an estimation. |
| ND | Not detected at laboratory MDL of 0.5 µg/L. |

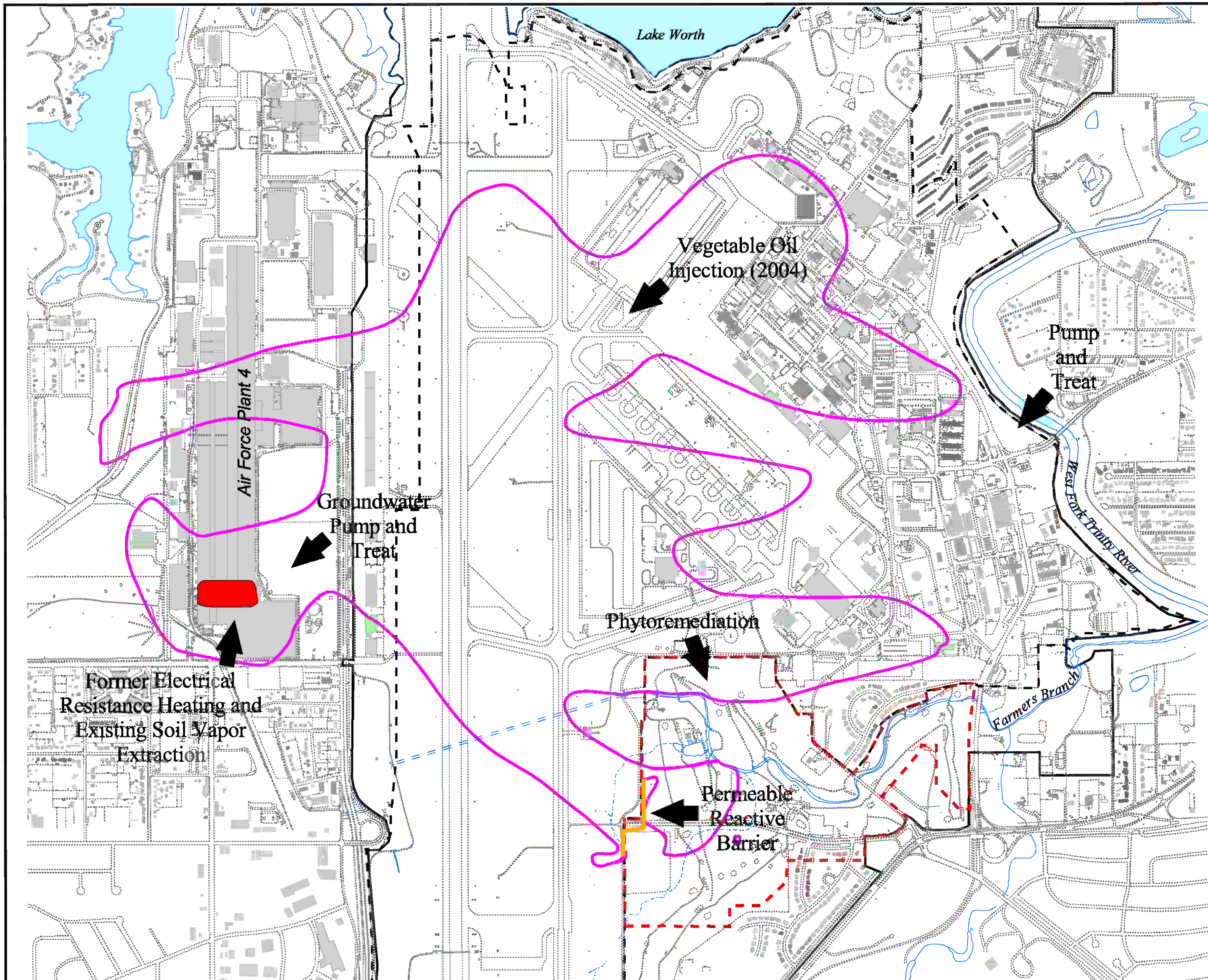
N

0 200 400 800
SCALE IN FEET

*Filename: X:/GSA002/DO_007/MAPS/ffs_s_lobe_tce_gw_plume/ VC_2004.mxd*
*Revised: 06/27/05 TH*
*Project: GSA002-007-06-07-03*
*Map Source: HydroGeoLogic, Inc. GIS Database*

HydroGeoLogic, Inc.—Focused Feasibility Study
Former Carswell AFB, Texas

**Figure 2.13**
**Current Remediation Strategies**
**Air Force Plant 4 and the**
**Former Carswell AFB**




**Legend**

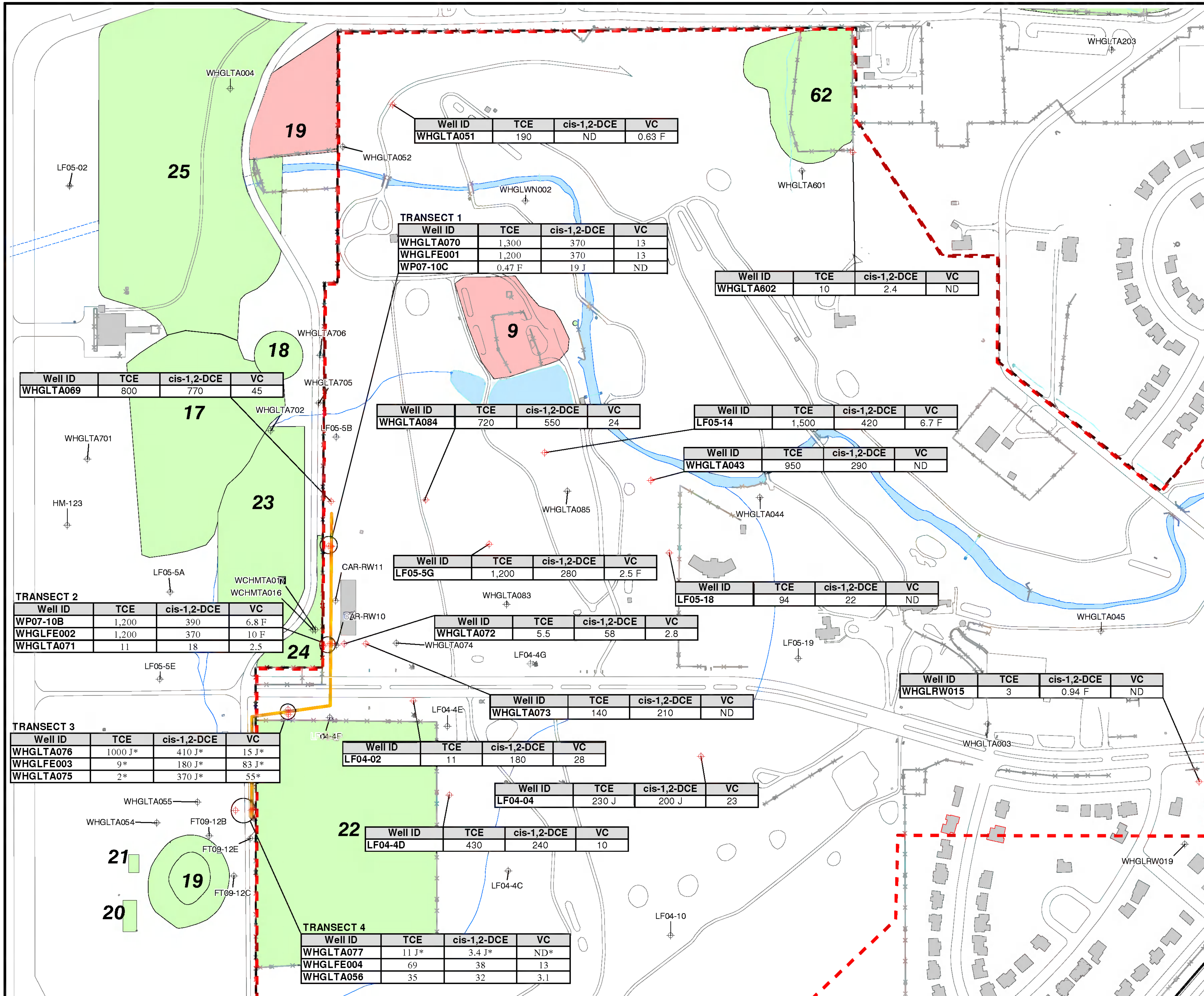
- Risk Assesment / FFS Area
- NAS Fort Worth JRB (Carswell Field)
- Former Carswell Air Force Base
- TCE Plume Boundary (5 μg/L) Provided by Earth Tech from April-May 2004 AFP 4 Basewide Sampling
- AFP4 TCE Source Area (As Provided by Shaw Environmental)

N

600 0 600 1200
SCALE IN FEET

*Filename: X:\GSA002\DO_007\Maps\ffs_s_lobe_tce_gw_plume\remediation_strategy.apr*
*Project: GSA002-007-06-07-02*
*Revised: 06/29/05 TH*
*Map Source: HydroGeoLogic, Inc. GIS Database, 2002*
*Jacobs Engineering*

# Figure 2.14
# PRB Performance Sampling Results October 2004




| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA051 | 190 | ND | 0.63 F |

TRANSECT 1

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA070 | 1,300 | 370 | 13 |
| WHGLFE001 | 1,200 | 370 | 13 |
| WP07-10C | 0.47 F | 19 J | ND |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA602 | 10 | 2.4 | ND |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA069 | 800 | 770 | 45 |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA084 | 720 | 550 | 24 |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| LF05-14 | 1,500 | 420 | 6.7 F |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA043 | 950 | 290 | ND |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| LF05-5G | 1,200 | 280 | 2.5 F |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| LF05-18 | 94 | 22 | ND |

TRANSECT 2

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WP07-10B | 1,200 | 390 | 6.8 F |
| WHGLFE002 | 1,200 | 370 | 10 F |
| WHGLTA071 | 11 | 18 | 2.5 |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA072 | 5.5 | 58 | 2.8 |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLRW015 | 3 | 0.94 F | ND |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA073 | 140 | 210 | ND |

TRANSECT 3

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA076 | 1000 J* | 410 J* | 15 J* |
| WHGLFE003 | 9* | 180 J* | 83 J* |
| WHGLTA075 | 2* | 370 J* | 55* |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| LF04-02 | 11 | 180 | 28 |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| LF04-04 | 230 J | 200 J | 23 |

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| LF04-4D | 430 | 240 | 10 |

TRANSECT 4

| Well ID | TCE | cis-1,2-DCE | VC |
|---|---|---|---|
| WHGLTA077 | 11 J* | 3.4 J* | ND* |
| WHGLFE004 | 69 | 38 | 13 |
| WHGLTA056 | 35 | 32 | 3.1 |

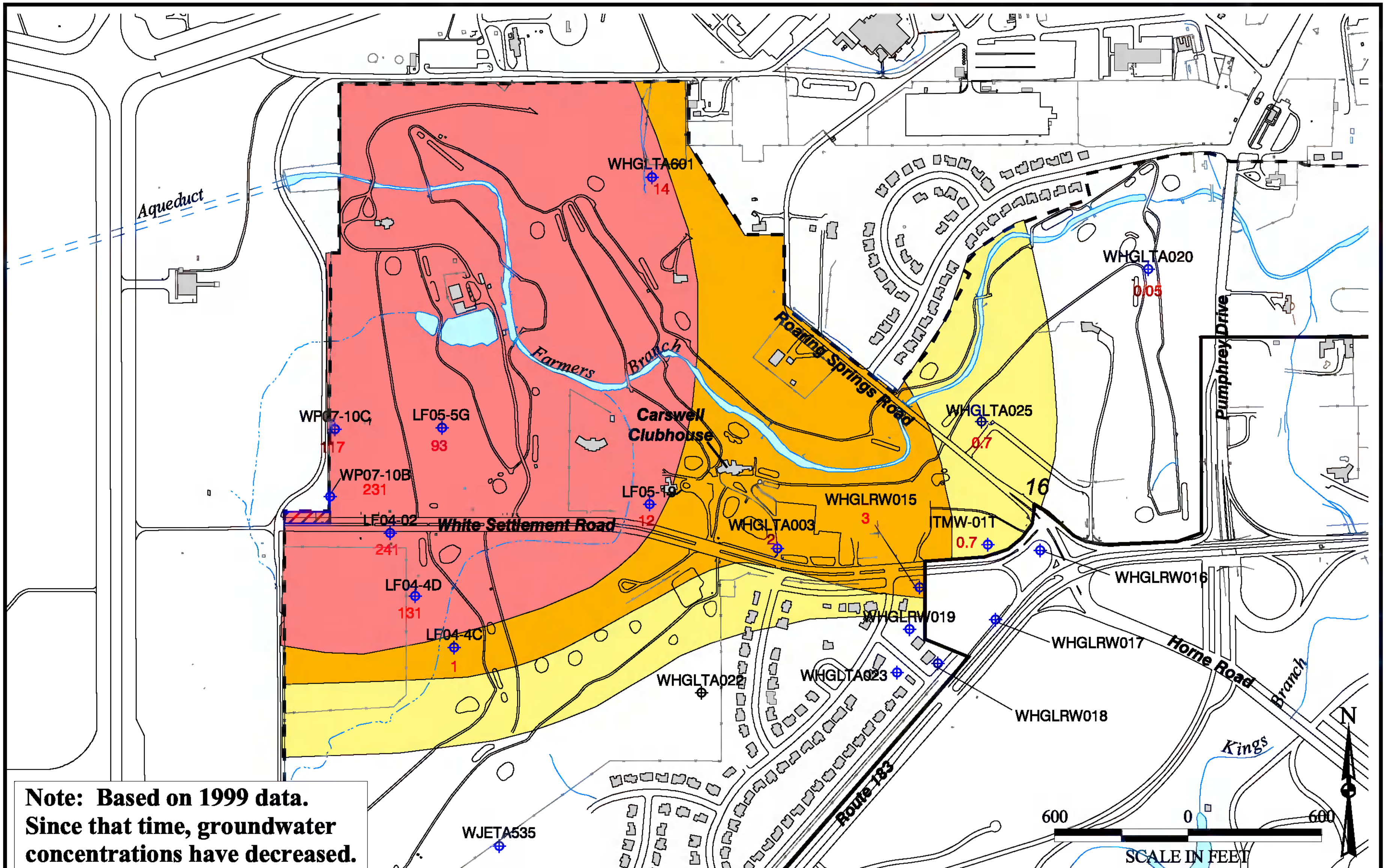
## Legend

- NAS Fort Worth JRB (Carswell Field)
- Former Carswell Air Force Base
- Risk Assessment/FFS Area
- Permeable Reactive Barrier Location
- Building/Structure
- Monitoring Well
- Monitoring Well Sampled
- F — The analyte was positively identified, but the associated value is below PQL.
- J — The analyte was positively identified, the quantitation is an estimation.
- ND — Not detected at laboratory MDL of 0.5 µg/L.
- Concentrations reported in µg/L
- * Well was not sampled during October 2004 therefore May 2004 data is reported
- Area of Concern
  - 9 Golf Course Maintenance Yard
  - 19 Fire Training Area No. 2
- Solid Waste Management Unit
  - 17 Landfill No.7
  - 18 Fire Training Area No. 1
  - 19 Fire Training Area No. 2
  - 20 Waste Fuel Storage Tank
  - 21 Waste Oil Tank
  - 22 Landfill No. 4
  - 23 Landfill No. 5
  - 24 Waste Burial Area No. 7
  - 25 Landfill No. 8
  - 62 Landfill No. 6

N

0 100 200 400
SCALE IN FEET

*Filename: X:/GSA002/DO_007/MAPS/ffs_s_lobe_tce_gw_plume/PRB_PerformSampResults.mxd*
*Revised: 06/17/05 tbraswell*
*Project: GSA002-007-06-07-03*
*Map Source: HydroGeoLogic, Inc. GIS Database*




**Note: Based on 1999 data. Since that time, groundwater concentrations have decreased.**

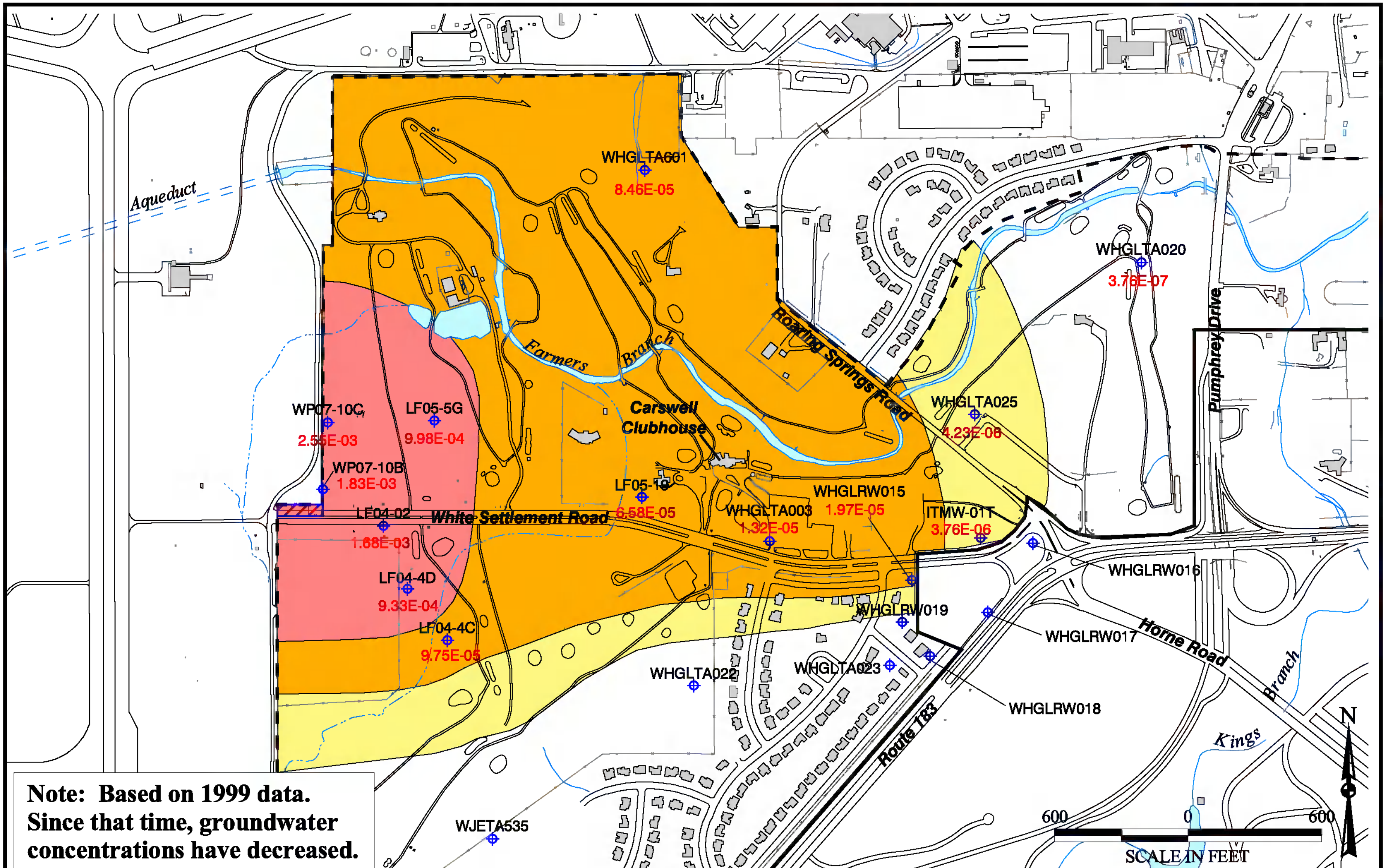
*Filename: X:\GSA002\DO_007\Maps\ffs_s_lobe_tce_gw_plume\ffs_organics_non-carc.apr*
*Project: GSA002-007-06-07-02*
*Revised: 06/29/05 TH*
*Source: HydroGeoLogic, Inc. ArcView GIS Database, 2002*

**Legend**

- NAS Fort Worth JRB (Carswell Field)
- Former Carswell Air Force Base
- Transferred Property
- Monitoring Wells
- 93 — HI
- Hazard Index: 10, 1, 0.1

**Figure 2.15**

**Cumulative Organic Non-Carcinogenic Hazard Isopleth For Residents**




**Note: Based on 1999 data. Since that time, groundwater concentrations have decreased.**

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*Project: GSA002-007-06-07-03*
*Revised: 06/30/05 TB*
*Source: HydroGeoLogic, Inc. ArcView GIS Database, 2002*

**Legend**

| Symbol | Description |
| --- | --- |
| Dashed line | NAS Fort Worth JRB (Carswell Field) |
| Solid line | Former Carswell Air Force Base |
| Grey | Transferred Property |
| Monitoring well symbol | Monitoring Wells |
| 9.98E-04 | ILCR |
| $10^{-4}$ / $1^{-5}$ / $0.1^{-6}$ | Incremental Lifetime Cancer Risk |

**Figure 2.16**

**Cumulative Organic Carcinogenic Risk Isopleth For Residents**

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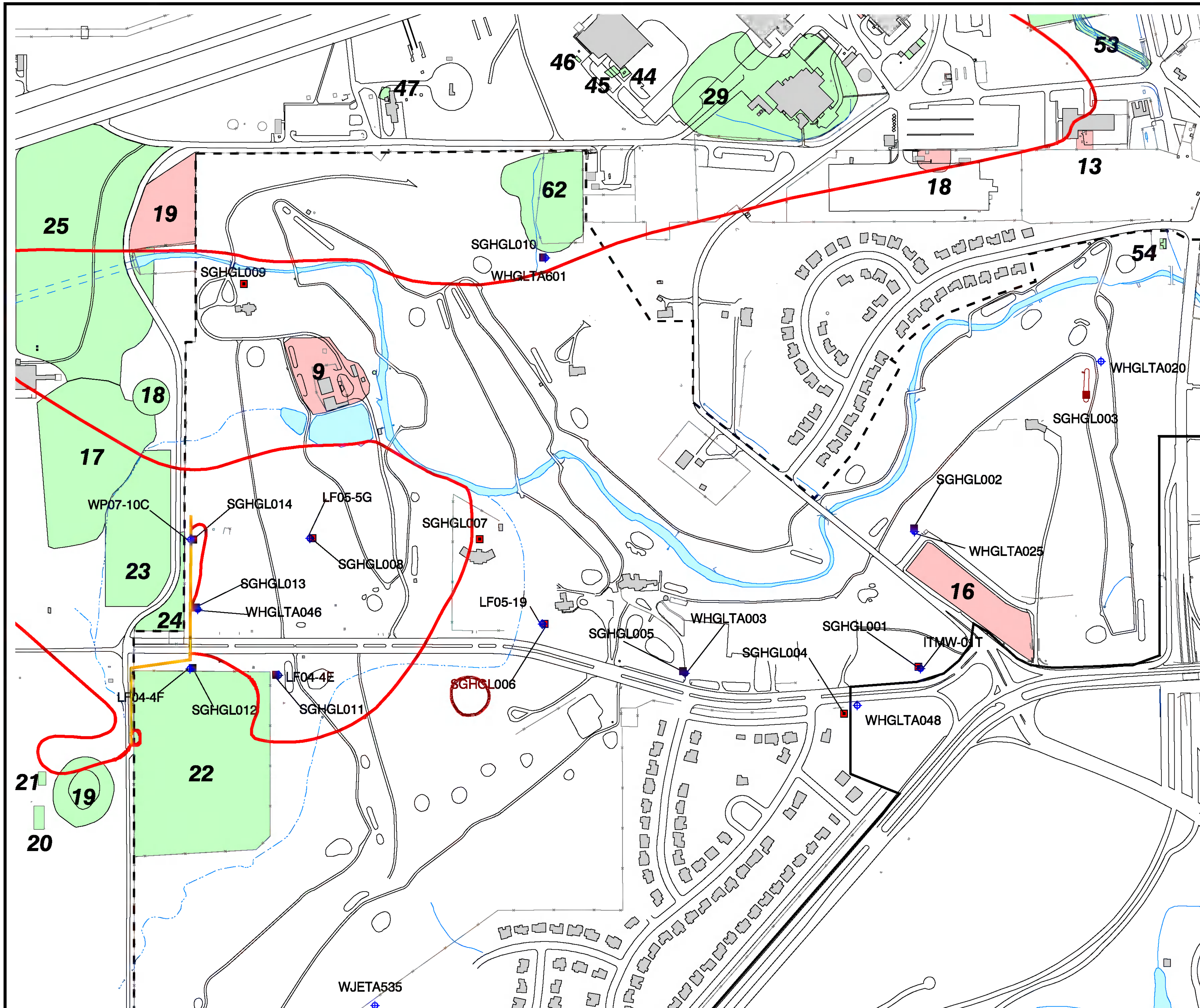
*Former Carswell AFB, Texas*

# Figure 2.17

## Soil Gas Sampling Locations




### Legend

- NAS Fort Worth JRB (Carswell Field)
- Former Carswell Air Force Base
- Trichloroethene Concentration Contour (5 µg/L)
- Permeable Reactive Barrier
- Monitoring Wells
- Soil Gas Sampling Location

**Area of Concern**

9 Golf Course Maintenance Yard
13 O/W Separator
16 Family Camp
18 Suspected Former Fire Training Area
19 Suspected Former Fire Training Area

**Solid Waste Management Unit**

17 Landfill No. 7
22 Landfill No. 4
23 Landfill No. 5
24 Waste Burial Area
25 Landfill No. 8
29 Landfill No. 2
62 Landfill No. 6

500 0 500 1000
SCALE IN FEET

N

*Filename: X:\GSA002\DO_007\ffs_s_lobe_TCE_GW_plume \soil_gas.apr*
*Project: GSA002-007-06-07-03*
*Revised: 06/27/05 TH*
*Map Source:HGL ArcView GIS Database 2002*

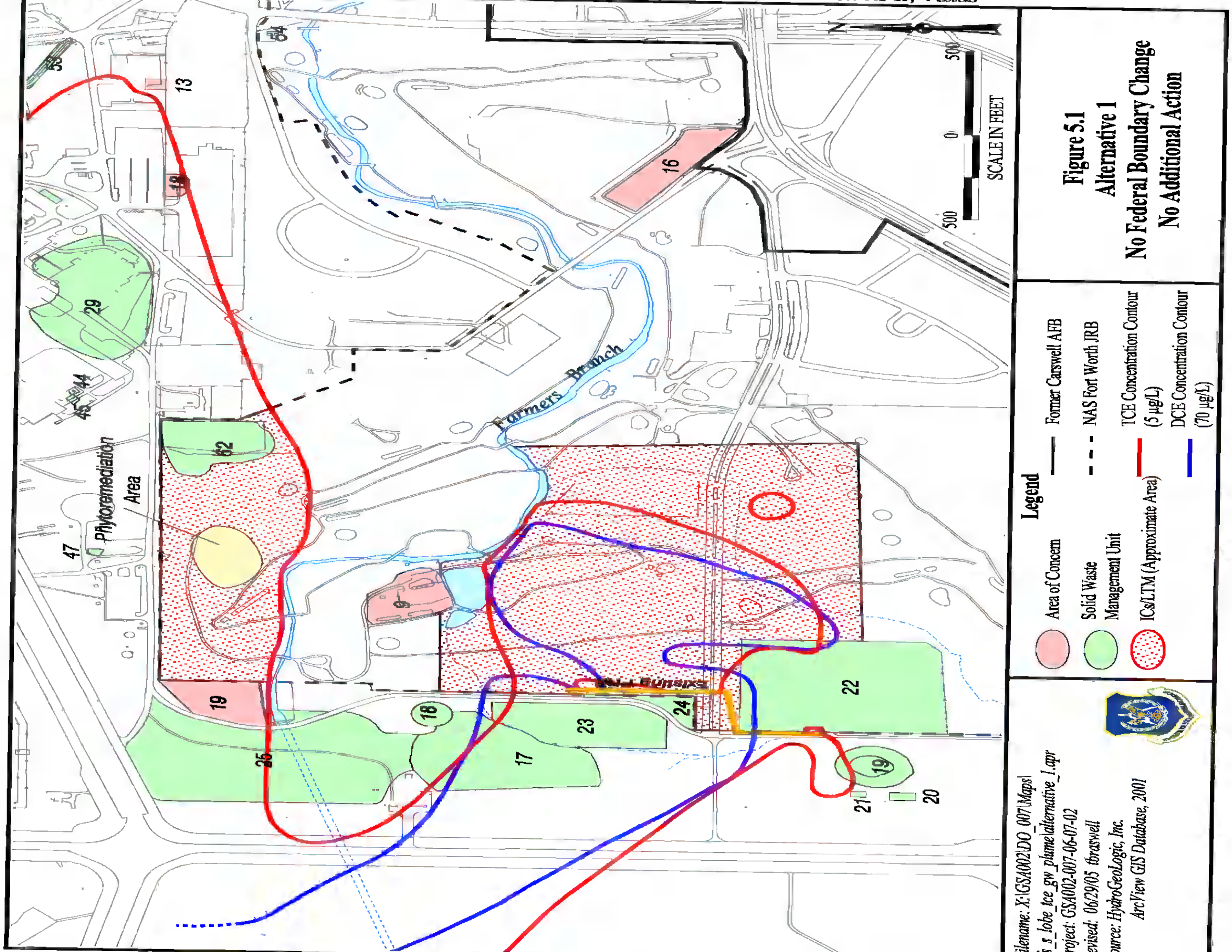
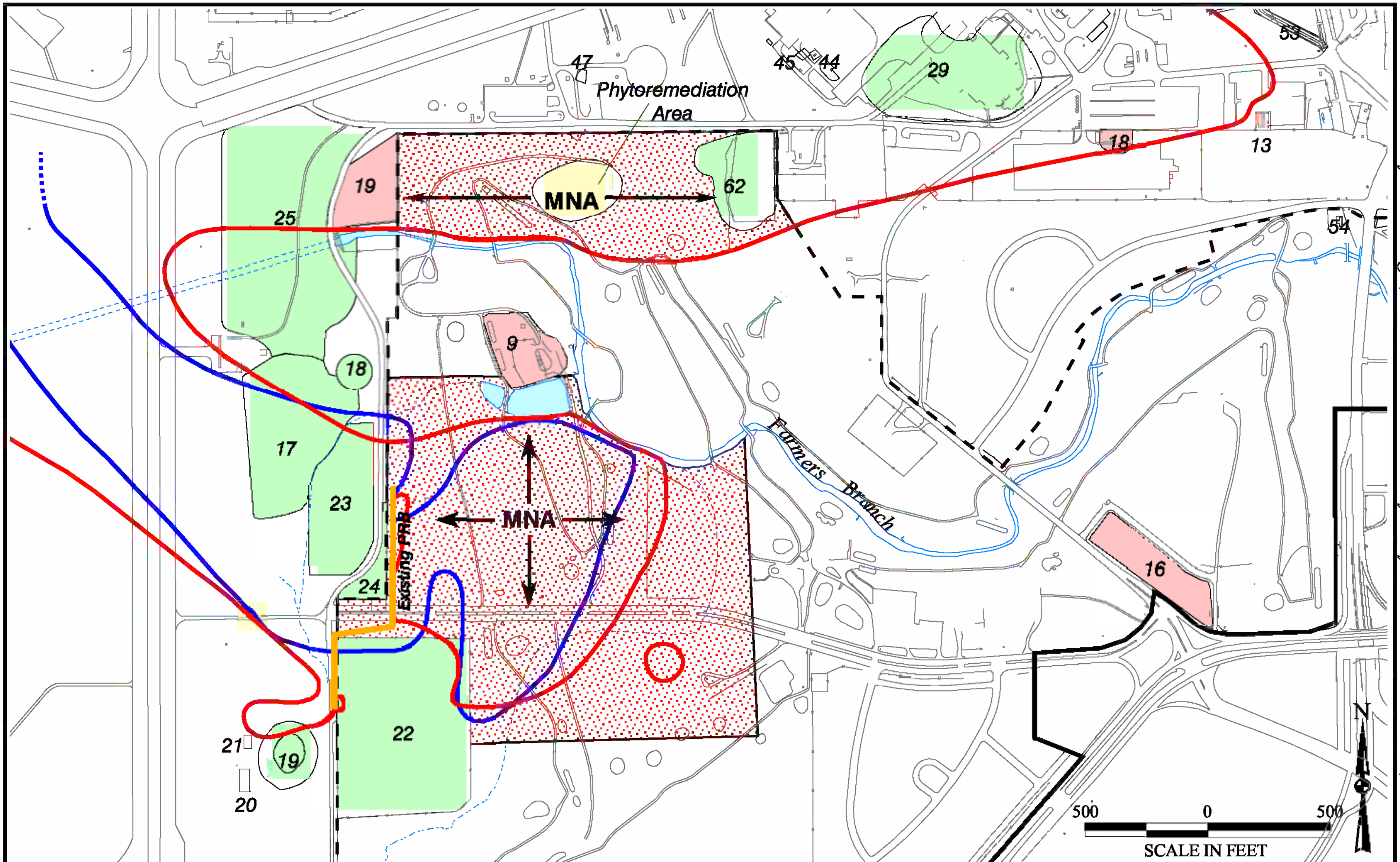


Figure 5.1
Alternative 1
No Federal Boundary Change
No Additional Action
Legend
Area of Concern
Solid Waste Management Unit
ICs/LTM (Approximate Area)
Former Carswell AFB
NAS Fort Worth JRB
TCE Concentration Contour (5 µg/L)
DCE Concentration Contour (70 µg/L)
SCALE IN FEET
500 0 500
Farmers Branch
Phytoremediation Area
Filename: X:\GSA002\DO_007\Maps\ffs_s_lobe_tce_gw_plume\alternative_1.apr
Project: GSA002-007-06-07-02
Revised: 06/29/05 tbraswell
Source: HydroGeoLogic, Inc.
ArcView GIS Database, 2001




*Air Force Center for Environmental Excellence*

*HydroGeoLogic, Inc.—Focused Feasibility Study—Former Carswell AFB, Texas*

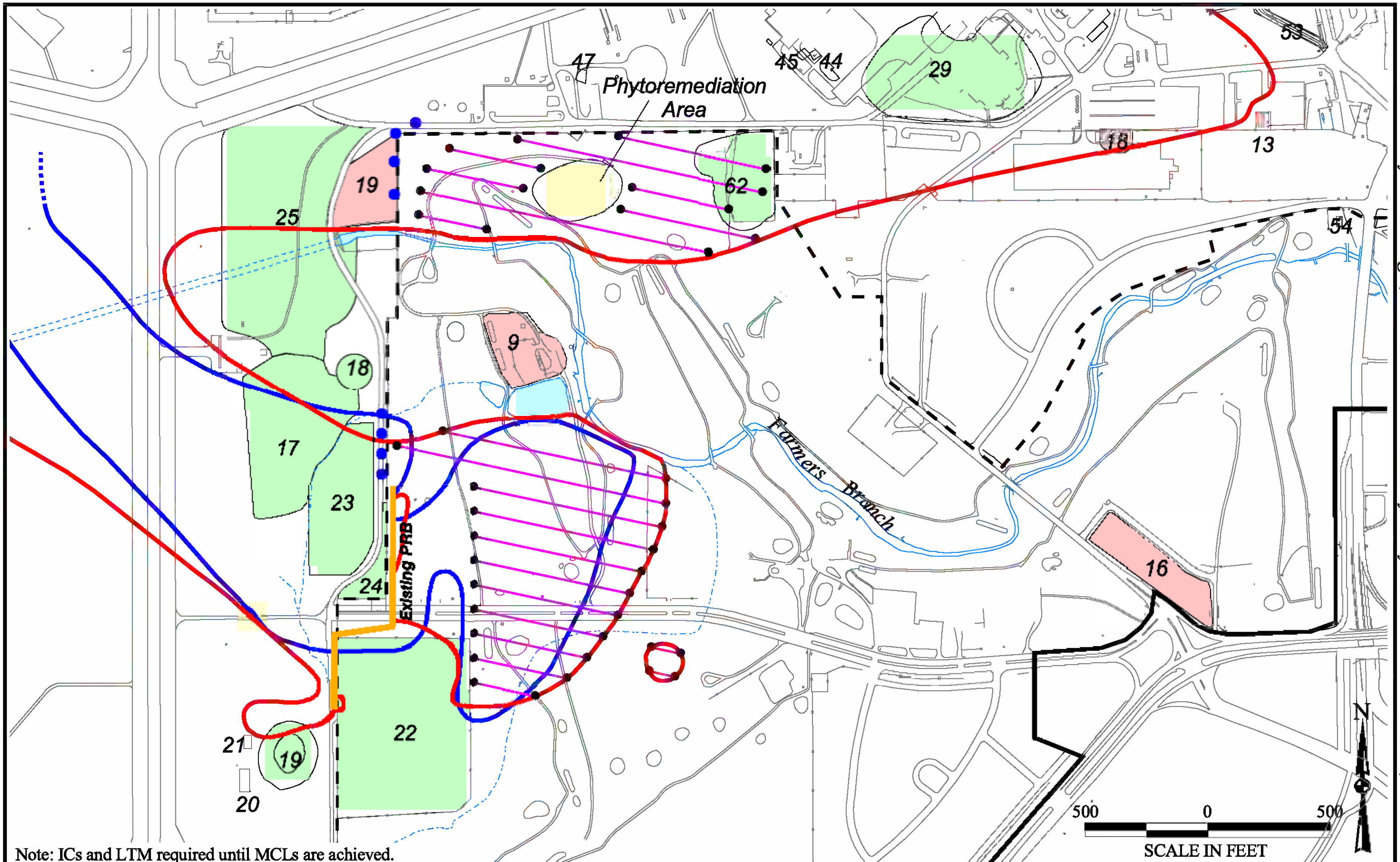
*Filename: X:\GSA002\DO_007\Maps \ffs_s_lobe_tce_gw_plume \alternative_2.apr*
*Project: GSA002-007-06-07-03*
*Revised: 06/29/05 tbraswell*
*Source: HydroGeoLogic, Inc.*
*ArcView GIS Database, 2003*

**Legend**

- Area of Concern
- Solid Waste Management Unit
- ICs/LTM (Approximate Area) (Until MCLs are achieved)
- Former Carswell AFB
- NAS Fort Worth JRB
- TCE Concentration Contour (5 µg/L)
- DCE Concentration Contour (70 µg/L)

MNA = Monitored Natural Attenuation

**Figure 5.2**
**Alternative 2**
**Monitored Natural Attenuation**

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*ffs_s_lobe_tce_gw_plume\alternative_3.apr*
*Project: GSA002-007-06-07-03*
*Revised: 06/29/05 tbraswell*
*Source: HydroGeoLogic, Inc.*
*ArcView GIS Database, 2001*

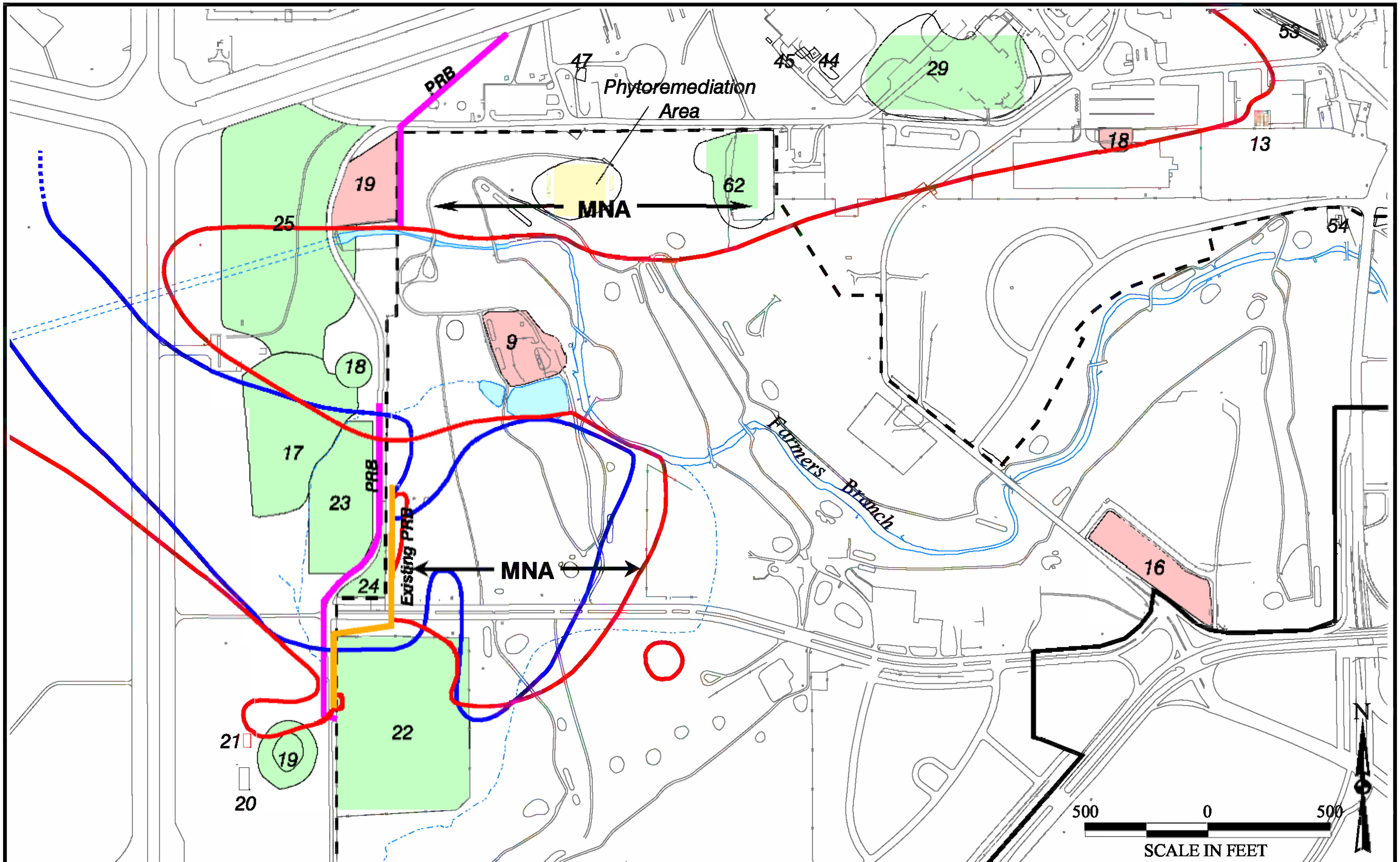
**Legend**

- Area of Concern
- Solid Waste Management Unit
- Former Carswell AFB
- NAS Fort Worth JRB
- TCE Concentration Contour (5 µg/L)
- DCE Concentration Contour (70 µg/L)
- Methane/Air Injection Well
- Pumping Well

**Figure 5.3**
**Alternative 3**
**Pump and Treat with Cometabolic Biosparging**

*Air Force Center for Environmental Excellence*

*HydroGeoLogic, Inc.—Focused Feasibility Study—Former Carswell AFB, Texas*

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Project: GSA002-007-06-07-03
Revised: 06/29/05 tbraswell
Source: HydroGeoLogic, Inc.
ArcView GIS Database, 2001

**Legend**

- Area of Concern
- Solid Waste Management Unit
- Former Carswell AFB
- NAS Fort Worth JRB
- TCE Concentration Contour (5 µg/L)
- DCE Concentration Contour (70 µg/L)
- **MNA** Monitored Natural Attenuation

**Figure 5.4**
**Alternative 4**
**Additional PRBs and MNA**

# APPENDIX A

# DATA GAPS INVESTIGATION

# APPENDIX A.1

# AQUIFER TESTS DATA

# APPENDIX A.1

# AQUIFER CHARACTERIZATION SUMMARY

## A.1.1 Aquifer Characterization Introduction

The following information provides a summary of October 2000 pump test and February 2001 slug test activities performed at NAS Fort Worth and the BRAC area in support of the Focused Feasibility Study and other planned remediation activities at the site. Printouts of the Aqtesolv® summary reports are included as attachments to this appendix.

## A.1.2 Aquifer Characterization for the Focused Feasibility Study

### Pump Test Summary

A groundwater pump test was performed at the Former Carswell AFB on October 9 through 13, 2000. The pump test was performed to determine the general hydraulic characteristics of the terrace alluvium aquifer in the vicinity of the designated pumping well (WHGLTA046). Well WHGLTA046 is located on the former Carswell AFB golf course, adjacent to the eastern perimeter of the NAS Fort Worth JRB. The well was installed approximately one week prior to performing the pump test and was placed in an area immediately off-site and hydraulically down gradient of the NAS Fort Worth JRB property boundary. The well was placed at this location based on the elevated dissolved chlorinated hydrocarbon concentrations found in this portion of the site. A better understanding of the aquifer characteristics in this area is necessary to evaluate potential remediation options for controlling, and ultimately remediating, the dissolved hydrocarbon plume. A second well, WHGLTA047 was installed 47 feet south east of the pumping well to act as an observation well. Existing monitoring wells WP07-10A, WP07-10B, WP07-10C, WITCTA057, WITCTA058, LF04-4E, LF-04-4F, and recovery wells CAR-RW08, CAR-RW10, and CAR-RW11 were used as observation wells during the pump test. Only wells WHGLTA047, WP07-10B, CAR-RW10, and the pumping well (WHGLTA046) provided usable data at the conclusion of the pump test. The remaining wells did not show sufficient drawdown during the test to provide interpretable data. Table A.1-1 lists the tested wells and their associated transmissivity and hydraulic conductivity values, expressed in square feet per day ($ft^2/d$) and feet per day (ft/d), respectively. Figure A.1-1also displays the values obtained during both the pump test and the subsequent slug test.

The pump test was performed in two phases. The first phase consisted of a step-drawdown test to determine the optimal pumping rate for the 72 hour constant rate test. Self contained Troll™ pressure transducers were placed in the pumping well, WHGLTA047, CAR-RW10, and WP07-10B to record groundwater drawdown during the step test. An electric ½ horsepower submersible positive displacement Grundfos™ pump was used to perform the test. The pump discharge was plumbed into the recovery well CAR-RW10 discharge line, upstream of the electronic flow meter and downstream of the one-way flow valve. The plumbing allowed use

# Table A.1-1
# Aquifer Test Summary
# NAS Fort Worth JRB, Texas

| Well | Distance to Pumping Well (ft) | Solution (Method) | T ($ft^2$/day) | S | K (ft/day) |
|---|---|---|---|---|---|
| **Pump Test Wells** | | | | | |
| WHGLTA046 (Pumping Well) | 0 | Theis | 1108.4 | NA | 110.84 |
| | | Cooper-Jacob | 1149.8 | NA | 114.98 |
| WHGLTA047 | 49.54 | Neuman | 1753.7 | 0.0387 | 175.37 |
| | | Theis | 1765.4 | 0.0868 | 176.54 |
| | | Cooper-Jacob | 1843.3 | 0.0725 | 184.33 |
| WP07-10B | 49.14 | Neuman | 1138.9 | 0.0203 | 113.89 |
| | | Theis | 1138.9 | 0.0427 | 113.89 |
| | | Cooper-Jacob | 1270 | 0.0341 | 127.00 |
| CAR-RW10 | 22.65 | Neuman | 1092.5 | 0.0342 | 109.25 |
| | | Theis | 1082.6 | 0.0374 | 108.26 |
| | | Cooper-Jacob | 1074.1 | 0.0331 | 107.41 |
| **Slug Test Wells** | | | | | |
| WP07-10A | | Bouwer & Rice | | | 78.02 |
| WP07-10C | | Bouwer & Rice | | | 54.33 |
| WHGLTA701 | | Bouwer & Rice | | | 42.54 |
| WHGLTA705 | | Bouwer & Rice | | | 7.787 |
| WHGLTA706 | | Bouwer & Rice | | | 11.18 |
| WHGLRW016 | | Bouwer & Rice | | | 96.01 |
| WHGLRW017 | | Bouwer & Rice | | | 314.1 |
| WHGLRW019 | | Bouwer & Rice | | | 99.75 |
| WHGLTA002 | | Bouwer & Rice | | | 9.737 |
| WHGLTA048 | | Bouwer & Rice | | | 9.963 |
| WHGLTA056 | | Bouwer & Rice | | | 51.16 |
| HM-123 | | Bouwer & Rice | | | 219.3 |
| ITMW-01T | | Bouwer & Rice | | | 318.1 |
| WITCTA057 | | Bouwer & Rice | | | 95.67 |
| FT08-11A | | Bouwer & Rice | | | 17.13 |
| LF05-5E | | Bouwer & Rice | | | 54.32 |

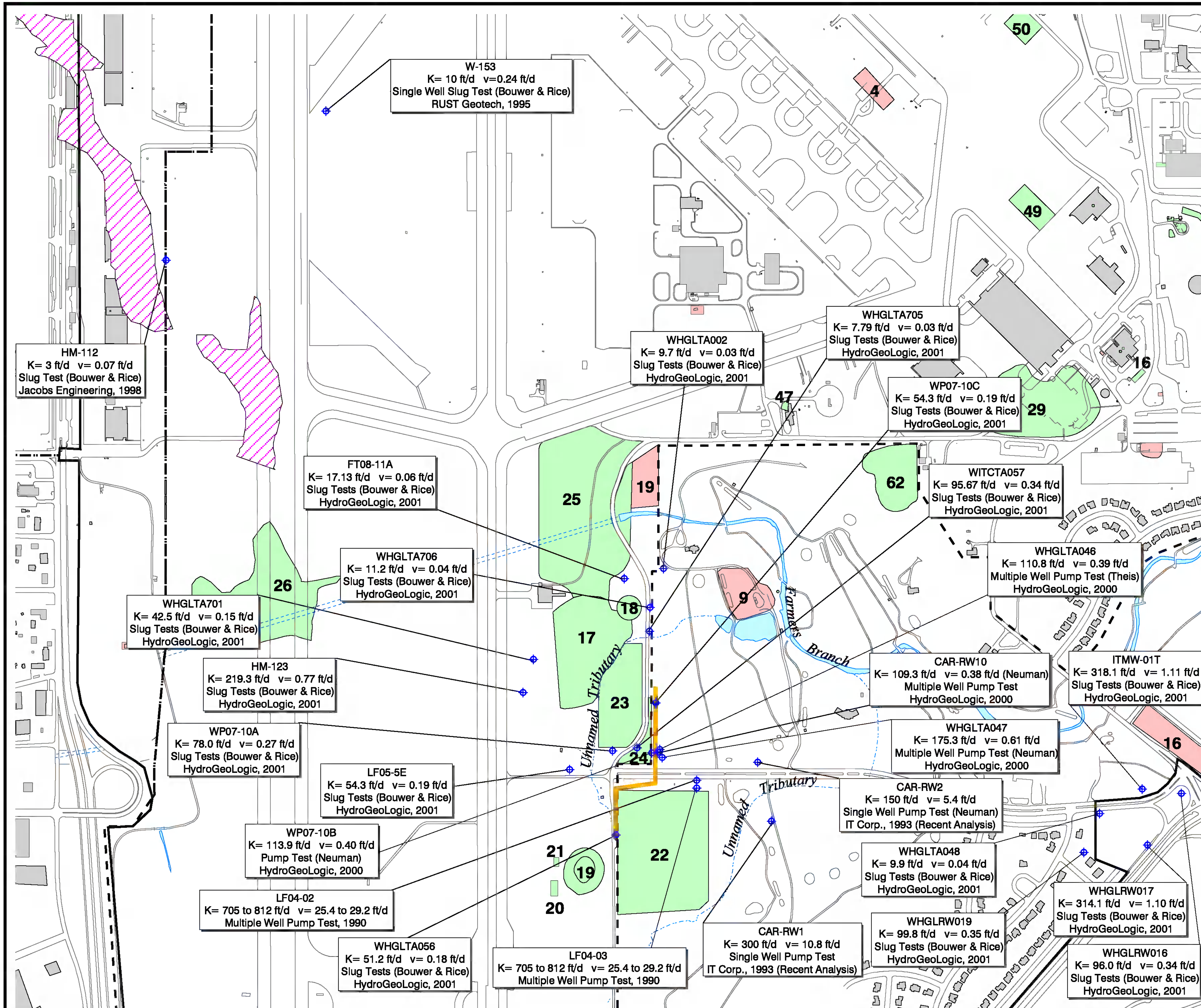
Note:
T - Transmissivity ($ft^2$/day)
S - Storativity
K - Hydraulic Conductivity (ft/day)

*HydroGeoLogic, Inc.—Focused Feasibility Study*
*Former Carswell AFB, Texas*

# Figure A.1-1

## Hydraulic Conductivity Data for PRB

U.S. Air Force Center for Environmental Excellence




## Legend

- NAS Fort Worth JRB (Carswell Field)
- Property Boundary of Air Force Plant 4
- Former Carswell Air Force Base
- Permeable Reactive Barrier Location
- Paluxy Window Area
- Solid Waste Management Unit
- Area of Concern
- Monitoring Well Location
- K Hydraulic Conductivity
- v Average Linear Velocity

N

400 0 400 800

SCALE IN FEET

*Filename: X:\Afc001\36bca\Report\hydraulic_conductivity_data.apr*
*Project: AFC001-036-05-03-01*
*Created: 03/07/01 jbelcher*
*Revised: 01/09/03 ACarrier*
*Map Source: HydroGeoLogic, Inc., ArcView GIS Database 2001*

HYDRO GeoLogic INC

of the existing recovery well's infrastructure and treatment of the pumping well's effluent through the LF4/5 treatment system. All existing recovery wells were shut down several days prior to initiating the pump test to allow aquifer stabilization and to avoid overloading the treatment system with the additional discharge created by the pump test well. The flow meter available at CAR-RW10 was capable of measuring flow to an accuracy of one-tenth of a gallon. Measuring flow downstream of the meter using a stopwatch and 5 gallon container tested the accuracy of the meter. The meter was found to be accurate within the capabilities of the stopwatch and container. The pump and associated system plumbing was tested on October 9, 2000 for leaks and functionality. The pump was operated in a range of 1 to 9 gpm (maximum pump setting). No leaks or other abnormalities were detected. The recovery well was allowed to recover to pre-test groundwater levels prior to initiating the step test.

The step test was started on October 10, 2000 at 1030 hrs. The extraction pump was activated in well WHGLTA046 at a flow rate of 2 gpm. The flow rate was increased to 4 gpm at 1205 hrs, and to 6 gpm at 1410 hrs. The pump was allowed to operate at 6 gpm until 1620 hrs. A calculation of drawdown taken from manual measurements of the drawdown revealed a sustained pumping rate of 6 gpm could potentially create greater drawdown in the well than was available in the water column (approximately 10 feet) if a steady state condition was not reached prior to 72 hrs. Based on these calculations, a pumping rate of 5.5 gpm was selected as the target pumping rate during the 72-hour constant rate test. Previous simulations using Aqtesolv® with estimated aquifer hydraulic properties showed that a pumping rate of 3 gpm or greater should provide measurable drawdown in observation wells located greater than 100 feet from the pumping well. The pump rate was set at the planned 5.5 gpm for the constant rate test immediately prior to shut down from the step test.

The 72-hour constant rate pump test was started at 2105 hrs on October 10, 2000. The pressure transducers placed in the observation wells were reset to record drawdown in logarithmic intervals beginning at 2100 hrs. The log interval was set to continue until a 20 minute interval between measurements was reached. At the 20 minute interval, the subsequent transducer readings were recorded on a 20 minute linear cycle. All wells were gauged manually with a Solinst® water level indicator capable of measuring water level in hundredths of feet. The manual measurements were taken to check the transducer data and act as backup measurements should one or more of the transducers fail during the test. The manual measurements were recorded on pump test data sheets, which are included as an attachment to this summary report. The manual well measurements were performed every two hours during the entire constant rate test. A shift schedule consisting of 2 people per shift was established to provide 24 hour coverage of the pump test. The pumping rate was monitored continuously during the first two hours of pumping to ensure the pump operated nominally and the flow rate did not vary from the pre-set rate of 5.5 gpm. The pump flow rate did not vary by more than 0.1 gpm during any portion of the test. No other pumping or discharge/treatment related difficulties were encountered during the test. All the Troll™ pressure transducers worked normally during the test except for an initial start-up problem with the transducer used in well WHGLTA047 during the step test. This transducer would not start as programmed for the constant rate test and was substituted with a different transducer. The malfunctioning transducer was diagnosed as having a cable connection problem that was remedied by substituting the programming cable with a replacement cable. The transducer was then placed in well LF04-4F to record background groundwater fluctuations.

Results obtained from the pump test show that the pumping well responded quickly to pump initiation and the greatest change in drawdown was observed within the first two minutes of pumping followed by a steady and consistent decline in the groundwater level. The maximum change in groundwater level at the pumping well was 2.3 feet from the pre-pumping level. The rate of groundwater level change decreased after approximately 50 hours of pumping and little change in the groundwater level was observed at the pumping well for the remaining 22 hours of pumping. The classic s-shaped curve associated with a delayed gravity response in an unconfined aquifer was not observed at the pumping well or the majority of the observation wells. Only observation well CAR-RW10 showed evidence of a delayed gravity response and this response occurred early in the test, within the first minute of pumping. The remaining observation wells with measurable drawdown showed a drawdown curve more commonly observed during a confined aquifer pump test. The wells with measurable drawdown data included WHGLTA047, CAR-RW10, WP07-10B, and the pumping well WHGLTA046. Drawdown was observed in observation wells as far as 250 feet from the pumping well, but the drawdown was not consistent and the data obtained from these wells and could not be used to provide a meaningful interpretation of aquifer characteristics within the vicinity of the wells. The observation wells with usable data all occur within an approximate fifty-foot radius of the pumping well.

The data obtained from the transducer data was transferred into a text format usable by Aqtesolv® for data evaluation. The data obtained by manual measurements were also formatted for use by the Aqtesolv® program. An unconfined solution using Neuman, Theis, and Cooper-Jacob methods was used to evaluate the pump test data. The Neuman method was the preferred method for the evaluation but results (transmissivity and specific storage) yielded by the other methods provided similar values. The average hydraulic conductivity in the pump test area was 126 ft/d (transmissivity of approximately 1260 $ft^2/d$ and specific yield of 0.03 to 0.05). This average was obtained by averaging the transmissivity values from the wells within a 50-foot radius of the pumping well.

### A.1.3 Aquifer Characterization for the Permeable Reactive Barrier Project

#### Slug Test Summary

Sixteen monitoring wells were slug tested at the NAS Fort Worth JRB/ Former Carswell AFB in support of the site characterization effort for the FFS and on-going aquifer evaluation for placement of the permeable reactive barrier (PRB). The slug tests were performed on February 14 through 17, 2001. The tests were performed on the NAS Fort Worth JRB property along the eastern property boundary, and along the eastern most perimeter of the former Carswell Air Force Base golf course, near State Route 183. The slug test results were used in conjunction with the pump test data to define the hydraulic characteristics of the

Terrace Alluvium aquifer located beneath the FFS area and for the design and placement the PRB.

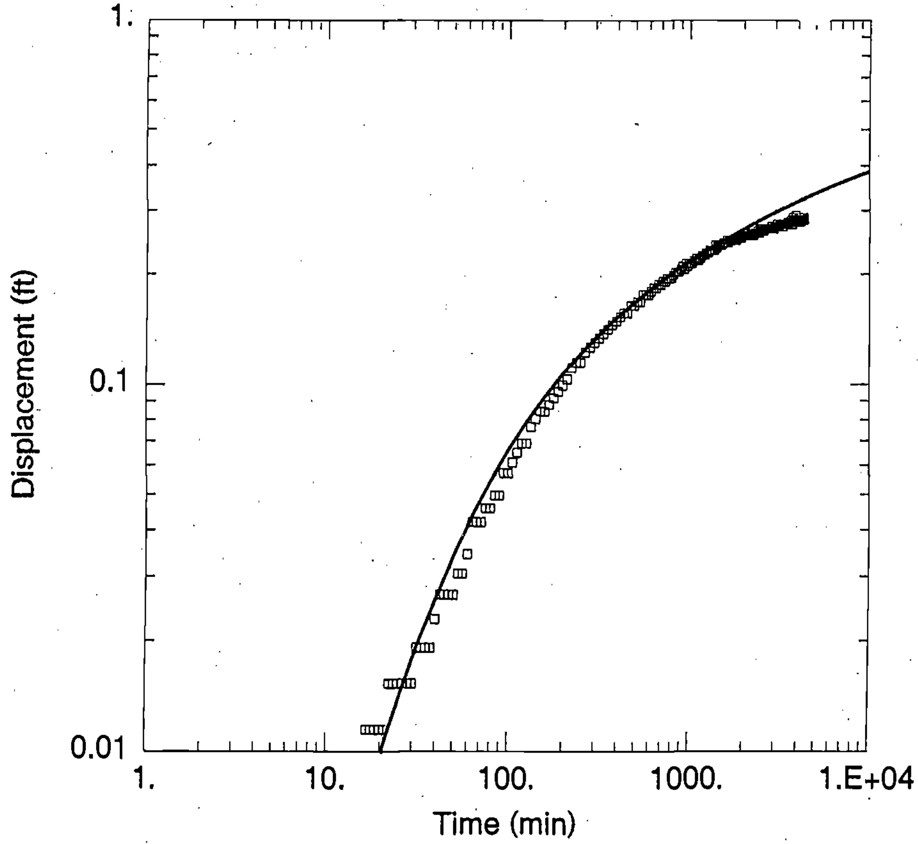
Table A.1-1 lists the tested wells and their associated hydraulic conductivity values, expressed in ft/d. All the wells tested are fully penetrating to bedrock and the water column present in each well was representative of the saturated aquifer thickness at the particular well location. The screen interval in each well varied from 5 to 20 feet, depending on depth to bedrock at the particular well location. Well data was obtained from the boring logs and well construction diagrams available for each tested well.

All of the tested wells were either 2-inch or 4-inch standard PVC constructed monitoring wells. The slug used for testing was a 4 foot long, 1-inch diameter PVC schedule 40 pipe filled with sand and sealed on each end with a cap. A stainless steel eyebolt was attached at one end of the slug to accommodate the rope used to raise and lower the slug in the well. Disposable nylon rope was used on the slug. A second, 3-foot long slug was constructed in an identical fashion as the 4-foot slug in the event the water column in a particular well was less than 4 feet in saturated thickness. An In-Situ Mini Troll™ self-contained pressure transducer was used to record the slug test data. The only manual measurements taken were the tested well's depth to water and a confirmation of the well's total depth. The pressure transducer was programmed to record changes in water levels at ½ second intervals. The measurement interval was kept short to record the expected rapid fluctuations in water levels in the highly transmissive sands that are typical of the saturated portion of the terrace alluvium. The transducer was programmed to start recording water levels prior to insertion of the first slug and continue recording until the transducer was manually shut off. Data collected by the transducer was downloaded to a laptop computer after each well was tested. The data was plotted on the laptop and qualitative analyses of the data were performed to determine if the captured data could be used for hydraulic characterization. If the data appeared to be usable, the transducer was reprogrammed for the next slug test.

Four slug tests were performed on each of the 16 slug test wells. The tests consisted of a slug insertion followed by well stabilization (recovery) then slug removal followed again by well stabilization. This procedure was repeated a second time in each well to provide four slug data sets per well (two in, two out). Most of the tested wells experienced full recovery and stabilization within five minutes of slug insertion or removal. It should be noted that the recovery of groundwater to static levels in the 4-inch diameter wells was generally quicker than was observed in the 2-inch diameter wells. A larger slug could have been used in the 4-inch wells to provide greater displacement of groundwater, which would have generated a slightly longer curve in the recovery data for the 4-inch wells. The greater groundwater displacement may have provided better data for evaluation of hydraulic conductivities in the vicinity of these wells. The data available for evaluation generally showed the aquifer in the vicinity of the 4-inch wells to have higher hydraulic conductivities than in the vicinity of the 2-inch wells. The higher values in the 4-inch wells may, in part, be attributed to greater well bore storage.

The transducer stores the data in binary format and required translation into text format for use in Aqtesolv®. Microsoft (MS) Excel® was used as an intermediate step between the binary transducer files and the text files. The data files were separated in MS Excel® into individual slug test components, providing four slug tests per well. The files were then converted into individual text files for each slug data set. Each of the four data files, per well, was input into Aqtesolv® and analyzed using both Bouwer & Rice and Hvorslev solutions. The results obtained using the Bouwer & Rice solution provided slightly lower hydraulic conductivities relative to the Hvorslev solution. The results provided on Table A.1-1 represent the hydraulic conductivities obtained through the Bouwer & Rice method. Bouwer & Rice is generally the preferred method to use for evaluating slug test data, particularly when the wells are fully penetrating through the saturated and the well design details are known. The values provided on Table A.1-1 consist of the values obtained from the best data set available from each well. In most cases, the conductivity values obtained from each well's data set were similar. The Aqtesolv® data simulations are provided as an attachment to this appendix.

Analysis of the slug test data provided conductivity results ranging from 7.8 ft/d at well WHGLTA705 to 318.1 ft/d at well ITMW-01T. The wells with the lower hydraulic conductivity values are located outside of the suspected paleochannel along the northern extent of the FFS location. The wells with the highest hydraulic conductivity are located within the generally accepted location of the paleochannel and at the eastern property boundary. The wells at the eastern property boundary, ITMW-01T for example, may also lie within the suspected paleochannel. The hydraulic conductivities in the general vicinity of the NAS Fort Worth JRB and BRAC area property boundary range between 7.79 ft/d (WHGLTA705) to 318.1 ft/d (ITMW-1T). The pump test performed near the NAS Fort Worth JRB and BRAC area boundary in October 2000 revealed an average hydraulic conductivity of 126 ft/d in this portion of the site. The pump test value is close to the 102 ft/d value obtained from well WP07-10C slug test data. Well WP07-10C is the well nearest the pump test location.




## WELL TEST ANALYSIS

Data Set: G:\...\10bt.aqt
Date: 08/02/02 Time: 13:54:21

## PROJECT INFORMATION

Company: HydroGeoLogic, Inc
Client: AFCEE
Project: AFC001-19BD
Test Location: Carswell AFB
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

$T = 1138.9\ ft^2/day$
$S = 0.02032$
$Sy = 0.02001$
$\beta = 4.$

## AQUIFER DATA

Saturated Thickness: 10. ft

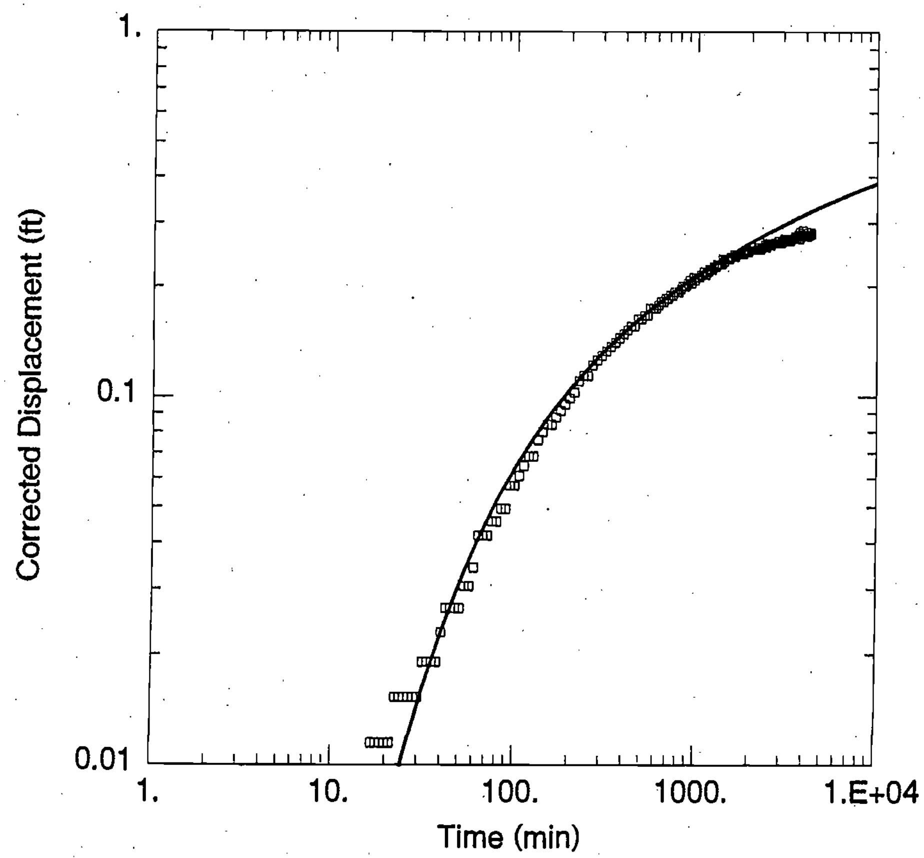
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA-046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| □ WP07-10B | 49.14 | 0 |




## WELL TEST ANALYSIS

Data Set: F:\...\10bth.aqt
Date: 08/19/02 Time: 15:12:46

## PROJECT INFORMATION

Company: HydroGeoLogic, Inc
Client: AFCEE
Project: AFC001-19BD
Test Location: Carswell AFB
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1138.9 $ft^2$/day
S = 0.0416
Kz/Kr = 0.1656
b = 10. ft

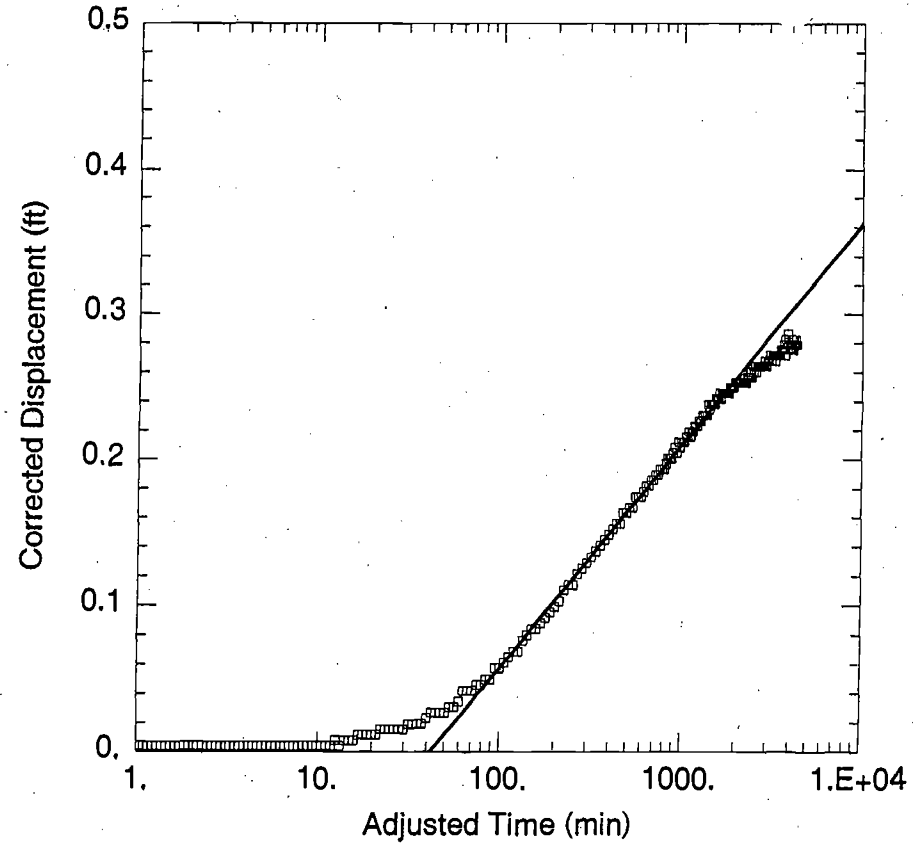
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA-046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| ▫ WP07-10B | 49.14 | 0 |




## WELL TEST ANALYSIS

Data Set: F:\...\10bCJ.aqt
Date: 08/19/02 Time: 15:18:14

## PROJECT INFORMATION

Company: HydroGeoLogic, Inc
Client: AFCEE
Project: AFC001-19BD
Test Location: Carswell AFB
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

$T = 1272.2\ ft^2/day$
$S = 0.03459$

## AQUIFER DATA

Saturated Thickness: 10. ft
Anisotropy Ratio (Kz/Kr): 0.1656

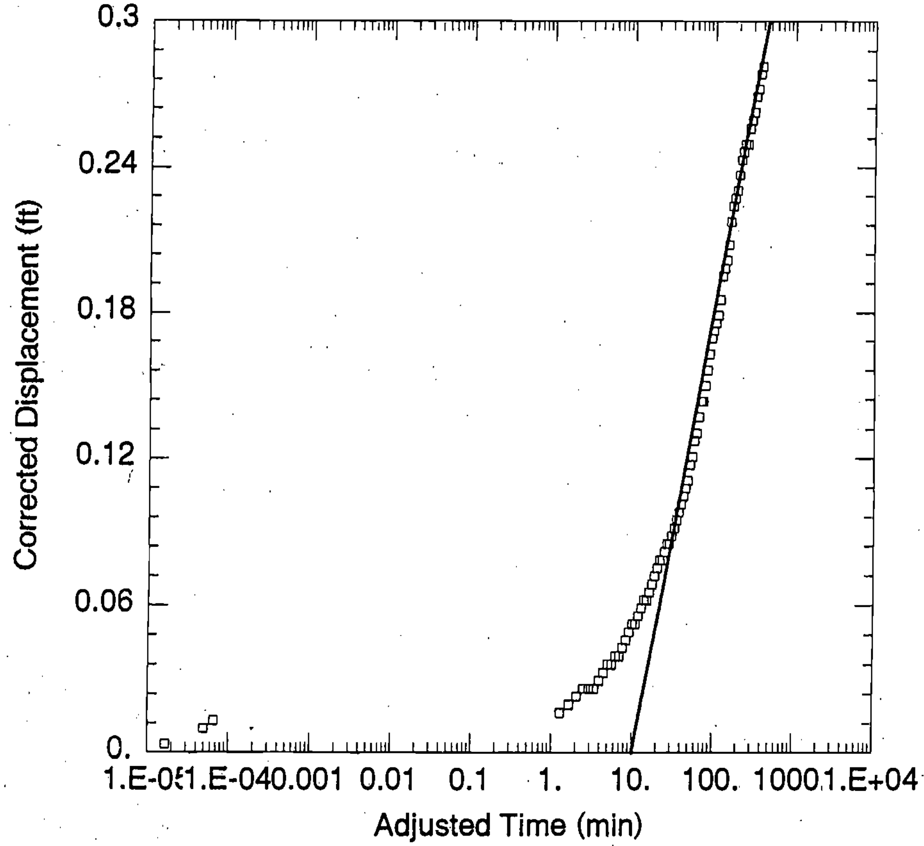
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA-046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| ▫ WP07-10B | 49.14 | 0 |




## AQUIFER TEST ANALYSIS

Data Set: G:\...\Car-rw10.aqt
Date: 08/02/02 Time: 13:54:12

## PROJECT INFORMATION

Company: HydroGeoLogic, Inc.
Client: AFCEE
Project: AFC001 DO35
Test Location: Carswell AFB, TX
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 1074.1 $ft^2$/day
S = 0.03309

## AQUIFER DATA

Saturated Thickness: 10. ft

Anisotropy Ratio (Kz/Kr): 1.174E-05

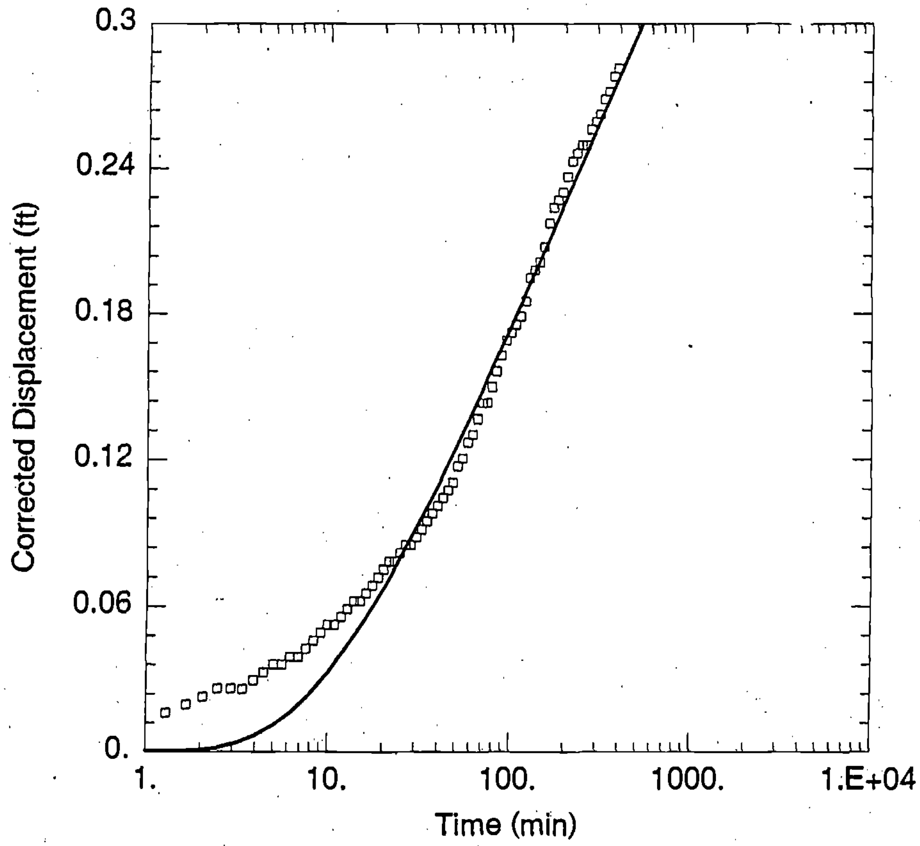
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA-046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| ▫ CAR-RW10 | 22.65 | 0 |




## AQUIFER TEST ANALYSIS

Data Set: G:\...\Car-rw10t.aqt
Date: 08/02/02 Time: 13:53:48

## PROJECT INFORMATION

Company: HydroGeoLogic, Inc.
Client: AFCEE
Project: AFC001 DO35
Test Location: Carswell AFB, TX
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1082.6 $ft^2$/day
S = 0.03738
Kz/Kr = 1.174E-05
b = 10. ft

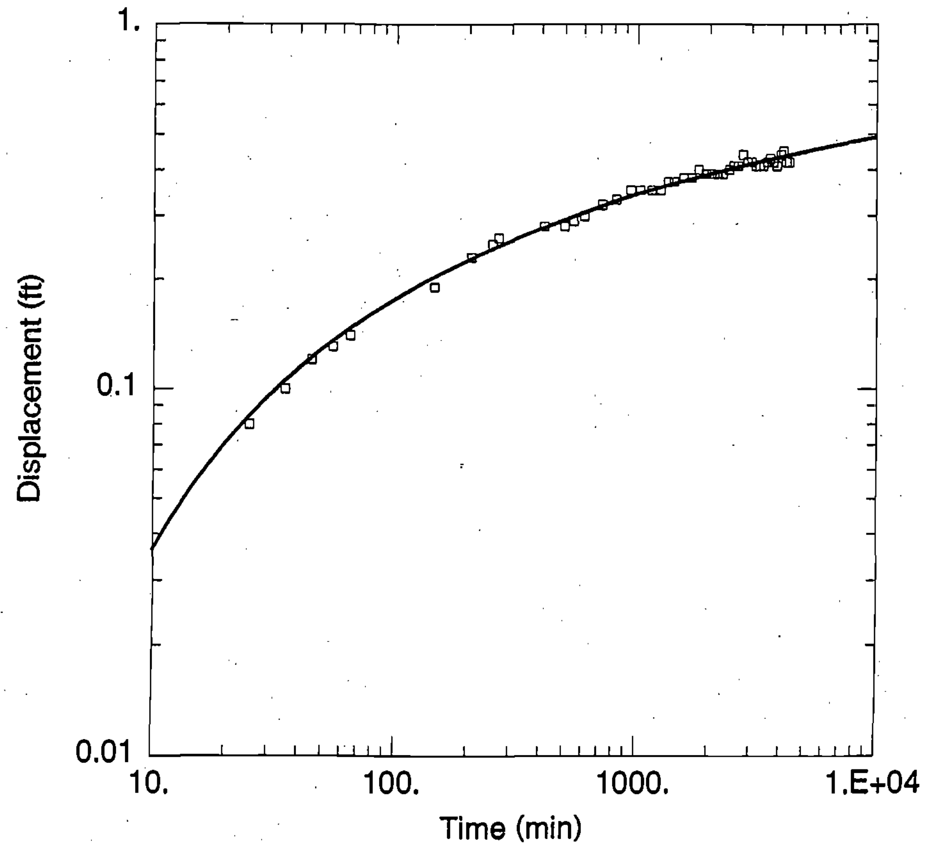
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA-046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| ▫ CAR-RW10 | 22.65 | 0 |




## WELL TEST ANALYSIS

Data Set: F:\...\Rw10man.aqt
Date: 08/19/02 Time: 15:31:55

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1092.5 $ft^2$/day
S = 0.03422
Sy = 0.5
ß = 0.0001447

## AQUIFER DATA

Saturated Thickness: 10. ft

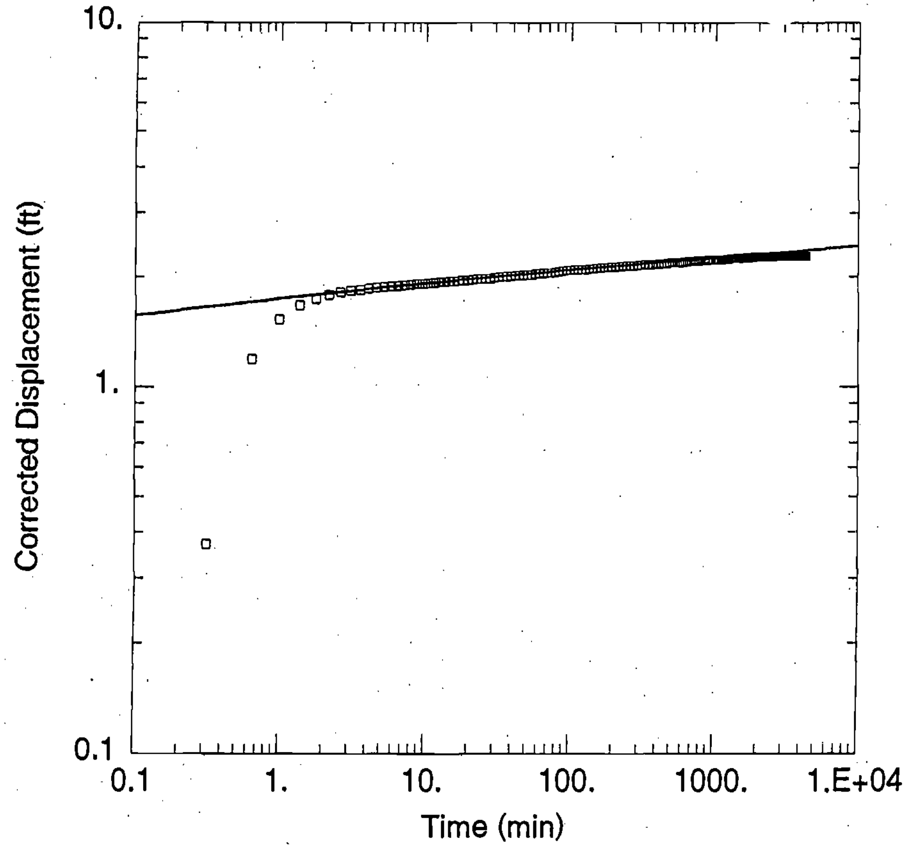
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA-046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| ▫ CAR-RW10 | 22.65 | 0 |




## WELL TEST ANALYSIS

Data Set: G:\...\046t.aqt
Date: 08/02/02 Time: 13:52:55

## PROJECT INFORMATION

Company: HydroGeoLogic, Inc.
Client: AFCEE
Project: AFC001-19BD
Test Location: Carswell AFB
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1108.4 $ft^2$/day
S = 6.51E-09
Kz/Kr = 1.
b = 10. ft

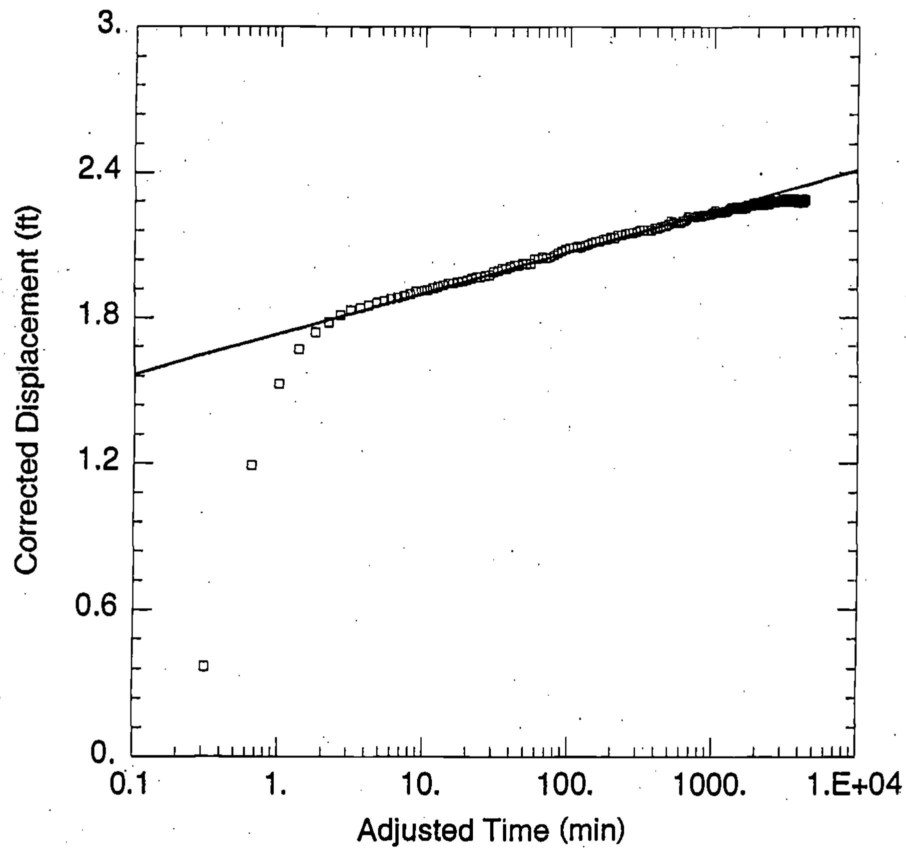
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA-046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| □ WHGLTA-046 | 0 | 0 |




## WELL TEST ANALYSIS

Data Set: G:\...\046CJ.aqt
Date: 08/02/02 Time: 13:52:43

## PROJECT INFORMATION

Company: HydroGeoLogic, Inc.
Client: AFCEE
Project: AFC001-19BD
Test Location: Carswell AFB
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

T = 1149.8 $ft^2$/day
S = 3.238E-09

## AQUIFER DATA

Saturated Thickness: 10. ft

Anisotropy Ratio (Kz/Kr): 2.076E+04

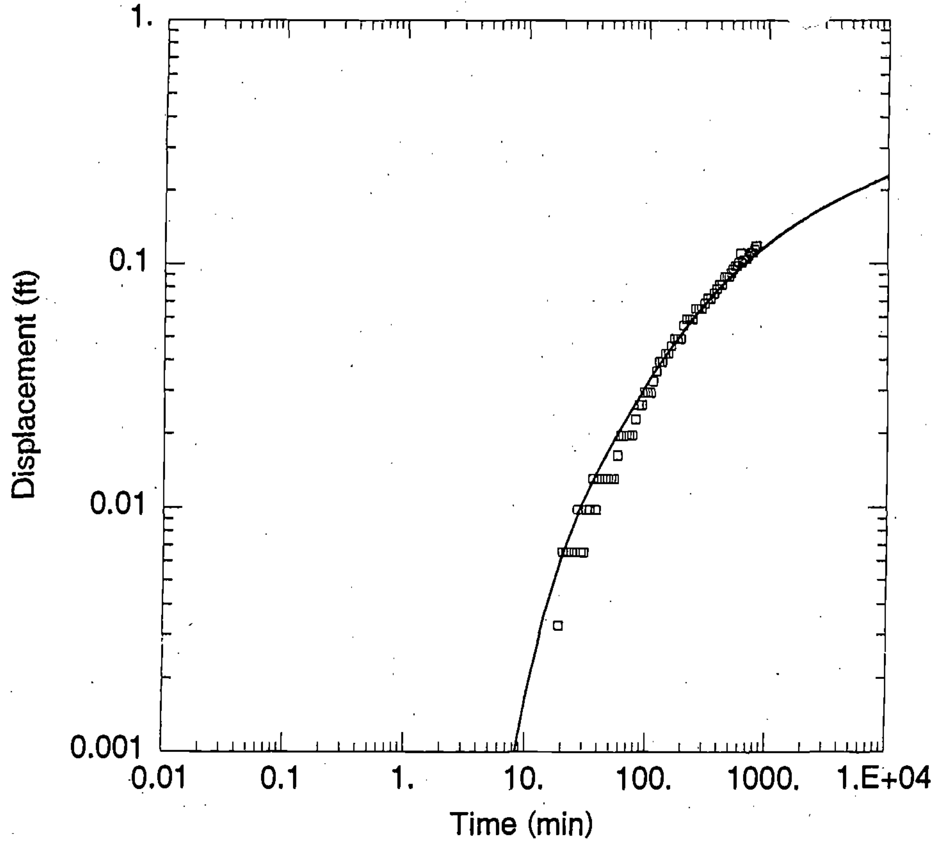
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA-046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| □ WHGLTA-046 | 0 | 0 |




## WELL TEST ANALYSIS

Data Set: G:\...\047.aqt
Date: 08/02/02 Time: 13:52:18

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-19BD
Test Location: Carswell
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1753.7 $ft^2$/day
S = 0.03873
Sy = 0.05623
ß = 1.

## AQUIFER DATA

Saturated Thickness: 10. ft

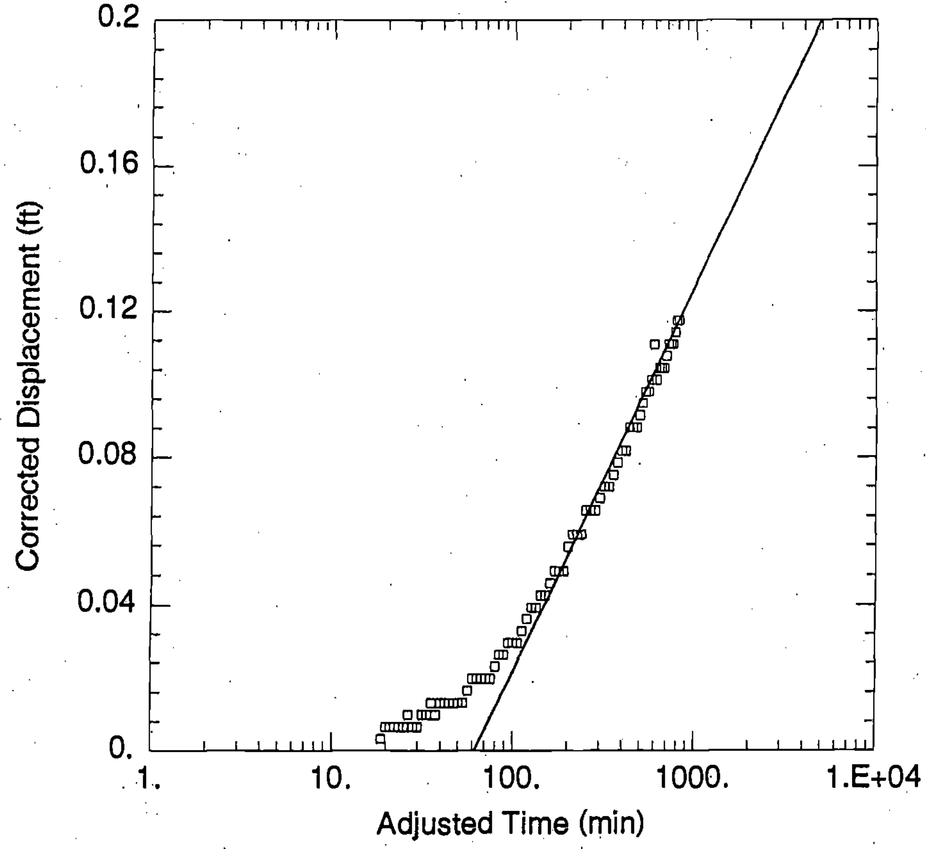
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| □ WHGLTA-047 | 49.54 | 0 |




## WELL TEST ANALYSIS

Data Set: G:\...\047cj.aqt
Date: 08/02/02 Time: 13:52:05

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-19BD
Test Location: Carswell
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Cooper-Jacob

$T = 1843.3\ ft^2/day$
$S = 0.07246$

## AQUIFER DATA

Saturated Thickness: 10. ft

Anisotropy Ratio (Kz/Kr): 0.04075

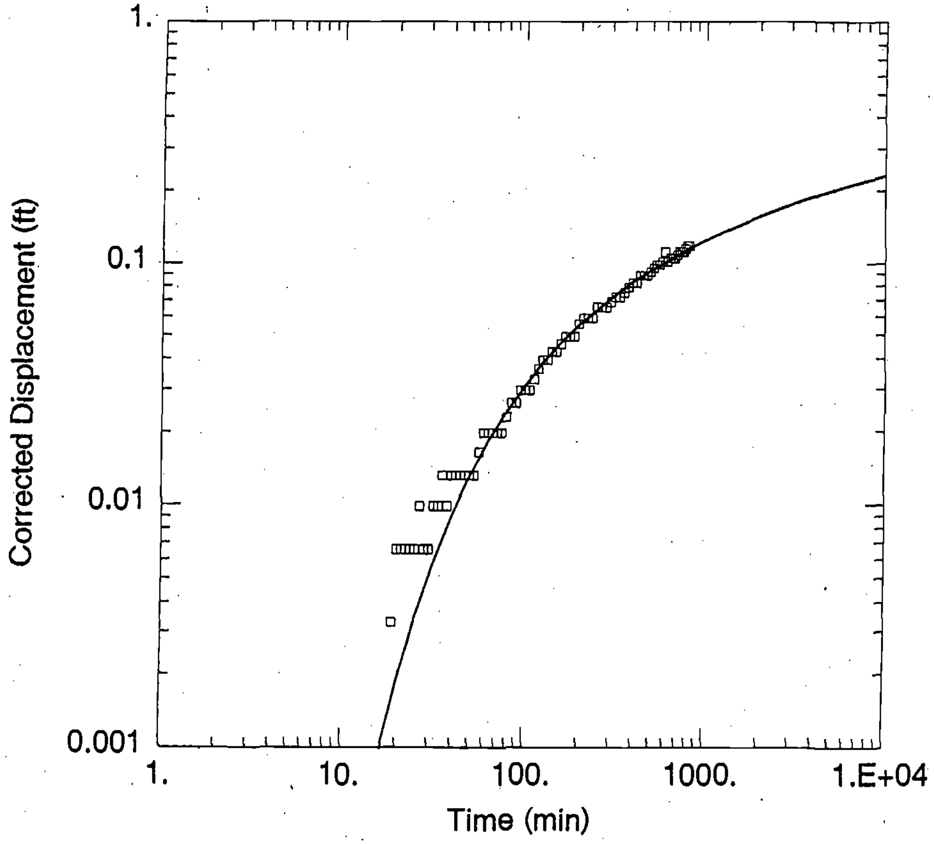
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| □ WHGLTA-047 | 49.54 | 0 |




## WELL TEST ANALYSIS

Data Set: G:\...\047t.aqt
Date: 08/02/02 Time: 13:51:51

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-19BD
Test Location: Carswell
Test Well: WHGLTA-046
Test Date: October 2000

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1765.4 $ft^2$/day
S = 0.08689
Kz/Kr = 1.
b = 10. ft

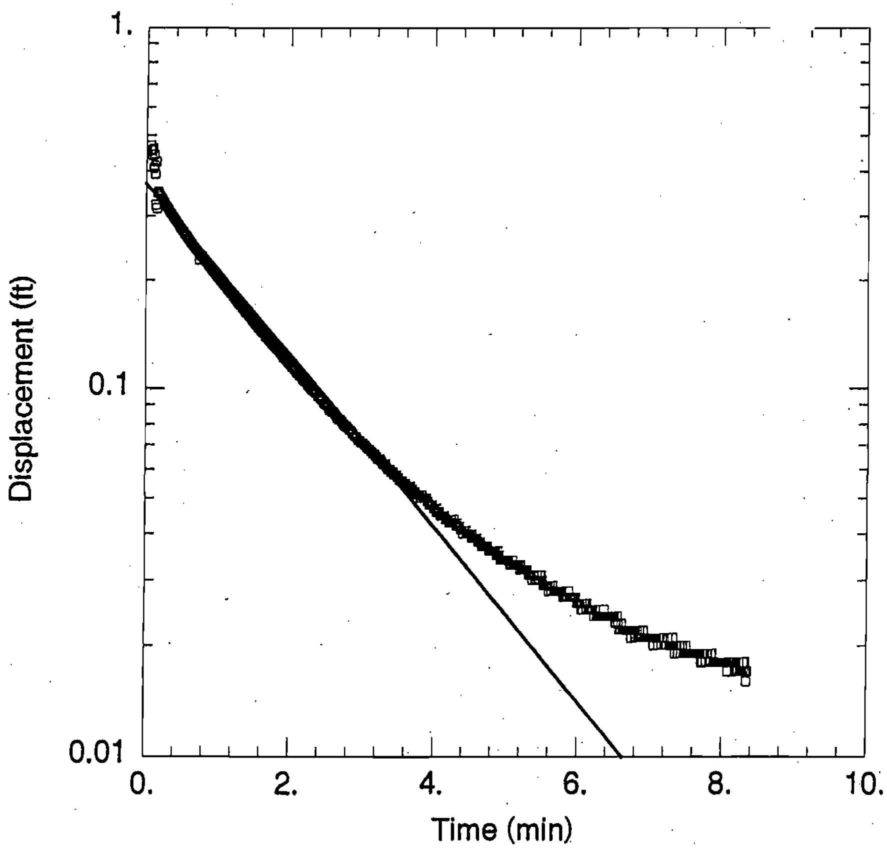
## WELL DATA

Pumping Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| WHGLTA046 | 0 | 0 |

Observation Wells

| Well Name | X (ft) | Y (ft) |
|---|---|---|
| □ WHGLTA-047 | 49.54 | 0 |




## WELL TEST ANALYSIS

Data Set: G:\...\705-1.aqt
Date: 08/02/02 Time: 15:48:15

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLTA705
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 7.787 ft/day
y0 = 0.3684 ft

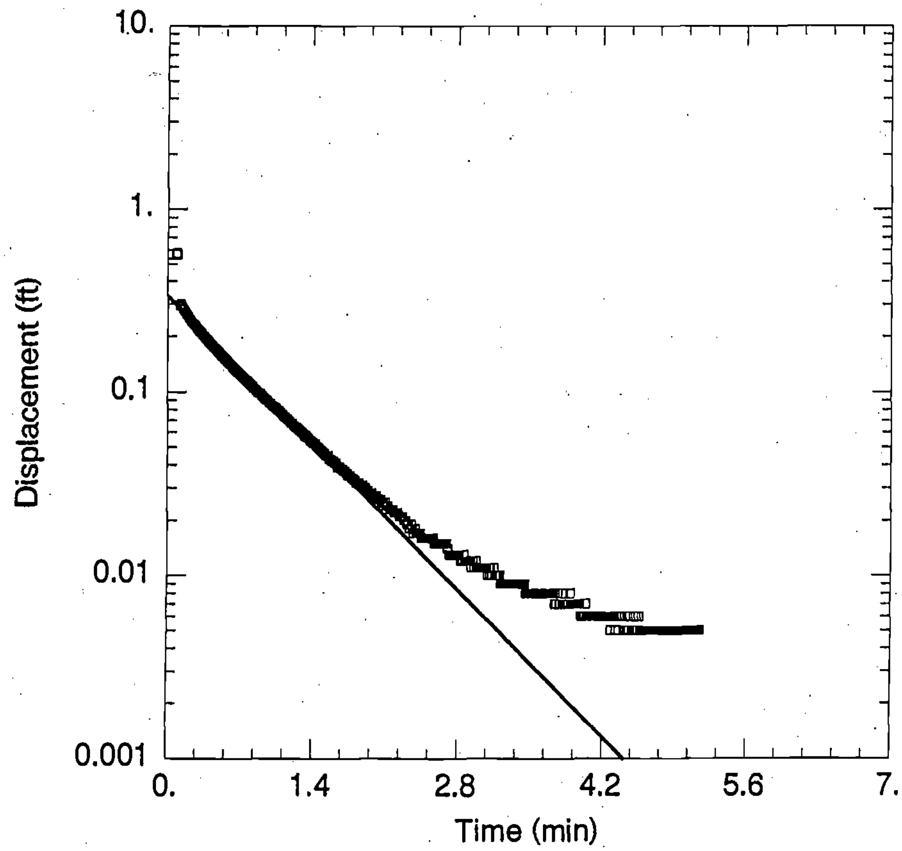
## AQUIFER DATA

Saturated Thickness: 8.13 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLTA705)

Initial Displacement: 0.452 ft
Wellbore Radius: 0.354 ft
Screen Length: 5. ft
Gravel Pack Porosity: 0.3

Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 10.69 ft




## WELL TEST ANALYSIS

Data Set: G:\...\048-2.aqt
Date: 08/02/02 Time: 15:48:02

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLTA048
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 9.963 ft/day
y0 = 0.3328 ft

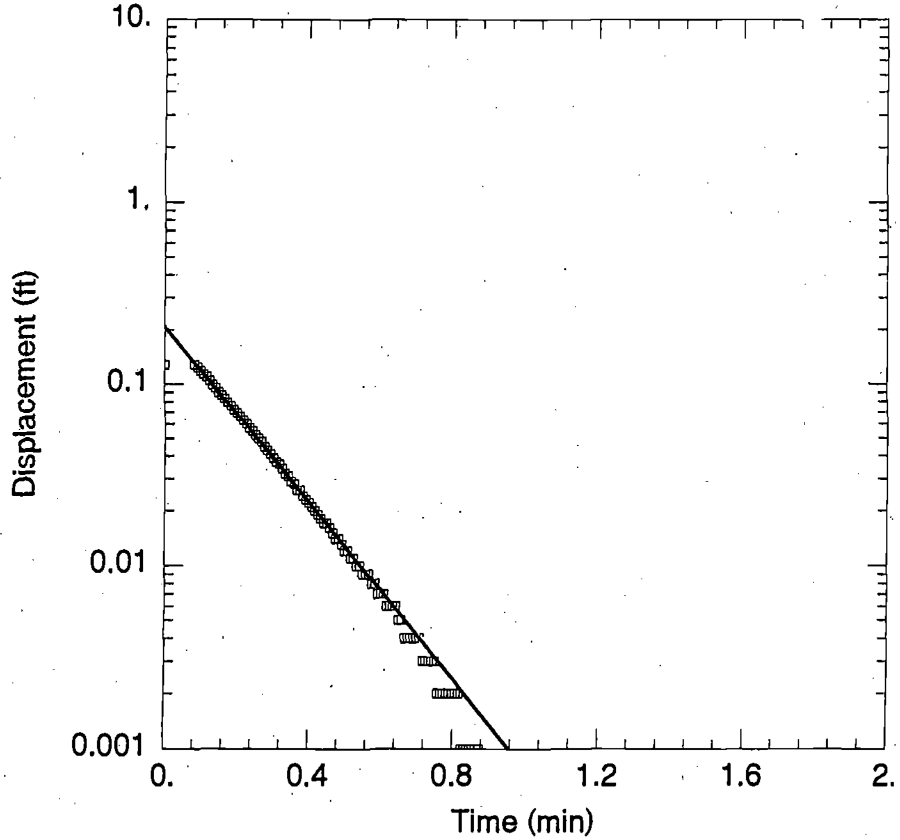
## AQUIFER DATA

Saturated Thickness: 9.38 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLTA048)

Initial Displacement: 0.567 ft
Wellbore Radius: 0.354 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3

Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 9.38 ft




## WELL TEST ANALYSIS

Data Set: G:\...\019-4.aqt
Date: 08/02/02 Time: 15:47:55

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLRW019
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

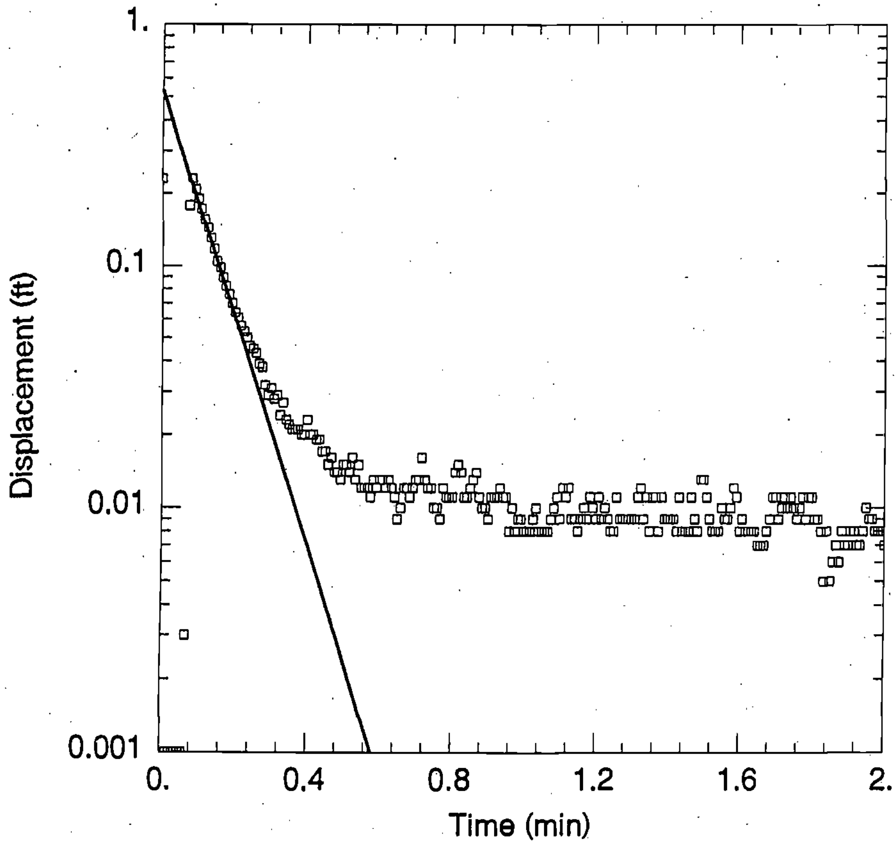
K = 99.75 ft/day
y0 = 0.2079 ft

## AQUIFER DATA

Saturated Thickness: 9.49 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLRW019)

Initial Displacement: 0.128 ft
Wellbore Radius: 0.58 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.58 ft
Total Well Penetration Depth: 9.49 ft




## WELL TEST ANALYSIS

Data Set: G:\...\5e-2.aqt
Date: 08/02/02 Time: 15:47:47

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: LF05-5E
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

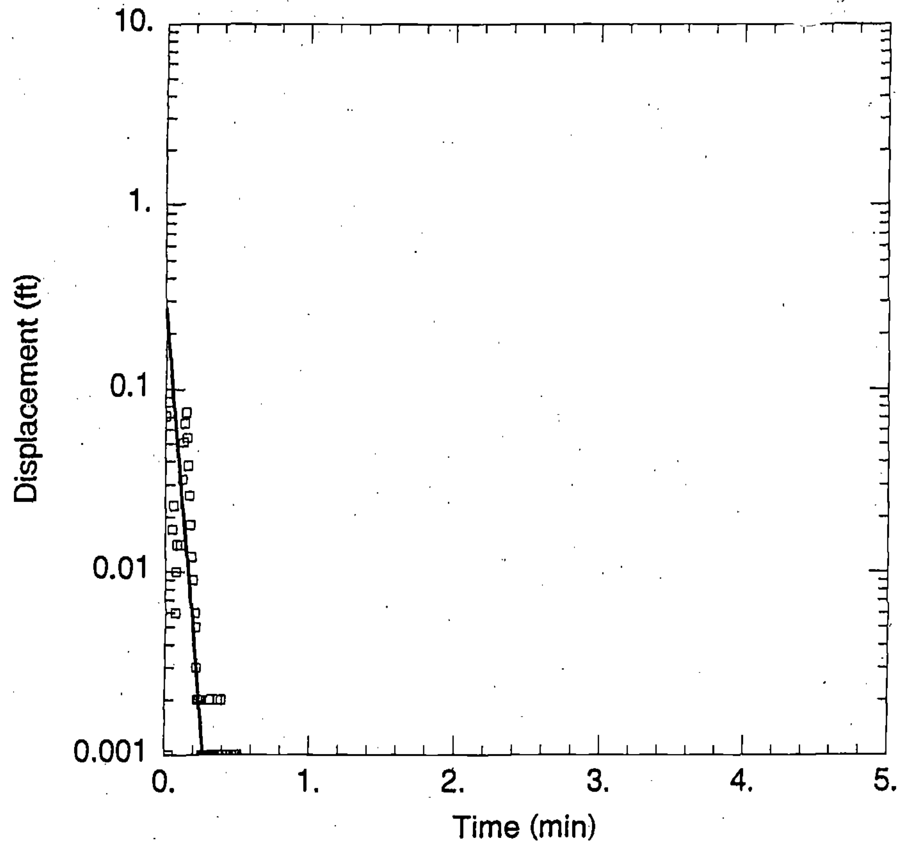
K = 54.32 ft/day
y0 = 0.5309 ft

## AQUIFER DATA

Saturated Thickness: 8.31 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (LF05-5E)

Initial Displacement: 0.231 ft
Wellbore Radius: 0.354 ft
Screen Length: 15. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 8.31 ft




## WELL TEST ANALYSIS

Data Set: G:\...\123-4.aqt
Date: 08/02/02 Time: 15:47:39

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: HM-123
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 219.3 ft/day
y0 = 0.2712 ft

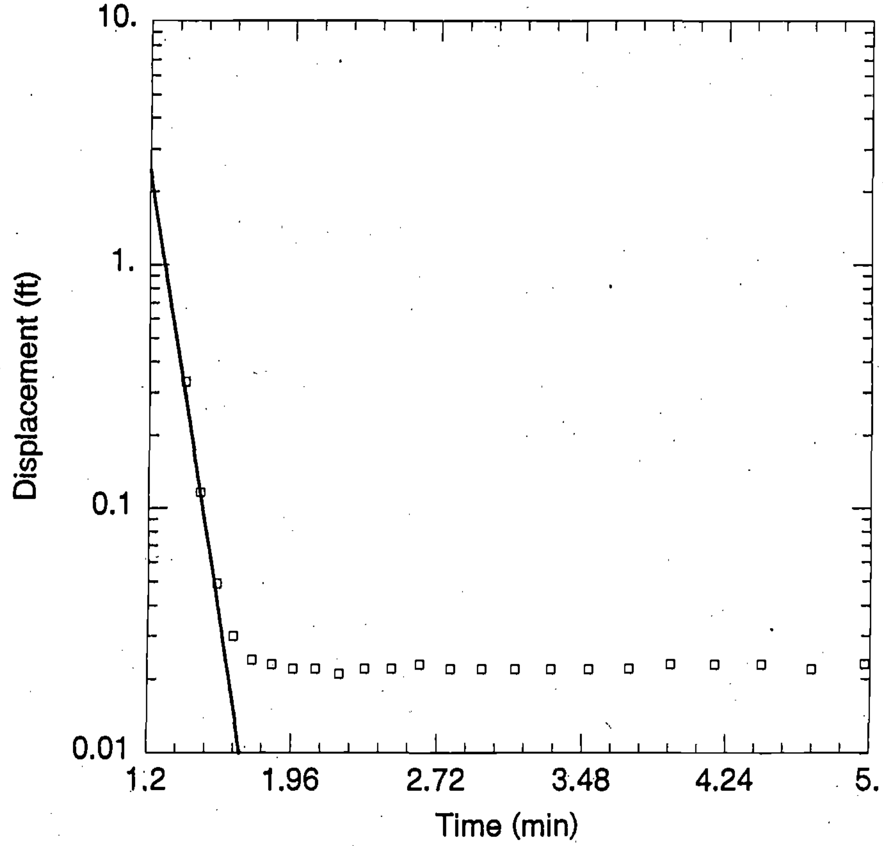
## AQUIFER DATA

Saturated Thickness: 13.62 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (HM-123)

Initial Displacement: 0.071 ft
Wellbore Radius: 0.58 ft
Screen Length: 20. ft
Gravel Pack Porosity: 0.3

Casing Radius: 0.167 ft
Well Skin Radius: 0.58 ft
Total Well Penetration Depth: 13.62 ft




## WELL TEST ANALYSIS

Data Set: F:\...\Wp07-10a.aqt
Date: 08/19/02 Time: 15:47:50

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WP07-10A
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

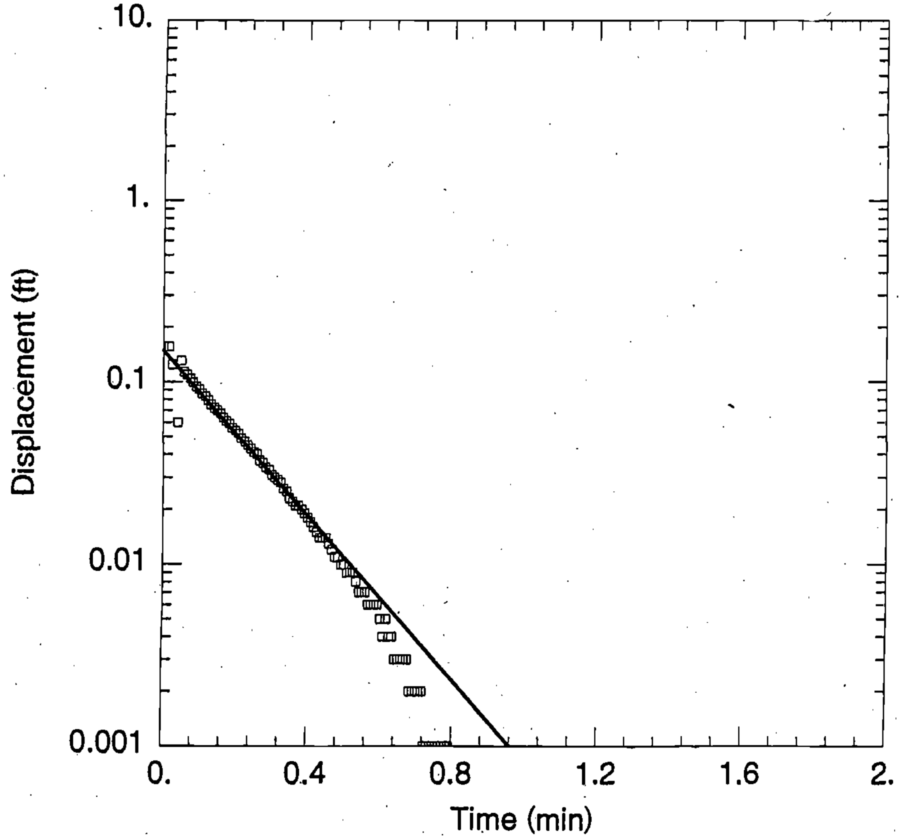
K = 78.97 ft/day
y0 = 1.654E+06 ft

## AQUIFER DATA

Saturated Thickness: 7.21 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WP07-10A)

Initial Displacement: 0.332 ft
Wellbore Radius: 0.354 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 7.21 ft




## WELL TEST ANALYSIS

Data Set: G:\...\016-4.aqt
Date: 08/02/02 Time: 15:47:19

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLRW016
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 96.01 ft/day
y0 = 0.1481 ft

## AQUIFER DATA

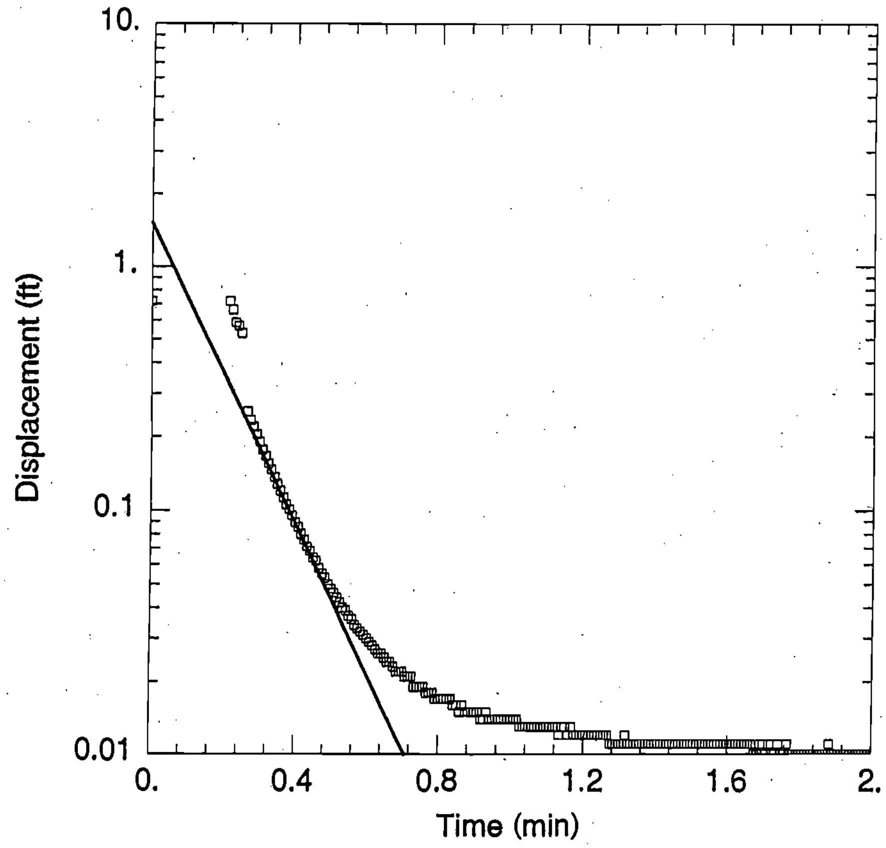
Saturated Thickness: 10.57 ft

Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLRW016)

Initial Displacement: 0.156 ft
Wellbore Radius: 0.58 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3

Casing Radius: 0.167 ft
Well Skin Radius: 0.58 ft
Total Well Penetration Depth: 10.57 ft




## WELL TEST ANALYSIS

Data Set: G:\...\Wp07-10c.aqt
Date: 08/02/02 Time: 15:46:56

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WP07-10C
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

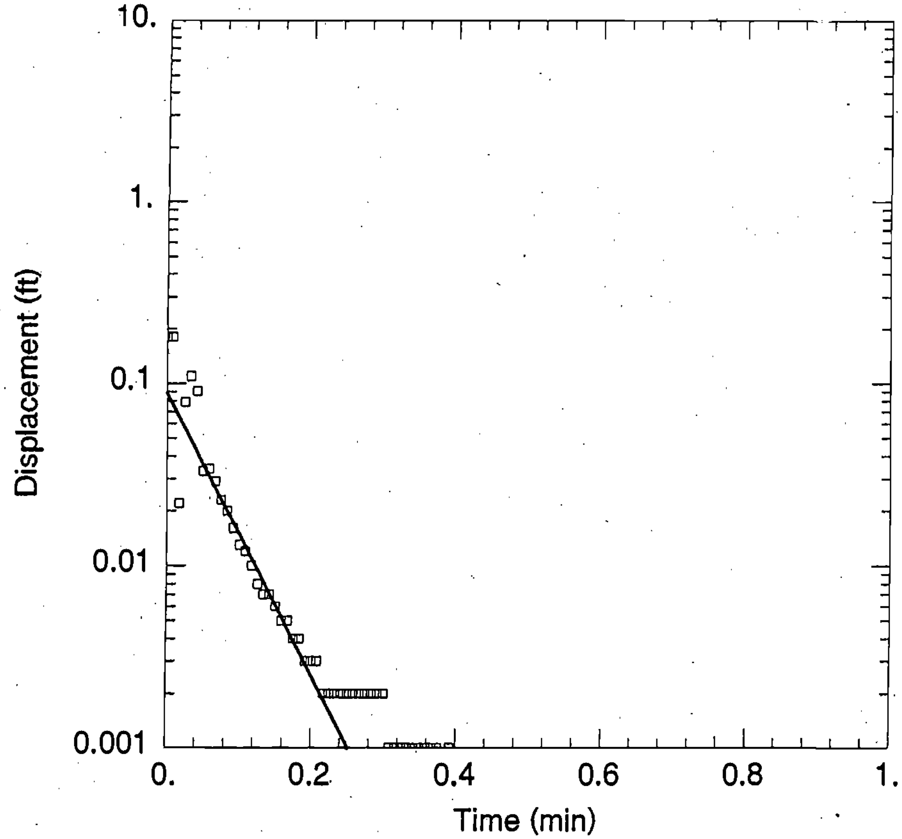
K = 54.33 ft/day
y0 = 1.51 ft

## AQUIFER DATA

Saturated Thickness: 9.84 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WP07-10C)

Initial Displacement: 0.719 ft
Wellbore Radius: 0.354 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 9.84 ft




## WELL TEST ANALYSIS

Data Set: G:\...\It01-3.aqt
Date: 08/02/02 Time: 15:46:45

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: ITMW-01T
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 318.1 ft/day
y0 = 0.08814 ft

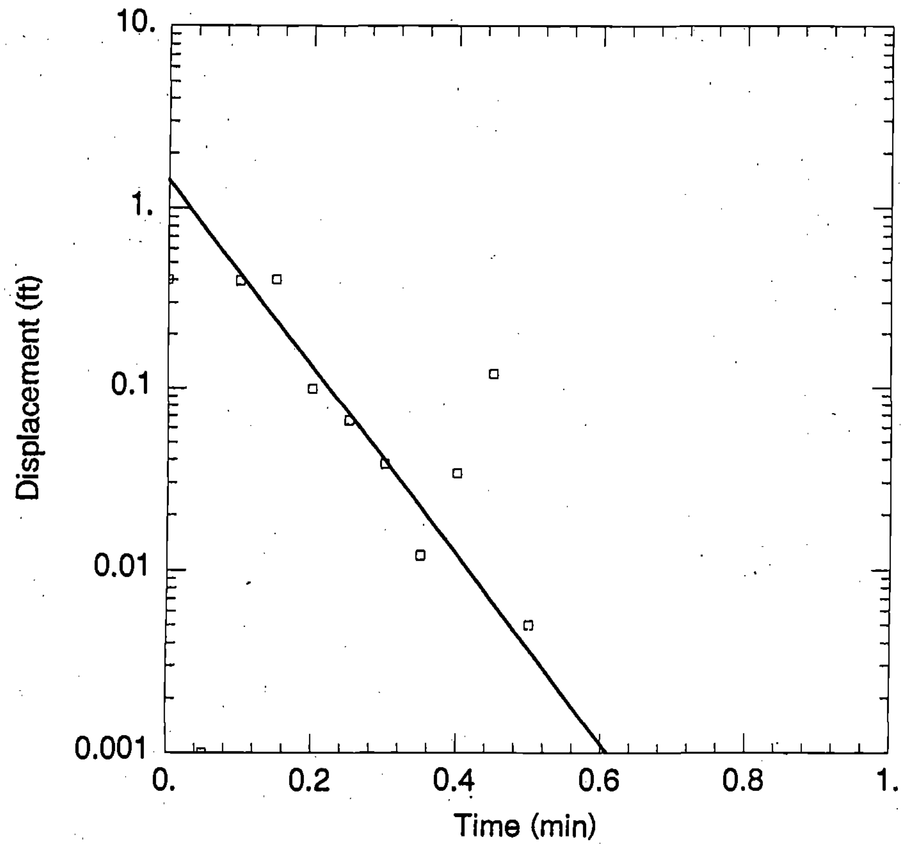
## AQUIFER DATA

Saturated Thickness: 9.45 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (ITMW-01T)

Initial Displacement: 0.181 ft
Wellbore Radius: 0.58 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3

Casing Radius: 0.167 ft
Well Skin Radius: 0.58 ft
Total Well Penetration Depth: 9.45 ft




## WELL TEST ANALYSIS

Data Set: G:\...\lt-057-2.aqt
Date: 08/02/02 Time: 15:46:28

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WITCTA057
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

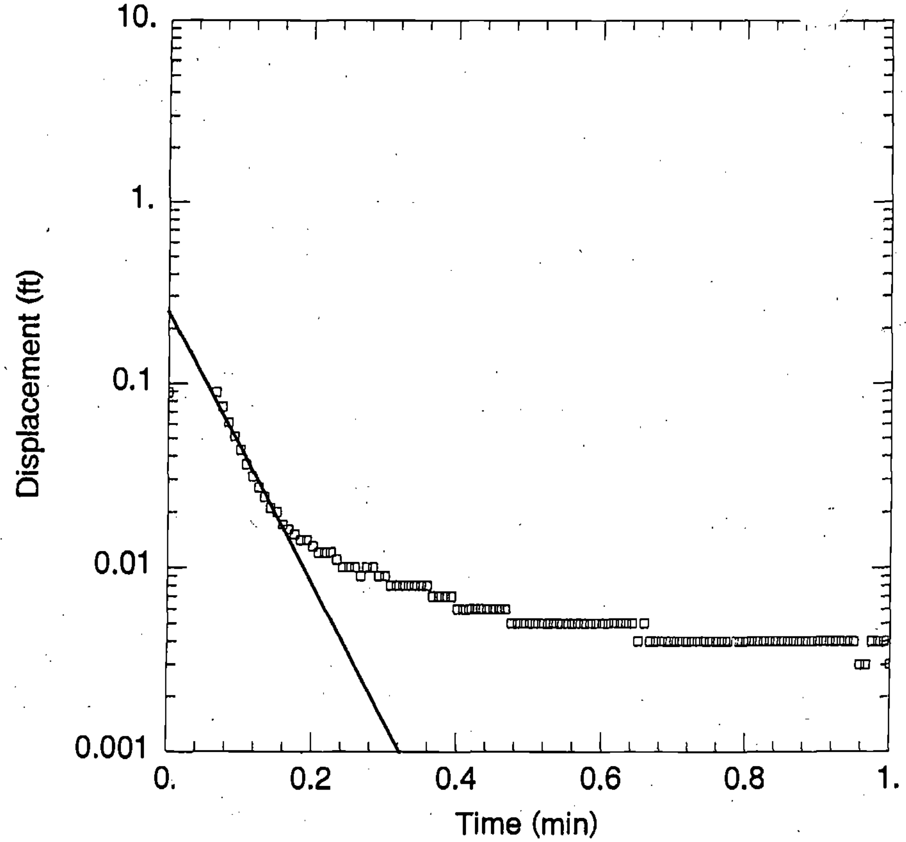
K = 95.67 ft/day
y0 = 1.426 ft

## AQUIFER DATA

Saturated Thickness: 11.92 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WITCTA057)

Initial Displacement: 0.402 ft
Wellbore Radius: 0.354 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 11.92 ft




## WELL TEST ANALYSIS

Data Set: G:\...\017-4.aqt
Date: 08/02/02 Time: 15:46:18

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLRW017
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

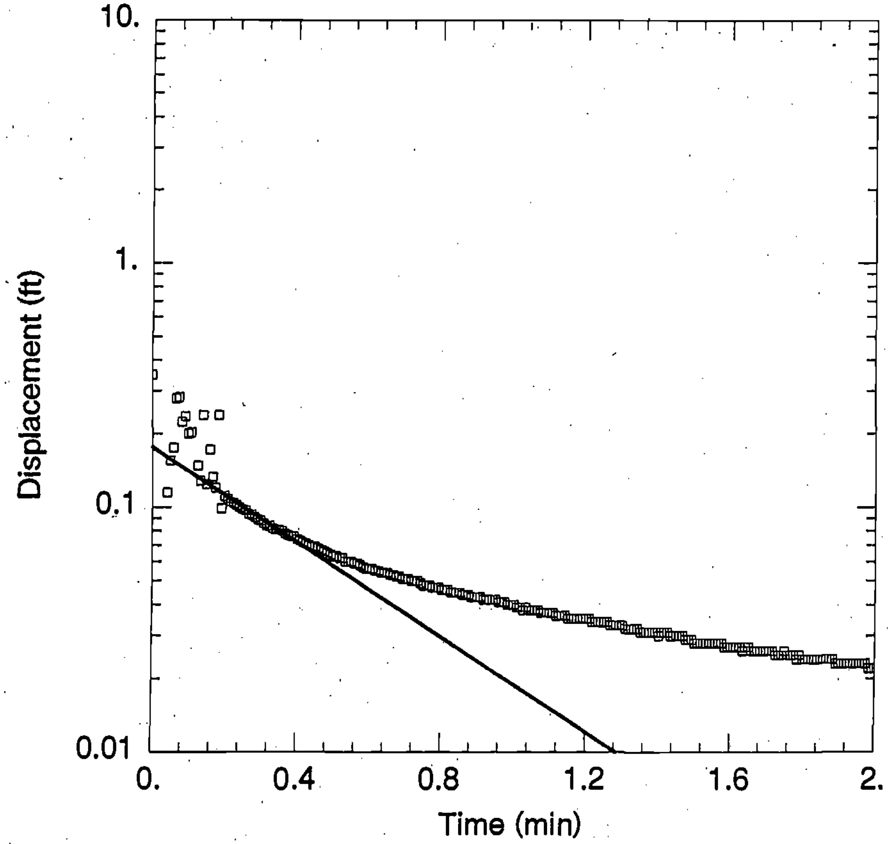
K = 314.1 ft/day
y0 = 0.2466 ft

## AQUIFER DATA

Saturated Thickness: 10.4 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLRW017)

Initial Displacement: 0.089 ft
Wellbore Radius: 0.58 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.167 ft
Well Skin Radius: 0.58 ft
Total Well Penetration Depth: 10.4 ft




## WELL TEST ANALYSIS

Data Set: G:\...\Ft08-2.aqt
Date: 08/02/02 Time: 15:46:07

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: FT08-11A
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

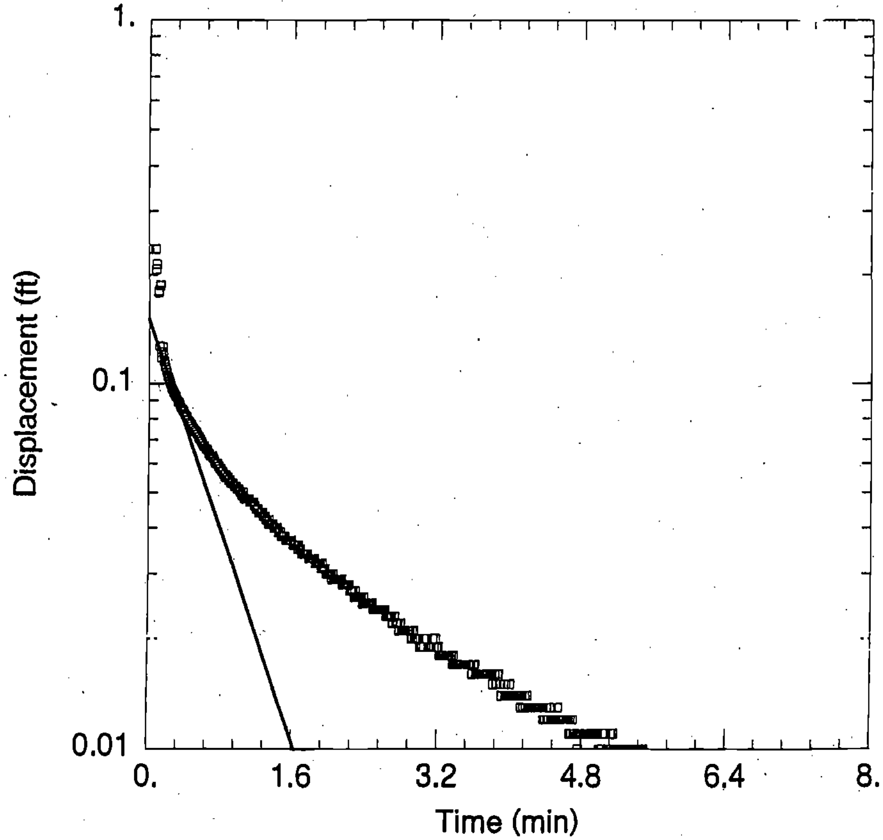
K = 17.13 ft/day
y0 = 0.1755 ft

## AQUIFER DATA

Saturated Thickness: 9.97 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (FT08-11A)

Initial Displacement: 0.349 ft
Wellbore Radius: 0.354 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 9.97 ft




## WELL TEST ANALYSIS

Data Set: G:\...\706-2.aqt
Date: 08/02/02 Time: 15:45:55

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLTA706
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 11.18 ft/day
y0 = 0.1504 ft

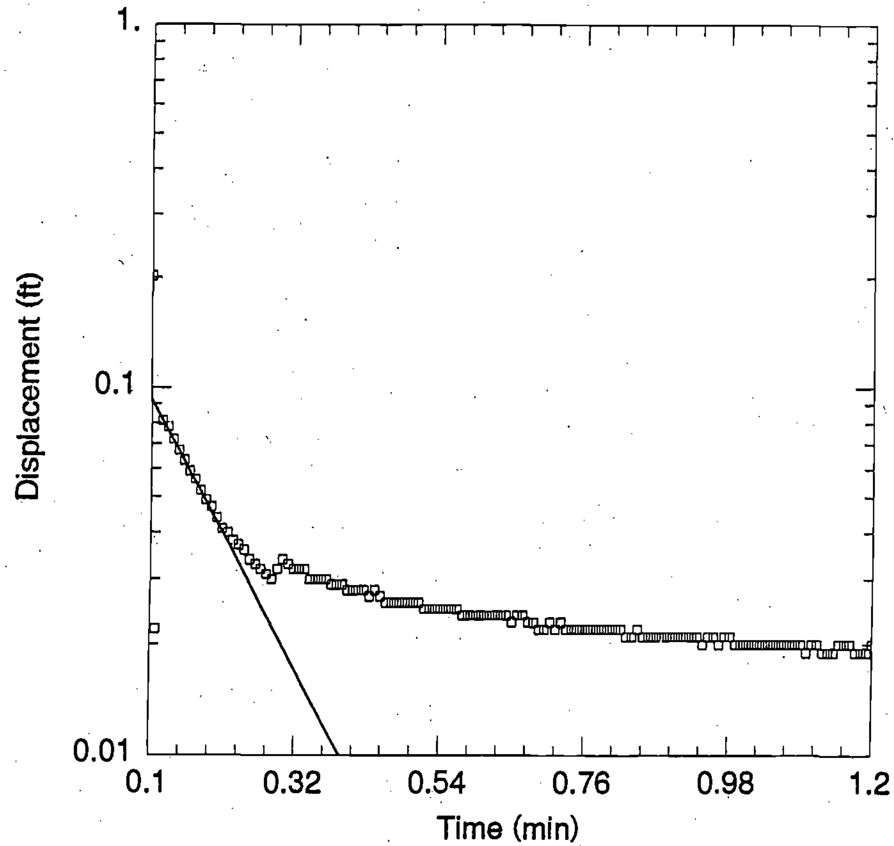
## AQUIFER DATA

Saturated Thickness: 6.1 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLTA706)

Initial Displacement: 0.236 ft
Wellbore Radius: 0.354 ft
Screen Length: 10. ft
Gravel Pack Porosity: 0.3

Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 6.1 ft




## WELL TEST ANALYSIS

Data Set: F:\...\701-1.aqt
Date: 08/19/02 Time: 15:39:57

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLTA701
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

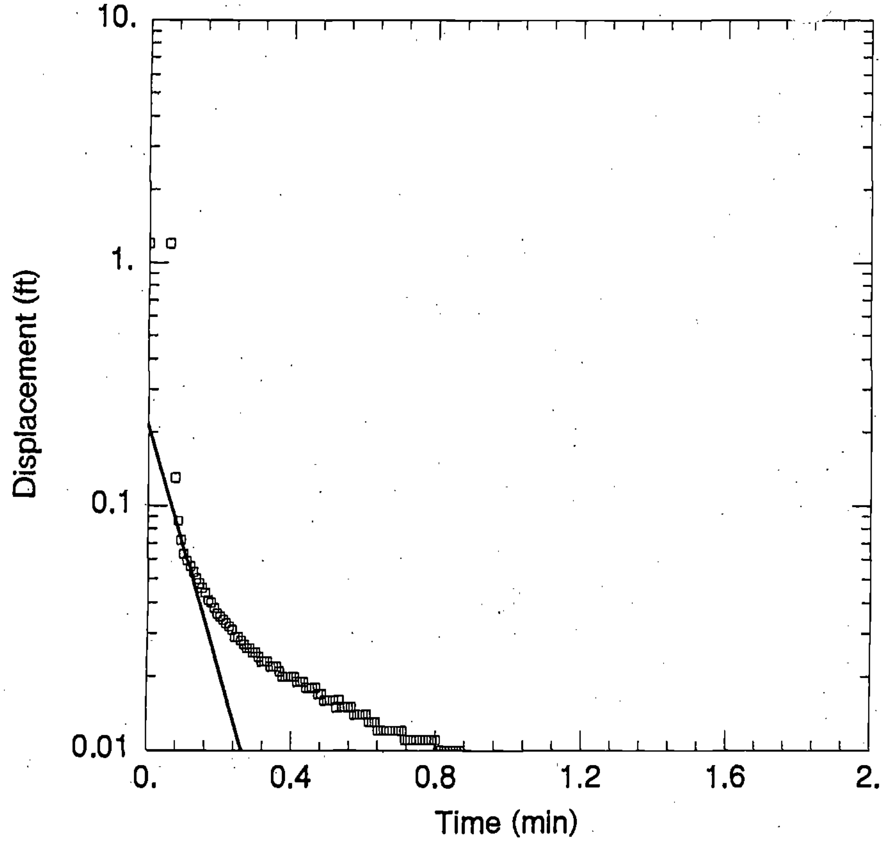
K = 42.54 ft/day
y0 = 0.1991 ft

## AQUIFER DATA

Saturated Thickness: 12. ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLTA701)

Initial Displacement: 0.283 ft
Wellbore Radius: 0.354 ft
Screen Length: 15. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 12.12 ft




## WELL TEST ANALYSIS

Data Set: G:\...\056-2.aqt
Date: 08/02/02 Time: 15:45:38

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLTA056
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 51.16 ft/day
y0 = 0.2129 ft

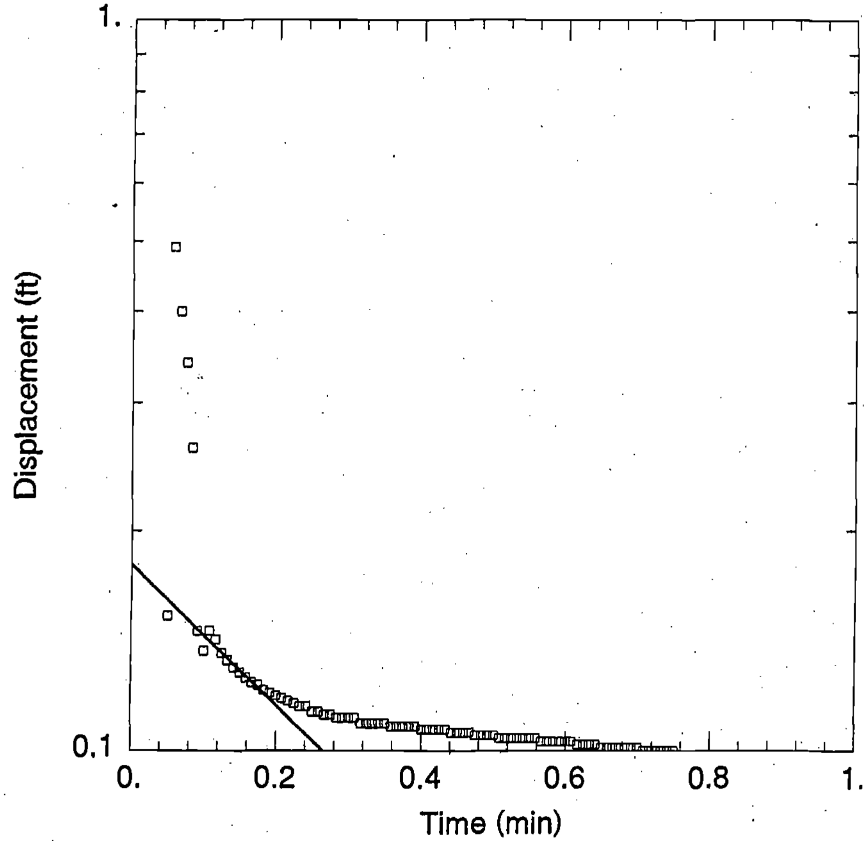
## AQUIFER DATA

Saturated Thickness: 5.25 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLTA056)

Initial Displacement: 1.2 ft
Wellbore Radius: 0.354 ft
Screen Length: 15. ft
Gravel Pack Porosity: 0.3

Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 5.25 ft




## WELL TEST ANALYSIS

Data Set: G:\...\Ta002-2.aqt
Date: 08/02/02 Time: 15:45:29

## PROJECT INFORMATION

Company: HydroGeoLogic
Client: AFCEE
Project: AFC001-35
Test Location: Carswell
Test Well: WHGLTA-002
Test Date: February 2001

## SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 9.737 ft/day
y0 = 0.1799 ft

## AQUIFER DATA

Saturated Thickness: 5.25 ft
Anisotropy Ratio (Kz/Kr): 1.

## WELL DATA (WHGLTA056)

Initial Displacement: 1.2 ft
Wellbore Radius: 0.354 ft
Screen Length: 15. ft
Gravel Pack Porosity: 0.3
Casing Radius: 0.083 ft
Well Skin Radius: 0.354 ft
Total Well Penetration Depth: 5.25 ft

# APPENDIX A.2

# AQUEDUCT ASSESSMENT

# APPENDIX A.2

# AQUEDUCT ASSESSMENT

As part of the Data Gaps Investigations for the Southern Lobe TCE Plume, HydroGeoLogic conducted an assessment of the subterranean aqueduct located beneath the runway and main flightline area of NAS Fort Worth JRB (Figure A.2-1). The aqueduct consists of two large drainage culverts, or tunnels, buried beneath the flightline area. The aqueduct is located south of AFP 4 and bisects the NAS Fort Worth JRB runway in a generally east-west direction. The aqueduct allows Farmers Branch Creek to flow east from the White Settlement community, beneath the runways. The majority of flow within Farmers Branch Creek is generated from surface water runoff. The remaining flow within Farmers Branch Creek is generated from recharge derived from the local Terrace Alluvium groundwater. Farmers Branch Creek is also fed by intermittent, unnamed tributaries prior to its entrance into the aqueduct and after its emergence within the golf course area.

The purpose of the aqueduct assessment was to evaluate its potential contribution to the southern lobe TCE plume and its effect, if any, on local groundwater flow.

A review of the aqueduct construction records was conducted. The as-built drawing of the aqueduct (USACE, 1952) shows that the aqueduct is only set on bedrock at the east and west ends of the tunnels, not in the area between Runway 1 and Runway 2 as shown on Figure 2.8. The aqueduct acts as a barrier on the eastern and western ends of the runway. Groundwater flows beneath the aqueduct in the area between the runways.

On December 5 and 6, 2000, HydroGeoLogic conducted a site reconnaissance of the aqueduct to evaluate/document structural integrity. No major structural problems were found; minor problems include:

- Small cracks in the seams of the concrete;
- Small areas of eroded concrete; and,
- Broken tie downs attached to a 30-inch inlet pipe in the north tunnel.

The detailed documentation of minor structural problems in the north and the south tunnels are summarized in Figure A.2-2 and accompanying photographs. Selected areas of interest and their corresponding photographs are available on Figure A.2-3.

Samples were collected from 2 storm water lines discharging to the south tunnel; no surface water was observed in the north tunnel. Samples were analyzed for VOCs by EPA Method 8260. One sample contained 0.5 µg/L of PCE and 0.6 µg/L p,m-xylene. The second sample contained 2 µg/L p,m-xylene, 1 µg/L o-xylene, and 1 µg/L naphthalene. These sample locations and detections are depicted on Figure A.2-3.
Figure A.2-1 (11x17) Runway Storm Drainage System

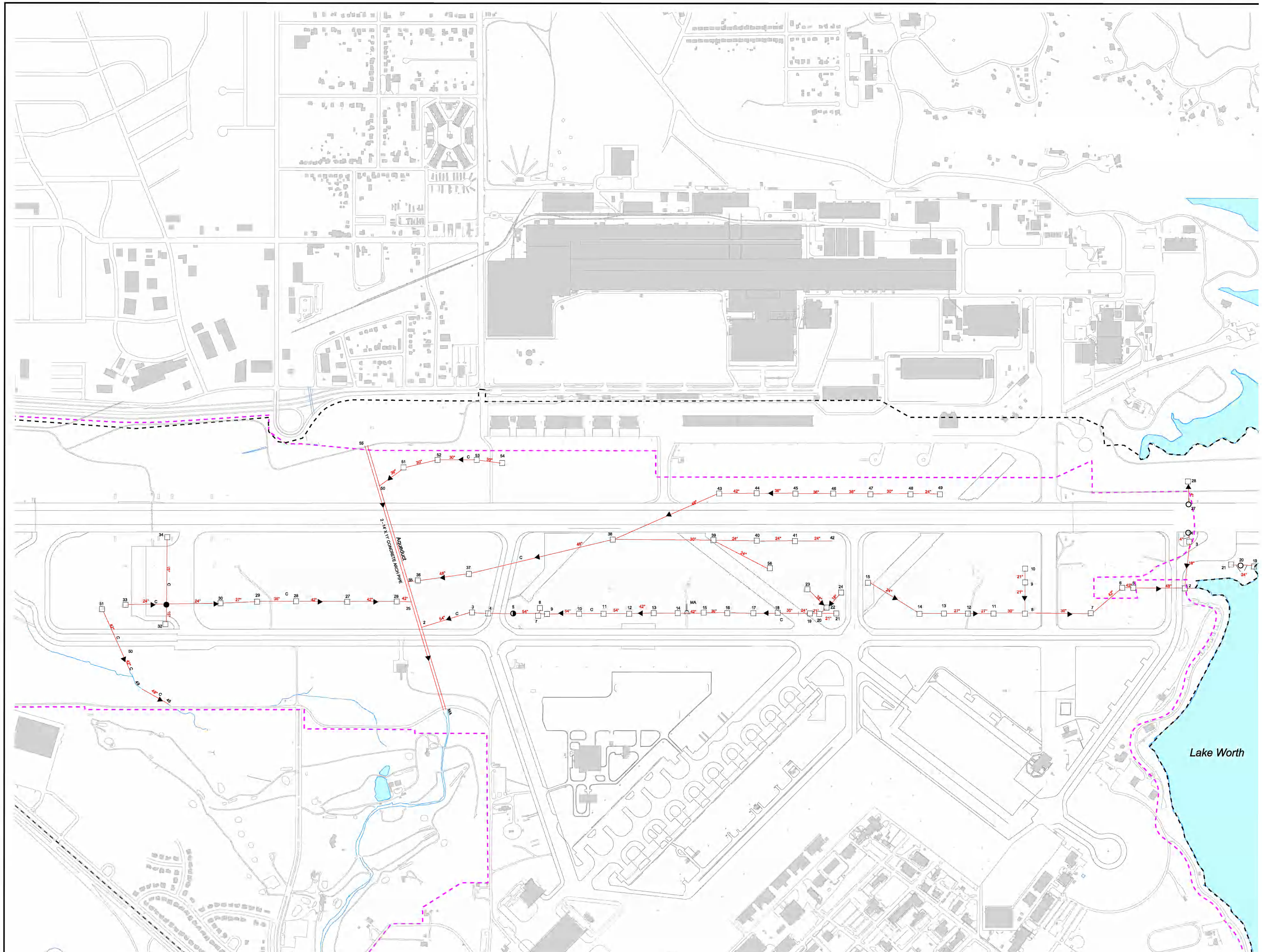

Lake Worth
Aqueduct
2 - 14' X 11' CONCRETE ARCH PIPE

**Figure A.2-2**
**Summary of Minor Structural Problems Found in Aqueduct**