ETIC ENGINEERING

REQUEST FOR VARIANCE ADDENDUM

FORMER KAISER FLUID TECHNOLOGIES
530 EAST SUGAR CREEK ROAD
CHARLOTTE, NORTH CAROLINA
NCDENR INCIDENT NO. 85906

JUNE 9, 2006

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EXECUTIVE SUMMARY

This *Request for Variance Addendum* has been prepared by ETIC Engineering, Inc. (ETIC) for the former Kaiser Fluid Technologies (KFT) facility, located at 530 East Sugar Creek Road in Charlotte, North Carolina. Site investigation activities identified halogenated volatile organic compounds (HVOCs) at low concentrations in groundwater that locally exceeded North Carolina Administrative Code (NCAC) 2L.002 groundwater quality standards (2L standards). Groundwater monitoring results (from 2001 to 2004) indicated low concentrations and a generally stable HVOC (primarily Trichloroethene [TCE]) plume at the site. Based on discussions with the North Carolina Department of Environment and Natural Resources (NCDENR), an expedited roadmap for site closure through the NCDENR's variance process was developed in July 2004. Consistent with this roadmap, supplemental investigation and application of a best available technology (BAT) (i.e., short term high vacuum dual phase extraction [HVDPE]) were conducted between August 2004 and April 2005. The following briefly summarizes the findings:

- Supplemental investigation activities identified the former settling tank, located outside the northwest corner of the facility building, as the primary suspected residual source area. HVOCs in groundwater, primarily TCE and to a limited extent 1,1,1-Trichloroethane (1,1,1-TCA) and 1,1-Dichloroethene (1,1-DCE), were defined to extend northward from the former settling tank area across the onsite parking area. The former settling tank was decommissioned in the late 1960s. Groundwater flow and associated HVOC (primarily TCE) migration from the residual source area (i.e., the former settling tank area) was conceptualized to occur primarily as horizontal flow through the fractures in the weathered bedrock (saprolite), which overlies more competent bedrock and along the saprolite/bedrock interface. The highest TCE concentration gradients were observed between the residual source area and downgradient locations (i.e., within 25 feet); the leading edge of the TCE plume, represented by non-detect levels, was completely contained within the site boundary.
- During the application of the BAT (short-term HVDPE using four source area extraction wells), TCE (and other HVOCs) concentrations in source area extraction wells declined. Stabilized water levels in observation wells and low and declining TCE mass removal rates indicated that HVDPE reached its maximum effectiveness during the 10-day event. Post-HVDPE monitoring results indicated that TCE concentrations had rebounded locally in a small portion of the residual source area (at and near well RW-3), but remained below pre-HVDPE levels throughout the residual source area. These findings indicated that: 1) the remaining TCE (and other HVOCs) mass was trapped in limited permeability and dead-end fractures at and in the immediate vicinity of the former settling tank; 2) mobility of TCE in groundwater was diffusion-limited; and 3) further HVDPE or other remedial activities were not practicable or otherwise likely to reduce the limited HVOC mass remaining beneath the site.

The site data indicated that the HVOC plume was locally constrained around the former settling tank area and that the BAT (HVDPE) was applied to the extent practicable. A request for site closure through the variance process was submitted to the NCDENR (in the 9 May 2005 *Request for Variance*). In a 9 September 2005 correspondence, the NCDENR requested: 1) additional information on the three water supply wells identified within a ½-mile radius of the site; 2) vertical definition of the HVOCs onsite; and 3) additional source reduction.

In response to the first two NCDENR requests, a limited investigation was conducted in November and December 2005. Supplemental information from the owners of the water supply wells indicated that the two wells located approximately 1,500 feet or more west (cross-gradient) of the site have non-potable uses, and the well located approximately 2,500 feet north (downgradient) of the site is inactive. In addition, the vertical extent of HVOCs was defined by the absence of HVOCs in the groundwater sample collected from well BW-2, which screens from 76 to 79 feet below ground surface (bgs), and is located adjacent to well RW-2 (screening from 15 to 25 feet bgs) and BW-1 (screening from 40 to 50 feet bgs).

In response to the NCDENR request for additional source reduction, ETIC submitted the 20 January 2006 *Source Reduction and Post-Remediation Groundwater Sampling Work Plan*, which was conditionally approved in a 17 February 2006 NCDENR correspondence. In this correspondence, the NCDENR requested additional post-remediation sampling, as well as the development of a groundwater model to simulate attenuation of HVOC concentrations within the footprint of the TCE plume following implementation of the additional source reduction program. Also, comments were solicited from North Carolina Department of Health and Human Services's (NCDHHS's) state toxicologist, one of the reviewers of the variance request. In a letter dated 17 February 2006, the state toxicologist indicated that "from a public health standpoint, there currently does not appear to be any potential impacts on drinking water wells in the area, and therefore any potential impact would not be considered significant." Furthermore, the state toxicologist indicated that the results of the post-remediation sampling would be used to determine the effectiveness of the source reduction program in reducing HVOC concentrations in the former settling tank area and ensuring reduction of future offsite impacts.

The source reduction activities were conducted in March and April 2006 and consisted of 1) excavation of the former settling tank area outside the facility building (approximately 26 feet long by 26 feet wide to the estimated depth of competent bedrock at 22 feet depth); 2) installation of a 3 foot thick zero-valent iron/sand (ZVI) reaction zone along the north (downgradient) face of the excavation (26 feet long by 3 feet wide, and from 10 to 22 feet bgs); and 3) construction of a monitoring well (ZVI-Well) within the reaction zone. Approximately 550 cubic yards (in-place volume) of excavated soil were disposed offsite at Allied Waste facility in Charlotte, North Carolina. Approximately 2,500 gallons of groundwater recovered during these remedial activities were transported for treatment and disposal to an offsite permitted facility maintained and operated by Clean Harbors in Chattanooga, Tennessee.

Following source reduction activities, two groundwater samples were collected from this well two weeks after installation of the reaction zone (2 May 2006) and approximately one month after the first sample (1 June 2006) to assess the effectiveness of the source reduction activities, per previous agreement with the NCDENR. TCE, 1,1,1-TCA, and 1,1-DCE, the three HVOCs previously reported in site wells at concentrations exceeding 2L standards, were not reported above laboratory reporting limits in this groundwater sample. The absence of HVOCs in this well following remediation efforts demonstrates the effectiveness of the source reduction activities and of the reaction zone in degrading dissolved HVOCs potentially migrating in shallow groundwater from the area upgradient of the ZVI/sand reaction zone. Per agreement with the NCDENR, a groundwater sample from well RW-2 (20 feet downgradient of the north face of the excavation) was collected on 1 June 2006. This groundwater sample reported HVOC concentrations that were consistent with and/or lower than previously reported concentrations.

A numerical groundwater flow and transport model was developed using the Lawrence Berkeley National Laboratory (LBNL) fracture-flow model TOUGH2 and the related solute transport code T2R3D to assess the future impact of the source reduction activities on TCE concentrations in onsite groundwater contained in the saprolite. Decline in TCE concentrations relative to initial concentration (i.e., current concentration) were conservatively simulated at well RW-2 (approximately 20 feet downgradient of the north face of the excavation) and four other locations within the downgradient portion of the TCE plume. The highly conservative model simulations indicate that following the remediation activities described above, TCE concentrations in onsite groundwater will further attenuate and decline toward the 2L standards over time.

In summary, the concentrations of TCE, the primary HVOC in groundwater, on the order of 1,000 µg/L (i.e., the residual source area) were historically constrained to the local area immediately adjacent to the former settling tank. This residual source area has since been the subject of multiple remedial efforts (i.e., removal of the former settling tank and application of a BAT consisting of 10-day HVDPE event) as well as the focus of the recently completed additional source reduction through the excavation and backfilling activities. The success of the recent additional source reduction activities was demonstrated by the absence of TCE (and 1,1,1-TCA and 1,1-DCE) in the sample collected from the ZVI-Well located within the reaction zone and along the downgradient edge of the excavation/backfill area. Additionally, conservative groundwater modeling simulations indicate that TCE concentrations in onsite groundwater will attenuate as a result of the source reduction and decline toward the 2L standards over time. Field data and model results further confirm that the potential for offsite migration of HVOCs is unlikely and that related exposure pathways associated with offsite water supply wells (closest well located 1,500 feet cross-gradient of the site) are considered incomplete.

Based on recent discussions with the NCDENR, ETIC understands that through completion of the supplemental plume characterization, well survey, and additional source reduction activities described herein, the NCDENR will consider the site conditions adequately defined and mitigated in support of site closure through the variance process without requiring long-term groundwater monitoring.

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TABLE OF CONTENTS

Section		Page
EXECUTIVE SUMMARY		i
TABLE OF CONTENTS		iv
1.0	INTRODUCTION	1
2.0	SITE BACKGROUND	2
2.1	Site Description and Previous Work	2
2.2	Site Hydrogeology	2
2.3	Distribution of HVOCs in Groundwater	3
3.0	EXPEDITED SITE CLOSURE ACTIVITIES	3
3.1	Regulatory Discussions with NCDENR	3
3.2	Supplemental Investigation Activities (From August 2004 to April 2005)	4
3.3	Request for Variance Application	5
3.4	Well Survey Activities	6
3.5	Vertical HVOC Plume Definition	6
4.0	ADDITIONAL SOURCE REDUCTION ACTIVITIES	7
4.1	Additional Source Reduction Scope of Work	7
4.2	Permitting Activities	7
4.3	Field Activities	8
4.3.1	*Excavation and Backfilling Activities*	*8*
4.3.2	*Zero-Valent Iron/Sand Reaction Zone and Monitoring Well Installation*	*9*
4.4	Post-Remediation Groundwater Monitoring	10
4.4.1	*Groundwater Sample Collection Procedure*	*11*
4.4.2	*Groundwater Analytical Results*	*11*
5.0	POST-REMEDIATION HVOC CONCENTRATION ESTIMATES	12
5.1	Site Conceptual Model	12
5.2	Code Selection	13
5.3	Model Discretization	13
5.4	Model Calibration	13
5.5	Model Results	14
6.0	RATIONALE AND RECOMMENDATION FOR CASE CLOSURE	15
7.0	NCDENR VARIANCE PROCESS AND ANTICIPATED SCHEDULE	15
8.0	REFERENCES	17

ATTACHMENTS

Figures

Figure 1	Site Vicinity Map
Figure 2	Site Plan
Figure 3	April 2005 Groundwater Elevations
Figure 4	TCE Iso Concentration Contour and Location of Cross Section A-A'
Figure 5	Schematic Cross Section A-A'
Figure 6	Site Vicinity Map with Approximate Water Supply Well Locations within ½ Mile
Figure 7	Locations of Excavation, ZVI, and ZVI-Well
Figure 8	Locations of Wells Destroyed During Remediation Activities
Figure 9	Comparison of Model-Simulated and Field TCE Concentrations Pre HVDPE Event
Figure 10	Simulated TCE Concentrations Relative to Initial Concentration at RW-2
Figure 11	Simulated TCE Concentrations after Source Removal at Several Locations Along the Center Line of the TCE Plume

Tables

Table 1	Cumulative Groundwater Analytical Data
Table 2	ZVI-Well Construction Details
Table 3	ZVI-Well and RW-2 Groundwater Analytical Results

Appendices

Appendix A	Water Supply Well Questionnaire
Appendix B	Standard Protocols For Well Installation, Well Development, Groundwater Sampling, and Well Destruction
Appendix C	Boring Logs, BW-1 and BW-2
Appendix D	Laboratory Analytical Reports, Phase I and Phase II Deep Well Installation
Appendix E	Wellhead Elevation, Pre-Excavation and Post-Excavation Survey
Appendix F	Hydrant Line Certification and Backfill Observation Report
Appendix G	Zero Valent Iron Reaction Zone, Quality Assurance Data
Appendix H	ZVI-Well Groundwater Purging and Sampling Forms
Appendix I	Laboratory Analytical Reports, ZVI-Well Monitoring
Appendix J	Application of Groundwater Flow and Solute Transport Model – Chemical Attenuation Prediction

1.0 INTRODUCTION

ETIC Engineering, Inc. (ETIC) is pleased to present this *Request for Variance Addendum* (Addendum) for the former Kaiser Fluid Technologies (KFT) Facility located at 530 East Sugar Creek Road in Charlotte, North Carolina (the site) (see Figure 1). The site is currently owned by Rockwell Collins, who is the variance request applicant.

Soil and groundwater investigation activities at the site identified low concentrations of halogenated volatile organic compounds (HVOCs) in groundwater that locally exceeded 15A North Carolina Administrative Code (NCAC) 2L.002 groundwater quality standards (2L standards). In lieu of long-term groundwater monitoring of the low concentration HVOC plume and with the goal of achieving expedited site closure through the variance process, ETIC conducted investigations and short-term remediation between August 2004 and April 2005 based on direction from the North Carolina Department of Environment and Natural Resources (NCDENR). During these site activities, the suspected source (former settling tank) was identified, a best available technology (BAT) (i.e., high vacuum dual phase extraction [HVDPE]) was applied to the residual source area, and the limited extent of HVOCs in the shallow water-bearing zone (consisting of unconsolidated overburden and weathered bedrock) was defined. An expedited site closure request through the NCDENR variance process was subsequently submitted in a 9 May 2005 *Request for Variance.*

In a 22 September 2005 correspondence, based on review of the *Request for Variance*, the NCDENR requested that the following activities be performed and documented as an addendum to the *Request for Variance*:

- Additional information on the water supply wells identified within ½-mile of the site;
- Vertical definition of the groundwater HVOC plume, through installation of monitoring wells, in the fractured bedrock aquifer underlying the overburden/weathered bedrock; and
- Additional source reduction.

In November and December 2005, ETIC installed two monitoring wells to define the vertical extent of HVOCs in the subsurface and acquired additional data from the water supply well owners/operators. The 20 January 2006 *Source Reduction and Post-Remediation Groundwater Sample Collection Work Plan* (Work Plan) described the results of these investigation activities and proposed source reduction (i.e., excavation of residual source area and placement of zero-valent iron[ZVI]/sand reaction zone) and short-term monitoring activities. In a 17 February 2006 correspondence, the NCDENR approved the Work Plan and requested additional post-remediation sampling, as well as the development of a numerical groundwater model to evaluate future attenuation in HVOC concentrations along the centerline of the plume following implementation of the additional source reduction program.

This Report presents summaries of the site background, expedited site closure activities (supplemental investigation activities, application of the BAT, well survey information and deep well investigations), additional source reduction activities (excavation of the residual source to the extent practicable, installation of a ZVI/sand reaction zone, and post-remediation monitoring), results of groundwater flow and solute transport modeling, rationale and recommendation for site closure through the variance process, and our understanding of anticipated closure schedule developed in accordance with the NCDENR regulations.

2.0 SITE BACKGROUND

2.1 Site Description and Previous Work

The KFT site is located in a commercial/industrial area of Charlotte, North Carolina. Topography in the site vicinity generally slopes northward (see Figure 1). Little Sugar Creek is located approximately 1,100 feet northwest of the site.

The facility has a 77,000-square foot building on a 5.02-acre parcel of land (see Figure 2). The original building was constructed in 1956 and expanded in 1964 and 1968. The site has been inactive since operations were discontinued in late 2002/early 2003.

Site operations, which included the design and manufacture of fluid control systems for the aerospace industries, began in 1956. Materials used in the manufacturing processes included steel, aluminum, and titanium. During the finishing processes, synthetic coatings and various plating materials were used. Industrial lathes, milling and tooling machines, grinders and precision honing equipment, and cutting, cooling, and lubricating oils were used for the manufacture of the parts. Industrial solvents were used for cleaning the parts.

2.2 Site Hydrogeology

The site lies in the Charlotte Belt of the Piedmont Physiographic Province in North Carolina, which is characterized by a rolling landscape and broad ridges (BBL 2001c). The Charlotte Belt consists of crystalline metamorphic and igneous rocks, namely: gneiss, schist, quartzite, granite, diorite, gabbro, and volcanic rocks, which are typically blanketed by weathered or partially weathered rock known as saprolite.

The subsurface beneath the site consists of silty clays to approximately 5 to 14 feet below ground surface (bgs), which are underlain in turn by weathered to partially weathered bedrock (saprolite) to approximately 22 feet bgs. Beneath the saprolite, the bedrock consists of metamorphosed quartz diorite and schist.

Groundwater is typically first observed at an approximate depth of 15 feet bgs within the primary (matrix pore space) and secondary (fracture-related) porosities of the saprolite. Previous investigations have indicated that the hydrogeologic conditions and groundwater hydraulics beneath the site are characterized by fracture flow, with hydraulic gradients toward the northwest (see Figure 3).

2.3 Distribution of HVOCs in Groundwater

Groundwater has been monitored at the site since 2001. In response to a 25 March 2002 NCDENR letter, semi-annual groundwater monitoring was initiated at the site. Prior to the supplemental investigation activities initiated by ETIC to expedite site closure, nine monitoring wells (MW-1 through MW-9) were part of the active monitoring network (Figure 3). These nine wells were gauged semi-annually. Wells MW-1, MW-3, and MW-5, which typically reported one or more HVOCs that exceeded 2L standards, were sampled semi-annually, while the remaining wells were sampled on an annual basis. HVOC concentrations in groundwater monitoring wells exhibited stable concentration trends.

The monitoring activities indicated that relatively small areas near the southwestern property boundary and outside the northwestern corner of the building were characterized by HVOCs above their respective 2L standards. Near the southwestern property boundary, in well MW-2, the only HVOC reported above its 2L standard was vinyl chloride, which was reported at a concentration of 0.019 milligrams per liter (mg/L). However, in the 25 March 2002 letter, the NCDENR attributed this detection to an offsite upgradient source and did not require further investigation in this area.

HVOC plumes (trichloroethene [TCE], 1,1,1-trichloroethane [TCA], and 1,1-dichloroethene [DCE]) from the former settling tank located outside the northwestern corner of the building were defined to extend northward; however, they exhibited a limited distribution, and were completely contained within the property boundaries. Cumulative analytical results are presented in Table 1.

3.0 EXPEDITED SITE CLOSURE ACTIVITIES

3.1 Regulatory Discussions with NCDENR

As described above, results of groundwater monitoring indicated that HVOC concentration trends in groundwater monitoring wells were stable. Despite these stable concentrations, the NCDENR had indicated that site closure would be granted only after the extent of HVOC plume in groundwater was delineated and after consecutive monitoring events demonstrated that HVOCs were below 2L standards. Site closure (i.e., concentrations reaching 2L standards) via a monitoring only (natural attenuation) approach was estimated to require numerous years, well beyond the timeframe desired by Rockwell Collins, the current site owner. ETIC was retained by Rockwell Collins in 2004, with the goal of developing (in conjunction with the NCDENR) and implementing a more expeditious approach to site closure. Subsequent discussions between ETIC and the NCDENR (including a 7 March 2005 meeting) resulted in the development of an expedited roadmap to site closure via the NCDENR's variance process, with the stated goal of achieving closure by December 2005.

To meet this goal, the following scope of work was developed based on negotiations with the NCDENR:

- Identifying the source area and completely delineating the lateral extent of the HVOC plume;
- Applying a BAT (eg, short-term HVDPE) to reduce residual HVOC mass to the extent practicable;
- Updating the historical well survey by identifying the location of existing water supply wells within a ½-mile radius of the site; and
- Preparing the Request for Variance.

A discussion of the supplemental investigation activities performed to implement the scope of work identified above, is described in Section 3.2

3.2 Supplemental Investigation Activities (From August 2004 to April 2005)

Between August 2004 and April 2005, ETIC conducted supplemental investigation activities, which included sampling temporary borings and installing two 2-inch monitoring wells (MW-10 and MW-11) and five 4-inch remediation wells (RW-1, RW-1A, RW-2, RW-3, and RW-4). Through this investigation program, the primary suspected former source of the HVOCs was identified as a former settling tank. A BAT consisting of a 10-day HVDPE event was applied to the former settling tank area. A search of the Mecklenberg County database for water supply wells within a ½-mile radius of the site was also conducted.

A detailed description of these activities was presented in a 9 May 2005 *Supplemental Investigation and Remediation Report.* A brief summary of results is presented below:

- Concentrations of over 1,000 ug/L of TCE were reported in a limited area near the northwestern corner of the site building. These results indicated that the primary suspected source of HVOCs was the former settling tank and/or associated piping.
- Limited HVOC mass was identified in unsaturated zone soil samples, indicating that there is no active source in the unsaturated zone contributing HVOC mass to the groundwater.
- A TCE plume from the former settling tank area was defined to extend northward across the parking area. Other HVOCs (e.g., 1,1,1-TCA and 1,1-DCE) exhibited a more limited distribution. These data indicated that the extent of HVOCs was adequately defined and limited to within the property boundaries. Figures 4 and 5 depict the extent of TCE, the primary HVOC, in plan and cross-sectional views, respectively.
- Low concentrations of TCE (less than 0.12 parts per million by volume [ppmv]) were detected in soil gas samples collected in the vicinity of the former settling tank, thereby, indicating a limited mass in the unsaturated zone and limited upward diffusive transport of TCE from the underlying groundwater to the unsaturated zone.
- Three water supply wells were identified within a ½-mile radius of the site; two of these wells were located approximately 1,500 feet or more west (cross-gradient), and

one well was located approximately 2,500 feet north (downgradient). Based on the low concentration of the HVOCs in groundwater, low groundwater flow rates, and the significant distance between the site and the nearest water supply well locations, there does not appear to be a significant risk to human health.

- During the application of the BAT, TCE concentrations in source area extraction wells declined in response to HVDPE. Stabilized water levels in observation wells and low and declining TCE mass removal rates indicated that HVDPE reached its maximum effectiveness during the 10-day event. Post-HVDPE monitoring results in groundwater samples collected approximately three months following BAT application indicated that TCE concentrations had rebounded locally in a small portion of the residual source area (near well RW-3), but remained below pre-remediation levels throughout the residual source area.

The findings of the supplemental investigation activities indicated that: 1) the remaining TCE (and other HVOC) mass was trapped in limited permeability and dead-end fractures; 2) mobility was diffusion limited; and 3) further HVDPE or other remedial activities were not likely to reduce the limited HVOC mass remaining beneath the site.

3.3 Request for Variance Application

The data collected at the site indicated that the HVOC plume was locally constrained around the former settling tank area (i.e., the residual source area), with the leading edge of the plume completely contained within the property boundaries. The results of the BAT applied to the residual source area indicated that 2L standards cannot be achieved in a timely and economically reasonable manner with continued application of an active remedial technology such as HVDPE. Excavation of the residual source was identified as the only active remedial alternative capable of further reducing the trapped HVOC mass. However, implementation costs for excavation (of a 25 foot by 25 foot area to the estimated bedrock depth of 22 feet bgs) were estimated to be greater than the assessed value of the land. Because the site conditions did not endanger the public health and safety, and the groundwater in the vicinity is not used for public benefit, excavation was considered to incur a financial hardship on the current property owner without equal or greater public benefit. Therefore, the 9 May 2005 *Request for Variance* recommended that the NCDENR review the site for expedited site closure through the variance process.

In a 9 September 2005 correspondence, the NCDENR requested that the following activities be performed and documented as an addendum to the *Request for Variance*:

- Additional information on the water supply wells identified within ½-mile of the site;
- Vertical definition of the groundwater HVOC plume, through installation of monitoring wells, in the fractured bedrock aquifer underlying the overburden/weathered bedrock; and
- Additional source reduction.

3.4 Well Survey Activities

In November 2005, supplemental information was solicited from the owners/operators of the three properties with water supply wells identified in the *Request for Variance*. This supplemental information indicated that the two wells located approximately 1,500 feet west (cross-gradient) of the site have non-potable uses and that the well located approximately 2,500 feet north (downgradient) of the site is not in use (Figure 6). Based on follow-up discussions with NCDENR, no additional well survey activities were needed to support the *Request for Variance*. Documentation of the well survey conducted by ETIC, including the responses provided to a questionnaire, is presented in Appendix A.

3.5 Vertical HVOC Plume Definition

To define the vertical extent of HVOCs, well BW-1 was installed in accordance with the NCDENR-approved scope of work presented in the 4 October 2005 *Response to September 22, 2005 Correspondence Memorandum*. In November 2005, well BW-1, which screens from 40 to 50 bgs, was installed adjacent to well RW-2, which screens from 15 to 25 feet bgs (see Figure 4). TCE concentrations in well BW-1 (120 micrograms per liter [µg/L] to 600 µg/L) were higher than those reported in well RW-2 (75 µg/L); therefore, the NCDENR requested that a deeper well be installed to characterize the vertical extent of TCE in groundwater at this location.

The deeper well was installed in accordance with the NCDENR-approved 12 December 2005 *Phase II - Deep Well Installation Memorandum*. In December 2005, well BW-2, which screens from 76 to 79 feet bgs was installed near wells RW-2 and BW-1. No HVOCs were reported in the groundwater sample collected from this well, thereby defining the vertical extent of TCE (and other HVOCs) and satisfying the NCDENR's request.

Figures 4 and 5 exhibit recent TCE concentrations in groundwater in plan and cross-sectional views, respectively. As shown in these figures, the extent of TCE exceeding 1,000 µg/L is largely limited to the area immediately adjacent to the former settling tank, with the plume laterally and vertically defined. Based on recent discussions with NCDENR, no additional characterization is needed to support the *Request for Variance*.

Well installation activities were conducted by South Atlantic Environmental Drilling and Construction Company of Fort Mill, South Carolina under the existing site investigation permit (#50000456) issued by the County of Mecklenburg. Because a subsurface investigation permit existed for the site, no new well drilling permit was required by the County of Mecklenburg to install these wells. Field procedures, boring logs, field data sheets, and laboratory analytical reports are enclosed in Appendices B, C, and D, respectively.

4.0 ADDITIONAL SOURCE REDUCTION ACTIVITIES

4.1 Additional Source Reduction Scope of Work

ETIC's scope of work for additional source reduction was described in the 20 January 2006 *Source Reduction and Post-Remediation Groundwater Sample Collection Work Plan* (Work Plan). This scope of work included excavation of the former settling tank area to the extent practicable (approximately 25 feet long by 25 feet wide to an estimated depth of bedrock of 22 feet bgs), destruction of wells located within the excavation footprint, backfilling a portion of the excavation with a 2-foot thick zero-valent iron (ZVI)/sand mixture, and one-time post-remediation groundwater sampling from a well (ZVI-Well) to be installed within the ZVI/sand backfill, and coordinating offsite disposal of soil and groundwater. This proposed scope of work was conditionally approved in a 17 February 2006 NCDENR letter. To support expedited site closure without long-term groundwater monitoring, the NCDENR requested the addition of the following:

- Additional groundwater sampling of the ZVI-Well and well RW-2, located 20 feet to the north (downgradient) of the excavation, one month after the collection of the planned post-remediation sample; and
- Development of a groundwater flow and transport model to predict future attenuation of TCE concentrations in onsite groundwater to the north (downgradient) of the excavation.

Also, comments were solicited from NCDHHS's state toxicologist on the Request for Variance and the proposed source reduction program. In a 17 February 2006 letter, the state toxicologist indicated that "from a public health standpoint, there currently does not appear to be any potential impacts on drinking water wells in the area, and therefore any potential impact would not be considered significant." Furthermore, the state toxicologist indicated that the results of the post-remediation sampling would be used to determine the effectiveness of the source reduction program in reducing HVOC concentrations in the former settling tank area and ensuring reduction of future offsite impacts.

4.2 Permitting Activities

The destruction of wells RW-1, RW-1A, RW-3, and RW-4, and installation of the ZVI-Well were conducted using an existing site investigation permit (#50000456) issued by the County of Mecklenburg. Therefore, no new well drilling permits were required. Because the size of this excavation project was less than 0.1 acre, an erosion control and grading permit was not required by the County of Mecklenburg.

4.3 Field Activities

In March and April 2006, field activities were performed by Regional Construction and Design, Inc. (Regional) of Charlotte, North Carolina and observed by ETIC. The following briefly describes the field activities.

4.3.1 Excavation and Backfilling Activities

Excavation activities were conducted at and around the former settling tank area to remove the residual HVOC source to the extent practicable; the areal dimensions of the excavation were 26 feet long by 26 feet wide (see Figure 7 for excavation location). Excavation proceeded to a depth of 22 feet bgs, where more competent (less fractured and less weathered) bedrock was observed in previous site borings; at and below 22 feet bgs, the use of a rock hammer was required for removal.

Well Destruction: During the first week of field activities, wells RW-1, RW-1A, RW-3, and RW-4, which were located within the excavation footprint, were destroyed (see Figure 8). The well casing, well-box, and well annulus material were removed using earth moving equipment.

Water Line Removal and Installation: Prior to the initiation of the excavation activities, a line supplying water to a fire hydrant located within the excavation footprint was capped at the eastern face of the excavation. The portion of this water line located within the excavation footprint and the fire hydrant were temporarily removed. Following excavation and backfilling, the water line and a new fire hydrant were installed. Subsequent pressure testing confirmed the hydraulic integrity of the installed water line and fire hydrant (see Appendix E).

Shoring Activities: Due to the proximity to the excavation area to the facility, a shoring system was installed to ensure the stability of the excavation sidewalls and integrity of the facility building and storm drain lines. Coble Trench Safety of Charlotte, North Carolina designed a proprietary shoring system consisting of slide rails with four corner vertical posts, which were connected by horizontal panels along each face of the excavation. The shoring system was advanced as the excavation deepened and removed as the excavation was backfilled. As described in the NCDENR-approved Work Plan, sidewall soil sampling and over-excavation were precluded from the scope of work due to the presence of the shoring.

Elevation Survey: A survey of pre- and post-excavation elevations of selected points inside the building is enclosed in Appendix F. The measured maximum difference in pre- and post-excavation elevations was 0.01 feet; these measurements confirm the effectiveness of the shoring system in minimizing settlement inside the building and thus ensuring the stability of the facility building.

General Backfilling and Resurfacing: Following the completion of the excavation to approximately 22 feet bgs, the shoring system was removed as the excavation was backfilled. Except for the ZVI/sand reaction zone installed along the northern excavation face (see Section 4.3.2), the excavation was backfilled from 4 feet bgs to 22 feet bgs with pit gravel (i.e., a gravelly sand mixture) and from 4 feet bgs to 6 inches bgs with imported silty sand fill material. The backfill materials were placed in 12-inch loose lifts and the material in each lift was compacted to at least 90% relative compaction. The specifications for the pit gravel and the silty sand material used for backfilling and the backfill observation report are included in Appendix E. The excavation area was resurfaced with sod to match the existing landscaping. A concrete curb and asphalt areas adjacent to the excavation area were replaced.

Soil and Water Handling: The excavation spoils were placed on and completely covered by 10-mil plastic sheeting and temporarily stored onsite pending disposal. Because of the low permeability of the subsurface surrounding the excavation, a limited volume of groundwater entered the excavation pit. The water was transferred to an onsite storage tank pending disposal.

Clean Harbors Environmental Services (Clean Harbors) of Reidsville, North Carolina coordinated soil and water disposal activities. Approximately 550 cubic yards (in-place volume) of excavation spoils were disposed offsite at an Allied Waste facility in Charlotte, North Carolina. Approximately 2,500 gallons of groundwater recovered during the excavation activities were transported for treatment and disposal to an offsite permitted facility maintained and operated by Clean Harbors in Chattanooga, Tennessee.

4.3.2 Zero-Valent Iron/Sand Reaction Zone and Monitoring Well Installation

ZVI/Sand Reaction Zone Construction: As described in the Work Plan, a ZVI/sand reaction zone is a permeable zone containing reactive material through which impacted groundwater can pass and undergo insitu remediation. The reaction zone was designed with the aid of EnviroMetal Technologies, Inc. (ETI) (www.eti.ca) to whom the technology patent (owned by University of Waterloo) is exclusively licensed. The insitu degradation involves an abiotic reductive dehalogenation process occurring on the surface of the granular iron, with the iron acting as an electron source.

ETI conservatively estimated that an iron thickness of 0.30 feet would provide the residence time for degradation of the current maximum HVOC groundwater concentrations to below 2L standards. To meet this design criteria, a 2-foot wide reaction zone composed of 20% ZVI and 80% sand mixture (2 feet wide * 20% [iron content] = 0.40 feet iron thickness equivalent) was described in the Work Plan. As a further conservative measure, a 3-foot wide reaction zone composed of 25% ZVI and 75% sand mixture (3 feet wide * 25% [iron content] = 0.75 feet iron thickness equivalent) was installed. Assuming the dry densities of ZVI and sand as 140 pounds per cubic feet (pcf) and 100 pcf, respectively, 25% ZVI by volume is the equivalent of 35% ZVI by dry weight. The ZVI/sand mix backfill specifications and quality assurance procedures are presented in Appendix G.

A 26-foot long by 3-foot wide ZVI/sand reaction zone, oriented approximately perpendicular to the historical northerly groundwater flow direction was installed along the northern face of the excavation (see Figure 7). The 3-foot wide ZVI/sand reaction zone was installed by placing the premixed ZVI/sand mixture from approximately 22 feet bgs, the bottom of the excavation, to 10 feet bgs, above the shallowest water levels reported in wells near the excavation. The ZVI/sand mixture was premixed by the supplier (Connelly GPM) and delivered to the site in 3,000 pound bags. The supplier's certification documenting compliance with the design requirements (25% ZVI/ 75% sand by volume [35% ZVI/ 65% sand by dry weight]) is included in Appendix G. Also, field testing (one test per five 3,000 pound bags) was conducted to confirm compliance with mix design requirements. The supplier's certification and the field testing method and results are included in Appendix G.

ZVI-Well Construction: During ZVI/sand reaction zone construction, a 2-inch diameter monitoring well (ZVI-Well), screening from 15 to 20 feet bgs (see Table 2 for well construction details), was placed within the reaction zone (see Figure 7). The ZVI-Well is located at the mid-point of the reaction zone in the east-west direction, and approximately 1 feet south of the excavation sidewall. A temporary 8-inch PVC conductor casing was installed around the ZVI well to prevent damage to the monitoring well during ZVI/sand backfilling/compaction. To compensate for the mass of ZVI displaced due to the presence of the well inside the reaction zone, the annulus (between the 8-inch PVC conductor casing and the 2-inch monitoring well) was backfilled with ZVI/sand mixture containing 32% ZVI by volume (~44 % by dry weight). After completion of reaction zone construction, the temporary 8-inch conductor casing was removed.

4.4 Post-Remediation Groundwater Monitoring

On 2 May 2006, approximately two weeks after installation, a groundwater sample was collected from the ZVI-Well. On 1 June 2006, approximately one month after the initial sampling event, groundwater samples were collected from the ZVI-Well and well RW-2, located 20 feet to the north (downgradient) of the excavation.

As described in the Work Plan, the ZVI/sand reaction zone was conservatively designed to treat HVOCs under historic groundwater flow conditions; purging the ZVI-Well at higher rates could potentially overcome this conservatism and yield results that are not representative of actual site conditions. Therefore, groundwater from this well was sampled using low flow sampling techniques to reduce the potential for decreased reaction times induced by increased groundwater flow rates during traditional purging. For consistency with previously conducted sampling, well RW-2 was sampled using the traditional 3 casing volume purging method.

4.4.1 Groundwater Sample Collection Procedure

Groundwater was purged using a peristaltic pump. Temperature, pH, specific conductivity, turbidity, salinity, oxidation-reduction potential (ORP) and dissolved oxygen (DO) were measured. Following purging, the groundwater sample was collected using the peristaltic pump. As mentioned above, low flow methods were used for the ZVI-Well and standard methods were used for well RW-2.

Groundwater samples were transported under chain-of-custody protocols to Pace Analytical of Huntersville, North Carolina, a state-certified laboratory, and analyzed for HVOCs using United States Environmental Protection Agency (EPA) Method 8260B. Field datasheets are presented in Appendix H.

4.4.2 Groundwater Analytical Results

Except for chloroethane, no HVOCs were reported in the ZVI-Well samples. Chloroethane was reported at concentrations of 4.7 µg/L in May 2006 and 1.7 µg/L in June 2006, which are well below the 2L standard of 2,680 µg/L (Table 3). The groundwater sample collected from well RW-2 in June 2006 reported concentrations that were consistent with or lower than previously reported concentrations (Table 3).

The ZVI empirical data available to ETI (the patent holder) indicates that 1,1,1-TCA degradation to ethane by the ZVI does not produce chloroethane as an intermediate product (Personal Communication with Mike Duchene, Senior Engineer of ETI). Therefore, the detection of the low concentrations of chloroethane in the ZVI-Well is likely not due to degradation of 1,1,1-TCA within the reaction zone, but rather breakdown of 1,1,1-TCA by naturally-occurring anaerobic biodegradation process in the subsurface. Concentrations of chloroethane at these low levels were likely undetectable in previously collected groundwater samples because of elevated concentrations of other HVOCs (such as TCE, 1,1,1-TCA, and 1,1-DCE) that resulted in elevated laboratory reporting limits.

The post-remediation sampling results demonstrate the effectiveness of the ZVI in degrading dissolved HVOCs potentially migrating from the area upgradient of the ZVI/sand reaction zone (see Table 3 and Appendix I). HVOC degradation by the ZVI is further supported by establishment of reducing geochemical conditions as indicated by the decline in ORP levels from approximately 197 to 210 millivolts (mV) in well RW-1 prior to the reaction zone installation (ETIC, 2005a) to -607 to -646 mV in the ZVI-Well during the May 2006 and June 2006 monitoring events.

5.0 POST-REMEDIATION HVOC CONCENTRATION ESTIMATES

As discussed previously, the NCDENR requested that a numerical groundwater flow and chemical transport model be developed to evaluate the future attenuation in HVOC concentrations downgradient of the former settling tank area (the former residual HVOC area), which has been the subject of past and recent remedial efforts. To this end, ETIC developed a site-specific numerical model using the Lawrence Berkeley National Laboratory (LBNL) flow model TOUGH2 (Pruess et al., 1999) and the related solute transport code T2R3D (Wu et al., 1996). TCE is the primary HVOC detected in onsite groundwater. 1,1,1-TCA and 1,1-DCE, which were the only other HVOCs consistently reported above 2L standards, exhibit a more limited distribution; accordingly their concentrations are anticipated to decline more rapidly than those of TCE. Therefore, TCE fate and transport, and associated attenuation, in groundwater following additional source reduction were simulated.

A description of the site conceptual model, basis for code selection, model discretization, calibration results, and model results is presented below (see Appendix J for detailed description).

5.1 Site Conceptual Model

The subsurface beneath the site is generally characterized by silts and clays from just beneath the surface to depths ranging from 5 to 14 feet bgs. These soils are in turn underlain by variably fractured and weathered bedrock (saprolite) to a depth of 22 feet bgs. Below 22 feet bgs, the bedrock encountered in boreholes and during excavation is less weathered and more competent. The unweathered bedrock was characterized as hard rock that could not be penetrated by an auger and required a rock hammer for removal during excavation.

Within the saprolite, groundwater flow and associated HVOC migration occurs primarily as horizontal flow through fractures and along the saprolite/bedrock interface. The groundwater flow direction is to the northwest based on groundwater elevations and is governed by and reflects the regional gradient. However, the distribution of dissolved TCE is oriented northward, which is consistent with regional fracture patterns.

5.2 Code Selection

In implementing the above conceptualization, the challenge is to develop a simulation model that adequately accounts for both the matrix pore components and fracture flow components. Model selection was based on the site-specific hydrogeology and the need to simulate flow and chemical transport contained both in the primary pore space of the matrix and the secondary pore space of the fractures. TOUGH2/T2R3D was selected as the numerical simulation code because it can handle a system with variations in porosity/permeability between the matrix and the fracture pore spaces.

5.3 Model Discretization

The TOUGH2/T2R3D groundwater model domain covered an area of approximately 26 acres (see Appendix J for model domain). Spatially, three levels of grid refinement were used: a fine grid size (grid block size from 6.6 to 14.4 feet) in the observed TCE plume area, a medium grid size (grid block size of 32.8 feet) for the area with available groundwater flow data, and a coarse grid size (grid block size of 131 feet) for the remainder of the model domain. Vertically, the model was discretized into two layers: the upper layer from ground surface to 22-31 feet bgs, representing the soil/saprolite material, and a lower layer from 22-31 to 60 feet bgs representing the more competent bedrock with limited fracture porosity.

5.4 Model Calibration

Hydraulic properties representative of subsurface hydrogeology and appropriate boundary conditions were input into the model to simulate groundwater flow conditions for calibration with observed non-pumping groundwater flow conditions and the groundwater flow conditions observed during the 10-day HVDPE event (see Appendix J for a detailed description). Also, the model was calibrated to ensure that simulated TCE transport is representative of observed TCE concentrations in shallow groundwater. Results of the chemical transport calibration are presented on Figure 9, which compares simulated TCE concentrations with observed concentrations in August-November 2004, prior to application of the BAT to the former settling tank area (the residual HVOC source area). Because of the conservative nature of the developed model, the simulated TCE concentrations were generally higher than observed TCE concentrations.

5.5 Model Results

Using the calibrated groundwater flow and solute transport model, attenuation of TCE concentrations downgradient of the former settling tank area (the area subject to previous and recent remedial efforts) were conservatively estimated at locations along the centerline of the TCE plume. The results of the model were used as a screening level evaluation, with particular emphasis on the model-simulated trends and general order of magnitude of the simulated concentrations over time. Importantly, the model simulations conservatively ignored processes known to significantly attenuate TCE in groundwater, including adsorption and biodegradation. As such, the model-simulated results necessarily reflect concentrations higher than those that will actually occur in the field.

Conservatively simulated concentrations of TCE over time following source removal relative to initial concentration (i.e., current concentration) at well RW-2, located 20 feet to the north of the excavation/remediation area shown on Figure 10. TCE concentrations over time were simulated at four additional locations (or points of interest), 40 feet, 80 feet, 120 feet, and 160 feet, respectively, northward along the plume centerline (downgradient) of the remediation area and are depicted on Figure 11. As expected, source removal efforts served to rapidly reduce TCE concentrations downgradient of the remediation area within a short period (to approximately one fifth of the initial concentration in approximately 20 years) at well RW-2 and concentrations continued to decline toward 2L standards at this location. TCE simulation results at the four other locations suggest that simulated concentrations would rise gradually to a level around or less than 100 µg/L and then decline rapidly toward 2L standards. The initial increase in concentration is attributed to the transport of TCE from upgradient areas (with higher TCE initial concentrations) and the rapid decline following this initial rise in concentration is attributed to the flux of groundwater (which does not contain TCE) through this area following this initial transport of TCE from upgradient areas.

Importantly, the magnitude of actual increase in TCE concentration will be significantly lower than those predicted by the model because the model does not incorporate the processes of adsorption and biodegradation. These processes would serve to significantly reduce the mass flux of TCE from upgradient areas into the points of interest. Additionally, processes such as biodegradation that serve to reduce mass of TCE in groundwater would also contribute to accelerated decline in TCE concentrations over time.. However, even with the exclusion of these processes from the model, the simulations indicate that TCE concentrations downgradient of the area targeted by recent remediation efforts, will continue to reduce over time, further limit the potential migration of TCE toward downgradient portions of the site, and will continue to decline toward 2L standards. Furthermore, the post remediation monitoring results and the model simulations indicate that future off-site migration of HVOCs is unlikely.

6.0 RATIONALE AND RECOMMENDATION FOR CASE CLOSURE

As described above, previous site investigations had defined the limited vertical and lateral extent of HVOCs in groundwater. The concentrations TCE, the primary HVOC in groundwater, on the order of 1,000 µg/L (i.e., residual source area) were locally constrained to the area immediately adjacent to the former settling tank. This residual source area has been the subject of past remedial efforts (removal of the former settling tank and application of a BAT consisting of 10-day HVDPE event) and was the focus of the recently completed additional source reduction activities through excavation and backfilling. The excavation area encompassed the lateral extent of groundwater containing TCE concentrations exceeding 1,000 µg/L. The emplaced ZVI/sand mixture in the reaction zone will continue to degrade potential HVOCs migrating from upgradient of the reaction zone. The success of the recent additional source reduction activities was demonstrated by the absence of TCE (and 1,1,1-TCA and 1,1-DCE) concentrations in the samples collected from the ZVI-Well. These remediation activities should significantly reduce the future HVOC mass flux into the dissolved portions of the HVOC plume, which should further reduce concentrations downgradient of the excavated area. As confirmed by the groundwater flow and transport model, TCE concentrations in onsite groundwater are anticipated to decline to below the 2L standard over time.

Supplemental water supply well information indicates that the two water supply wells located 1,500 feet or more west (cross-gradient) of the site have non-potable uses and the well located 2,500 feet north (downgradient) of the site is inactive. For the reasons stated above, the potential for offsite migration of HVOCs is unlikely, and related exposure pathways associated with offsite water supply wells are considered incomplete. Based on recent discussions, we understand that through completion of the additional plume characterization, well survey, and additional source reduction activities described herein, the NCDENR will consider the site conditions adequately defined and mitigated in support of site closure through the variance process without requiring long-term groundwater monitoring.

7.0 NCDENR VARIANCE PROCESS AND ANTICIPATED SCHEDULE

Based on discussions with the NCDENR and the NCDHHS staff, ETIC understands that the NCDENR will review this report and following concurrence with the recommendations contained herein, will forward it to the Director with the recommendation to grant variance from the North Carolina 2L standards without long-term groundwater monitoring. Following his review and concurrence with the site closure recommendation, ETIC understands that the Director will support the placement of the variance documentation on public notice, which will be followed by a public hearing. Subsequent to the public hearing, the variance documentation will be placed on the NCDENR's Environmental Management Commission's (EMC's) Groundwater Committee's Agenda for review during a regularly scheduled meeting. Once approved by the EMC Groundwater Committee, the variance request will be placed in front of the full EMC for final approval.

Based on our discussions with the NCDENR, ETIC understands that the regulatory process for variance approval will likely require approximately four to six months. Following approval of the variance request, ETIC will destroy the remaining site wells, including the ZVI-Well.

8.0 REFERENCES

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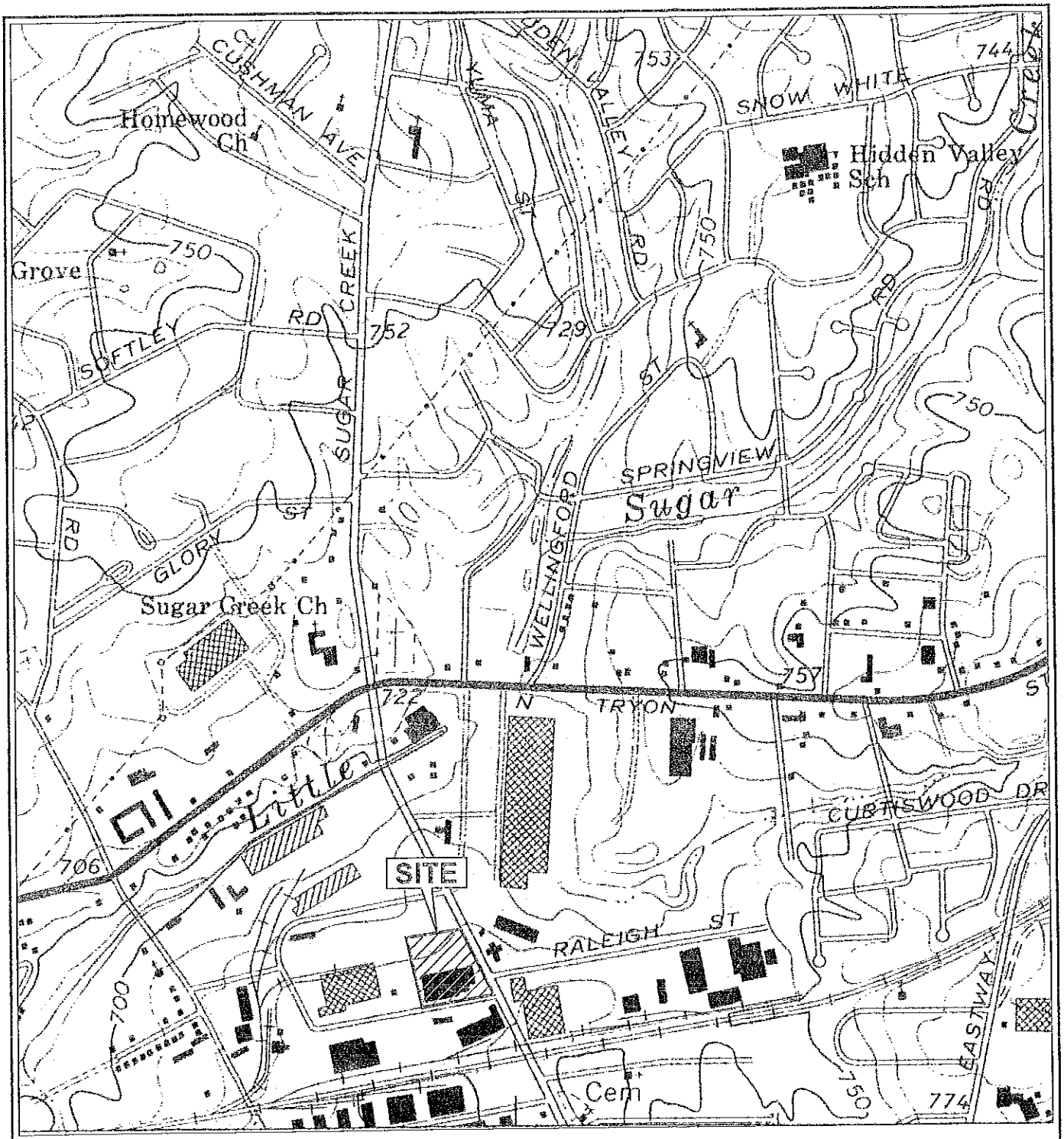
FIGURES



Source Map: USGS Derita, NC Quadrangle

N

0 500 1,000

Scale (feet)

SITE VICINITY MAP

FORMER KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

ETIC ENGINEERING

Date:	Figure:
6/08/2006	1

TOPO0406_FIG16.DWG

LEGEND:

- Destroyed groundwater well
- Existing groundwater well
- Groundwater screening location (temporary boring - grab groundwater sample collected)
- Soil matrix sample
- Soil vapor sample
- Property and proposed variance boundary
- Fence
- Estimated ground surface elevation
- ZVI Zero Valent Iron

SB28
MW11
SB30
SB29
SB31
MW10
SB17
SB18
SB24
SB19
SB25
SB22b
MW-5
SB16
MW-7
RW2
BW2
BW1
SB21
SB20
SB26
3' Thick ZVI Reaction Zone
SB15c
ZVI-WELL
GW-5
SB23
SB27
SB13A
MW-3
GW-6
SB14
GW-1
MW-1
MW-6
MW-9
MW-8
MW-4
GW-3
MW-2
GW-2
EAST SUGAR CREEK ROAD
RALEIGH STREET

N

0 30 60
Scale (feet)

SITE PLAN

KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

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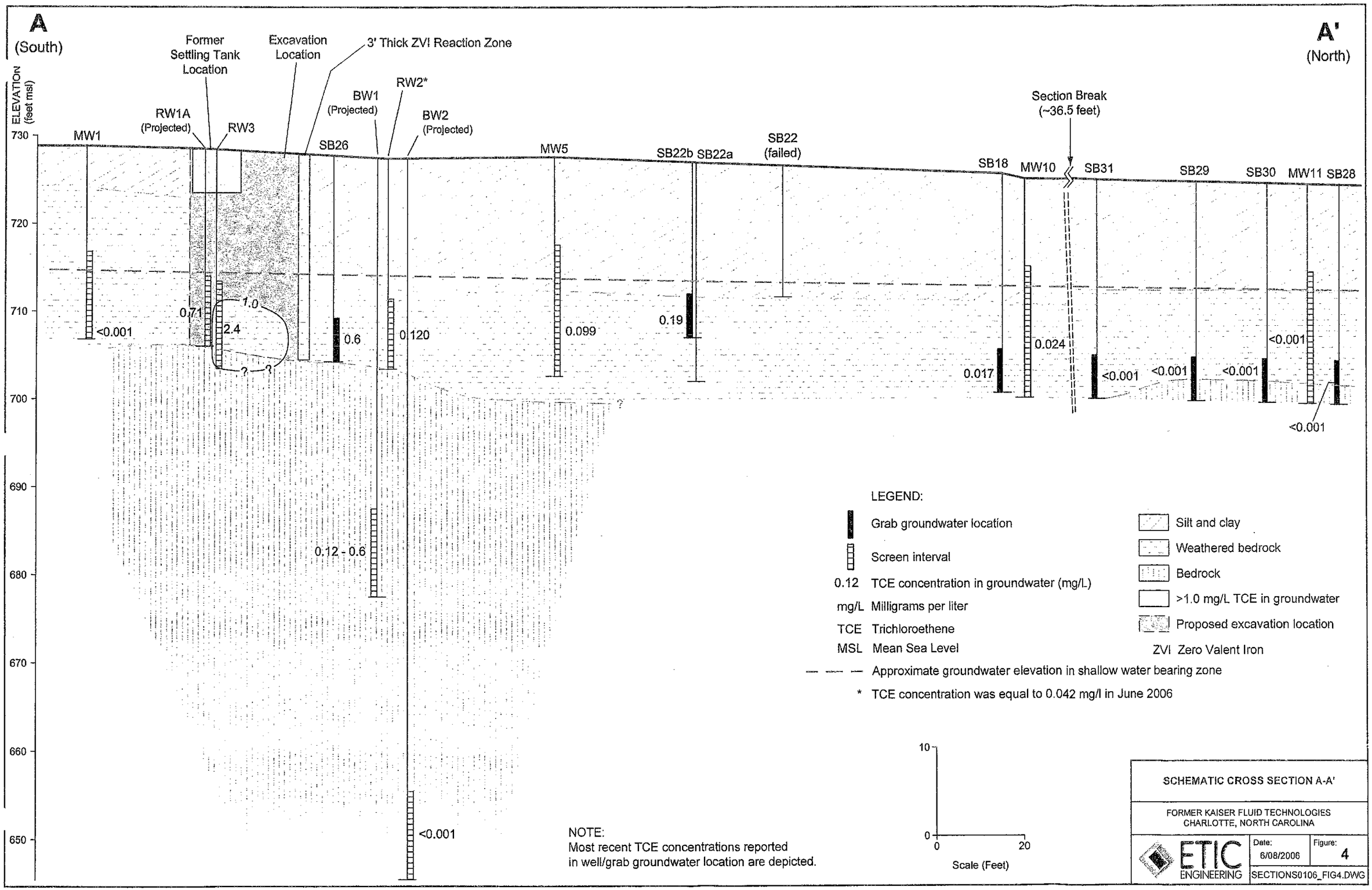
Date: 6/08/2006

Figure: 2

SITEPLAN0406_FIG2.DWG



LEGEND:

- Grab groundwater location
- Screen interval
- 0.12 TCE concentration in groundwater (mg/L)
- mg/L Milligrams per liter
- TCE Trichloroethene
- MSL Mean Sea Level
- — — — Approximate groundwater elevation in shallow water bearing zone
- * TCE concentration was equal to 0.042 mg/l in June 2006
- Silt and clay
- Weathered bedrock
- Bedrock
- >1.0 mg/L TCE in groundwater
- Proposed excavation location
- ZVI Zero Valent Iron

NOTE:
Most recent TCE concentrations reported in well/grab groundwater location are depicted.

10
0
0
20
Scale (Feet)

SCHEMATIC CROSS SECTION A-A'

FORMER KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

ETIC ENGINEERING

Date: 6/08/2006

Figure: 4

SECTIONS0106_FIG4.DWG

LEGEND:

- Destroyed groundwater well
- Existing groundwater well
- Groundwater screening location (temporary boring - grab groundwater sample collected)
- Property and proposed variance boundary
- Fence
- 712.0 — Groundwater elevation contour (ft msl)
- (710.72) Groundwater elevation (ft msl)
- ZVI Zero Valent Iron
- * Data not used for contouring

SB28
MW11 (712.26)*
SB30
SB29
SB31
(710.72)
MW10
SB17
SB18
SB24
712.0
SB19
712.0
SB25
714.0
SB22b
(713.78)
MW-5
SB16
(714.17)
RW2
BW1
BW2
SB21
SB20
(714.51)
SB26
SB15c
ZVI-WELL
(716.08)
716.0
MW-7
GW-5
SB23
SB27
SB13A
SB14
MW-3
(715.26)
GW-6
(714.46)
GW-1
(715.17)
MW-1
(714.81)
(715.08)
MW-6 (716.86)
MW-9
(716.25)
716.0
718.0
MW-8
(717.48)
MW-4
(718.99)
GW-3
MW-2 (718.05)
GW-2
718.0
EAST SUGAR CREEK ROAD
RALEIGH STREET
CENTRAL IRON & METAL WAREHOUSE

N

0 30 60
Scale (feet)

APRIL 2005
GROUNDWATER ELEVATIONS

KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

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Date: 6/08/2006
Figure: 5
SITEPLAN0406_FIG5.DWG

LEGEND:

- Destroyed groundwater well
- Existing groundwater well
- Property and proposed variance boundary
- Fence
- ZVI Zero Valent Iron

MW11
MW10
MW-5
MW-7
RW2
BW2
BW1
ZVI-WELL
MW-3
MW-1
MW-6
MW-9
MW-8
MW-4
MW-2
EAST SUGAR CREEK ROAD
RALEIGH STREET

N

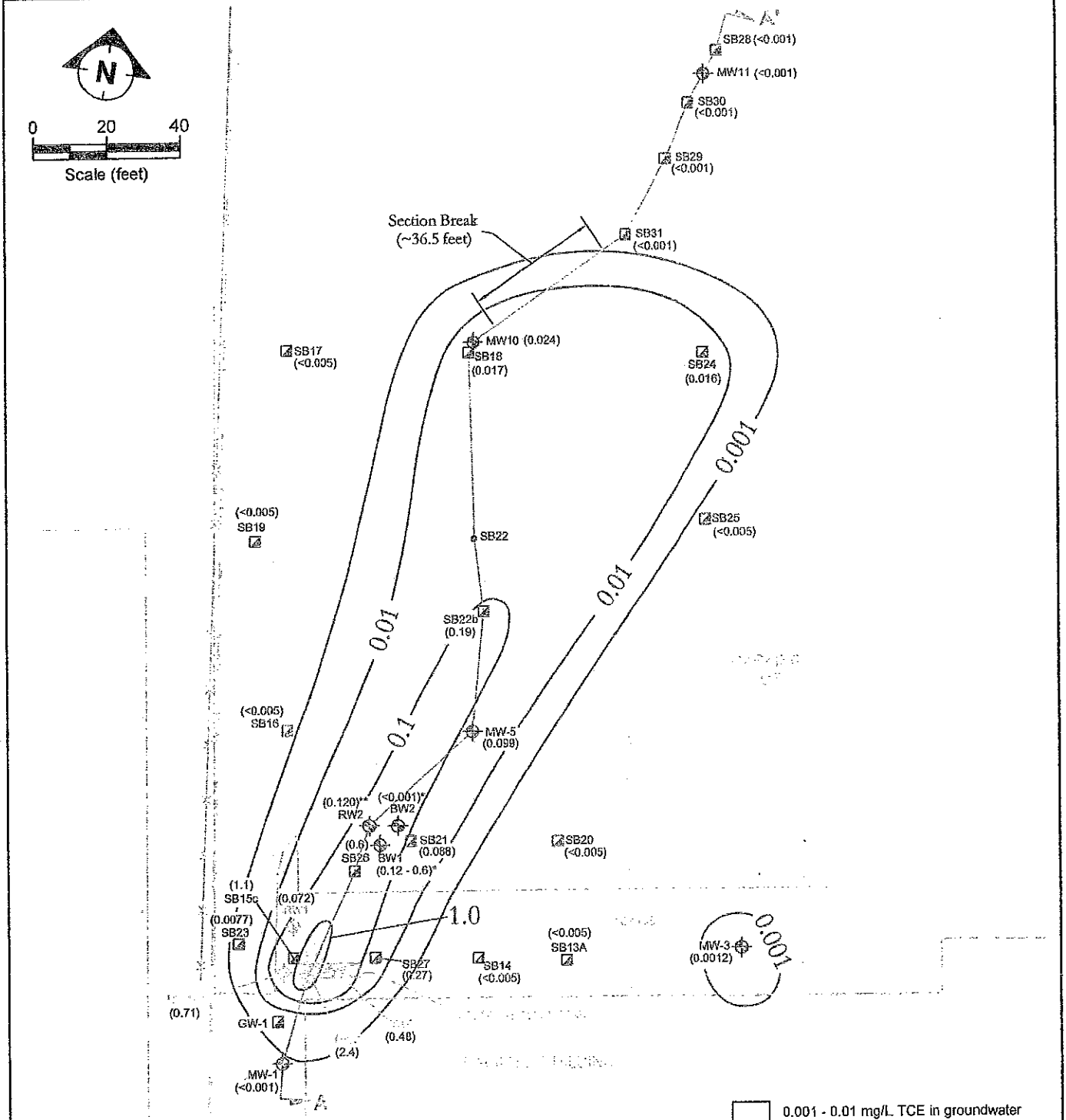
0 30 60
Scale (feet)

LOCATIONS OF WELLS DESTROYED DURING REMEDIATION ACTIVITIES

KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

ETIC ENGINEERING

Date: 6/08/2006
Figure: 8
SITEPLAN0406_FIG8.DWG



LEGEND:

- • Soil boring
- Existing groundwater well
- Destroyed groundwater well
- Grab groundwater sample location
- ** TCE concentration was 0.042 mg/l in June 2006
- Property Boundary
- A A' Cross section location
- Fence
- (0.17) TCE concentration in mg/L
- < Less than noted laboratory reporting limit
- > Greater than the noted concentration
- mg/L Milligrams per liter
- TCE Trichloroethene
- * Data not used for contouring

NOTE: Most recent TCE concentrations reported in well/grab groundwater location are depicted.

- 0.001 - 0.01 mg/L TCE in groundwater
- 0.01 - 0.1 mg/L TCE in groundwater
- 0.1 - 1.0 mg/L TCE in groundwater
- >1.0 mg/L TCE in groundwater

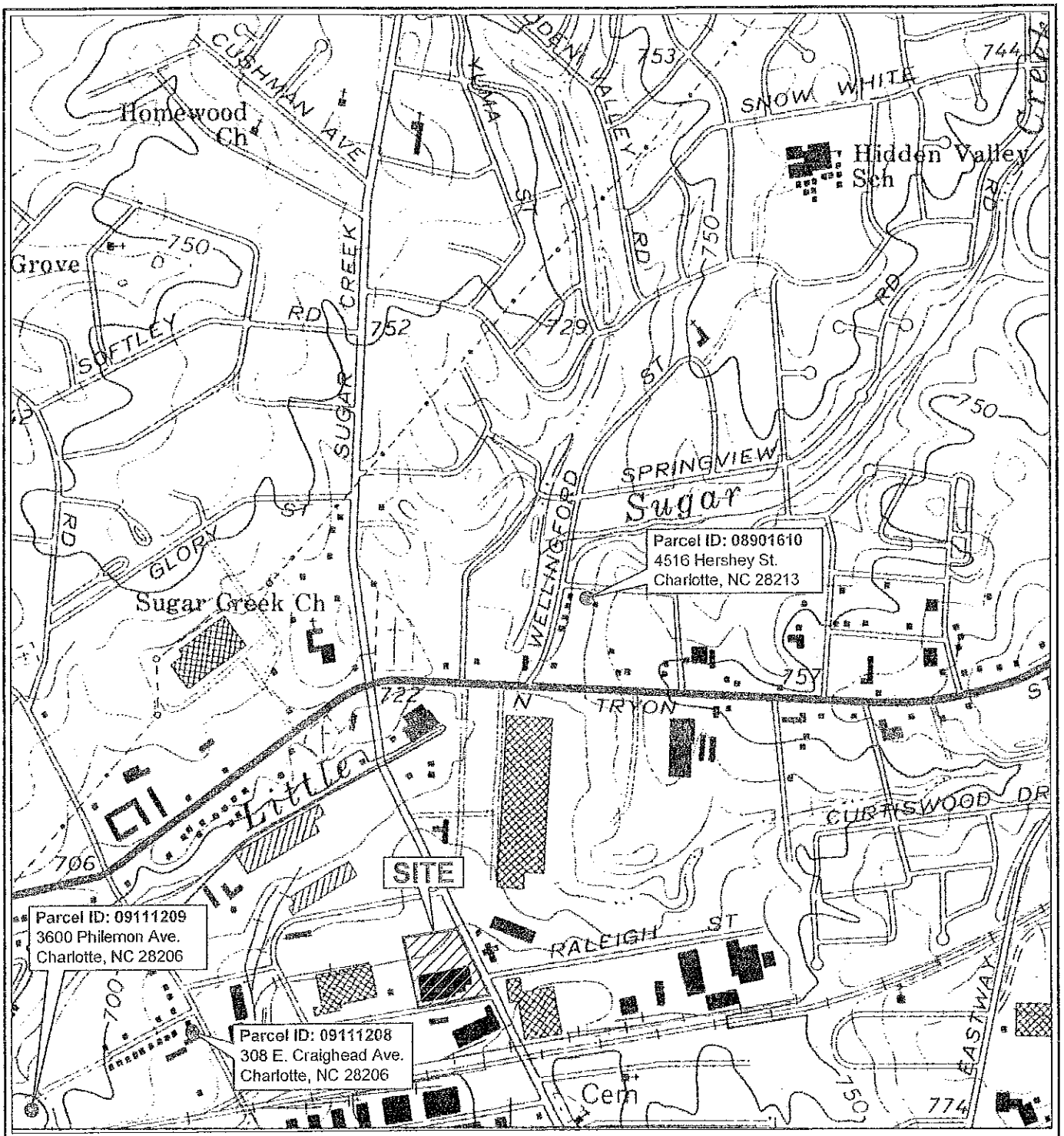
TCE ISOCONCENTRATION CONTOURS AND LOCATION OF CROSS SECTION A-A'

FORMER KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

ETIC ENGINEERING

Date:	Figure:
6/08/2006	3

VARADD0406_FIG37.DWG



Source Map: USGS Derita, NC Quadrangle

N

0 500 1,000

Scale (feet)

SITE VICINITY MAP WITH APPROXIMATE WATER SUPPLY WELL LOCATIONS WITHIN 1/2-MILE

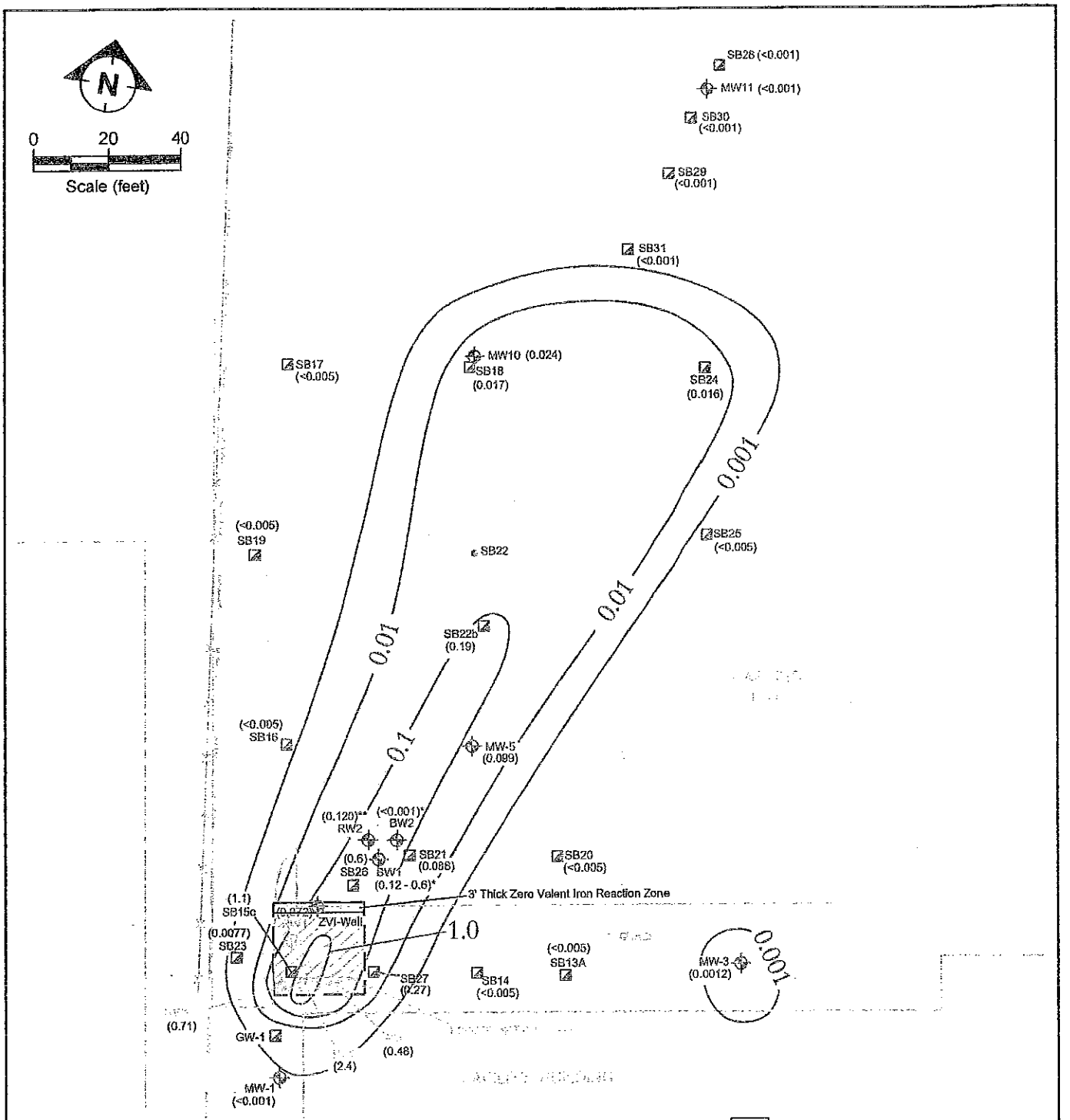
FORMER KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

ETIC ENGINEERING

Date: 6/08/2006

Figure: 6

TOPO0406_FIG16.DWG



LEGEND:

- Soil boring
- Groundwater well
- Grab groundwater sample location
- Property Boundary
- Excavation Boundary
- Fence
- (0.17) TCE concentration in mg/L
- < Less than noted laboratory reporting limit
- > Greater than the noted concentration
- mg/L Milligrams per liter
- TCE Trichloroethene
- * Data not used for contouring
- Destroyed groundwater well
- ** TCE concentration was 0.042 mg/l in June 2006

NOTE: Most recent TCE concentrations reported in well/grab groundwater location are depicted.

- 0.001 - 0.01 mg/L TCE in groundwater
- 0.01 - 0.1 mg/L TCE in groundwater
- 0.1 - 1.0 mg/L TCE in groundwater
- >1.0 mg/L TCE in groundwater

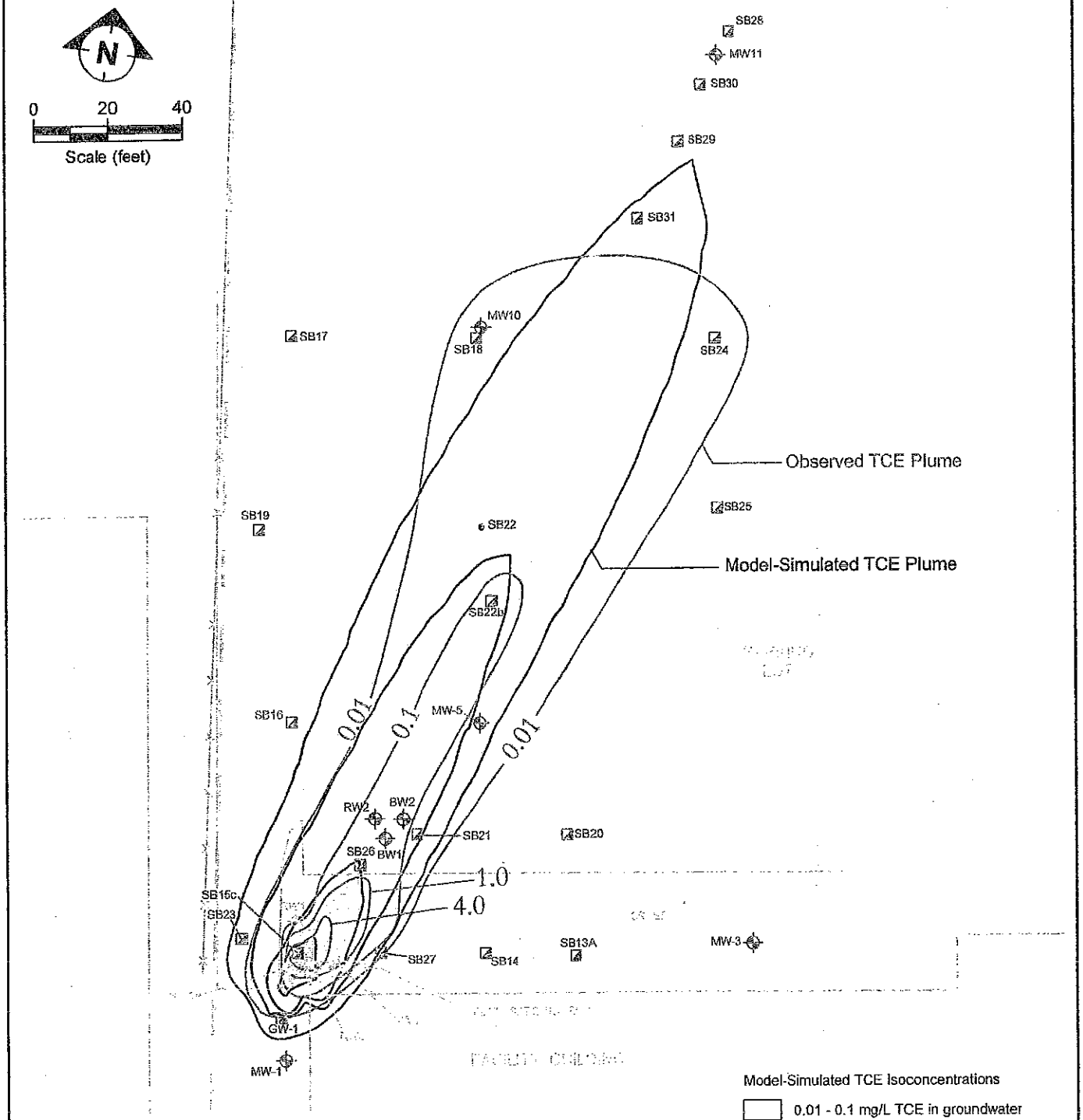
LOCATIONS OF EXCAVATION, ZVI/SAND REACTION ZONE, AND ZVI-WELL

FORMER KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

ETIC ENGINEERING

Date:	Figure:
6/08/2006	7

VARADD0406_FIG37.DWG



Model-Simulated TCE Isoconcentrations

- 0.01 - 0.1 mg/L TCE in groundwater
- 0.1 - 1.0 mg/L TCE in groundwater
- 1.0 - 4.0 mg/L TCE in groundwater
- Greater than 4 mg/L TCE in groundwater

LEGEND:

- Soil boring
- Existing groundwater well
- Destroyed groundwater well
- Grab groundwater sample location
- Property Boundary
- Fence
- mg/L Milligrams per liter
- TCE Trichloroethene

COMPARISON OF MODEL-SIMULATED AND FIELD TCE ISOCONCENTRATIONS (PRE-HVDPE EVENT)

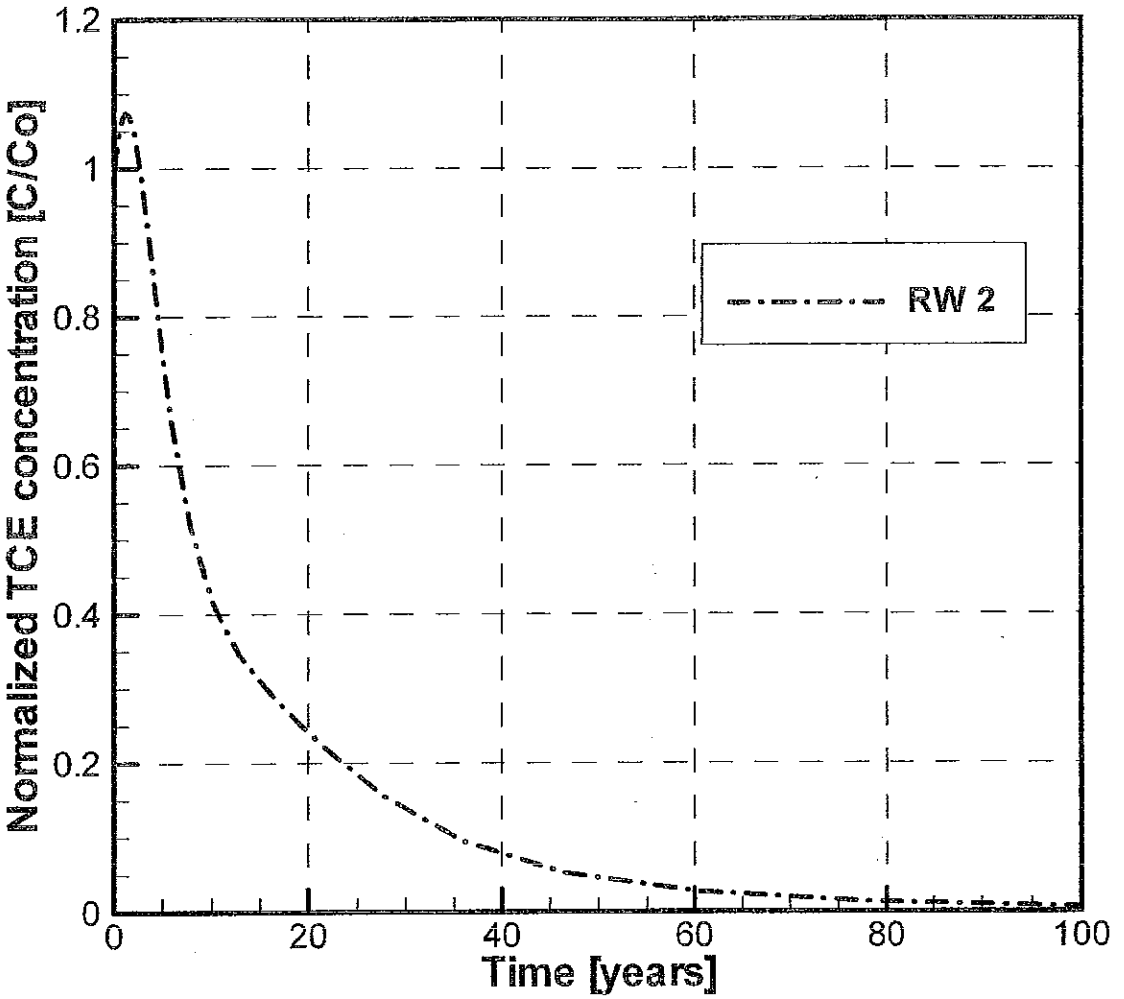
FORMER KAISER FLUID TECHNOLOGIES
CHARLOTTE, NORTH CAROLINA

ETIC ENGINEERING

Date: 6/08/2006

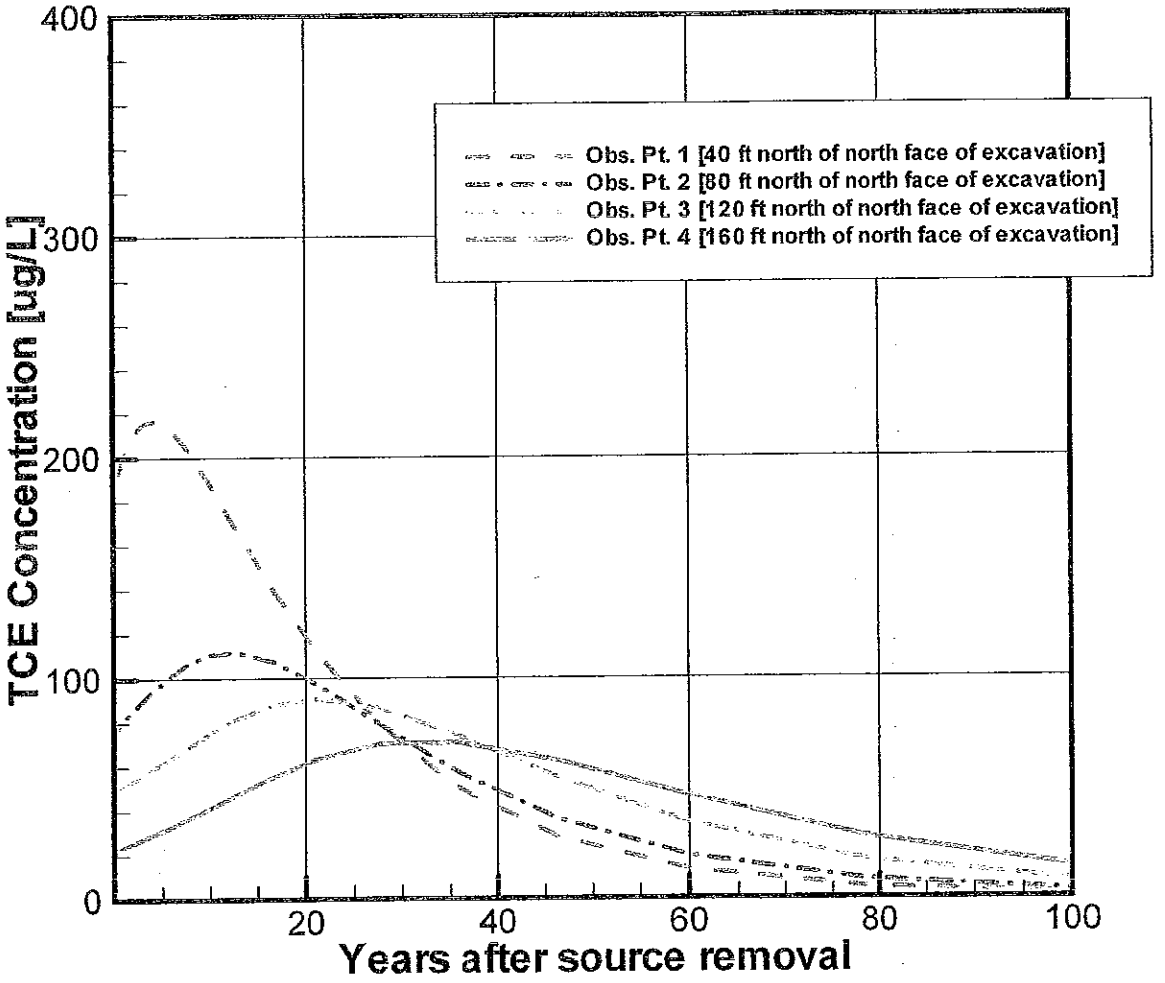
Figure: 9

FIGURE_9.DWG



C/Co TCE Concentration/Initial TCE Concentration

SIMULATED TCE CONCENTRATION AFTER SOURCE REMOVAL RELATIVE TO INITIAL CONCENTRATION AT RW-2		
FORMER KAISTER FLUID TECHNOLOGIES CHARLOTTE, NORTH CAROLINA		
ETIC ENGINEERING	FIGURE 10	Date: 6/08/2006



ug/L Micrograms per liter

SIMULATED TCE CONCENTRATION AFTER SOURCE REMOVAL AT SEVERAL LOCATIONS ALONG THE CENTER LINE OF THE PLUME		
FORMER KAISTER FLUID TECHNOLOGIES CHARLOTTE, NORTH CAROLINA		
ETIC ENGINEERING	FIGURE 11	Date: 6/08/2006

TABLES

TABLE 1 CUMULATIVE GROUNDWATER ANALYTICAL DATA
FORMER KAISER FLUID TECHNOLOGIES, 530 EAST SUGAR CREEK ROAD, CHARLOTTE, NORTH CAROLINA

Well Number	Date	Casing Elevation (feet)	Depth to Water (feet)	GW Elevation (feet)	Concentration (mg/L)									
					Benzene	Chloro-benzene	Dichloro-difluoromethane	1,1,1-TCA	1,1-DCA	PCE	TCE	cis-1,2-DCE	1,1-DCE	Vinyl Chloride
MW1	09/21/01	728.84	16.69	712.15	<0.0005	<0.0005	<0.0005	**0.03**	**0.0013**	<0.0005	**0.0041**	<0.0005	**0.026**	<0.0005
MW1	10/30/01	728.84	17.03	711.81	<0.0005	<0.0005	<0.0005	**0.025**	**0.0014**	<0.0005	**0.0059**	<0.0005	<0.0005	<0.0005
MW1	05/16/02	728.84	15.32	713.52	<0.0005	<0.0005	**0.00078**	**0.0044**	<0.0005	<0.0005	**0.0016**	<0.0005	**0.00093**	<0.0005
MW1	08/23/02	728.84	17.17	711.67	<0.0005	<0.0005	<0.0005	**0.018**	<0.0005	<0.0005	**0.0078**	<0.0005	**0.0027**	<0.0005
MW1	10/24/02	728.84	15.98	712.86	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW1	11/26/02	728.84	14.87	713.97	<0.0005	<0.0005	<0.0005	**0.013**	<0.0005	<0.0005	**0.0057**	<0.0005	**0.001**	<0.0005
MW1	05/22/03	728.84	12.16	716.68	<0.0005	<0.0005	<0.0005	**0.0067**	**0.0014**	<0.0005	**0.029**	<0.0005	**0.002**	<0.0005
MW1	11/24/03	728.84	14.46	714.38	<0.0005	<0.0005	<0.0005	**0.0045**	**0.00096**	<0.0005	**0.02**	<0.0005	**0.002**	<0.0005
MW1	05/11/04	728.84	14.45	714.39	<0.0005	<0.0005	<0.0005	**0.00067**	<0.0005	<0.0005	**0.0054**	<0.0005	<0.0005	<0.0005
MW1	11/16/04	728.84	14.74	714.10	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.0013**	<0.0005	<0.0005	<0.0005
MW1	01/25/05	728.84	14.76	714.08	NA	<0.001	<0.001	**0.0027**	<0.001	<0.001	<0.001	<0.001	**0.0012**	<0.001
MW1	04/03/05	728.84	13.76	715.08	NA	<0.001	<0.001	**0.0024**	<0.001	<0.001	<0.001	<0.001	**0.0014**	<0.001
MW2	09/21/01	730.50	16.67	713.83	<0.0005	**0.0061**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.014**	<0.0005	**0.0021**
MW2	10/30/01	730.50	17.03	713.47	<0.0005	**0.0072**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.016**	<0.0005	**0.0019**
MW2	05/16/02	730.50	16.34	714.16	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	08/23/02	730.50	17.12	713.38	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	10/24/02	730.50	15.94	714.56	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	11/26/02	730.50	14.63	715.87	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	05/22/03	730.50	12.12	718.38	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	11/24/03	730.50	14.28	716.22	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	05/11/04	730.50	13.93	716.57	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	11/16/04	730.50	14.30	716.20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	01/25/05	730.50	14.25	716.25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW2	04/04/05	730.50	12.45	718.05	NA	**0.0027**	<0.001	<0.001	<0.001	<0.001	<0.001	**0.0068**	<0.001	**0.0033**
MW3	09/21/01	729.67	17.02	712.65	<0.0005	<0.0005	<0.0005	<0.0005	**0.0017**	<0.0005	**0.00083**	**0.0028**	**0.0064**	<0.0005
MW3	10/30/01	729.67	17.31	712.36	<0.0005	<0.0005	<0.0005	<0.0005	**0.0017**	<0.0005	**0.00073**	**0.0022**	**0.0083**	<0.0005
MW3	05/16/02	729.67	15.99	713.68	<0.0005	<0.0005	<0.0005	<0.0005	**0.0015**	<0.0005	**0.0056**	**0.016**	**0.0058**	<0.0005
MW3	08/23/02	729.67	17.50	712.17	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.0056**	**0.014**	**0.0044**	<0.0005
MW3	10/24/02	729.67	16.50	713.17	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW3	11/26/02	729.67	15.56	714.11	<0.0005	<0.0005	<0.0005	<0.0005	**0.0016**	<0.0005	**0.0089**	**0.020**	**0.0049**	<0.0005
MW3	05/22/03	729.67	13.50	716.17	<0.0005	<0.0005	<0.0005	<0.0005	**0.0028**	<0.0005	**0.0048**	**0.024**	**0.006**	<0.0005
MW3	11/24/03	729.67	14.97	714.70	<0.0005	<0.0005	<0.0005	<0.0005	**0.002**	<0.0005	**0.002**	**0.0095**	**0.004**	<0.0005
MW3	05/11/04	729.67	15.05	714.62	<0.0005	<0.0005	<0.0005	<0.0005	**0.0022**	<0.0005	<0.0005	**0.06**	**0.0078**	<0.0005

TABLE 1 CUMULATIVE GROUNDWATER ANALYTICAL DATA
FORMER KAISER FLUID TECHNOLOGIES, 530 EAST SUGAR CREEK ROAD, CHARLOTTE, NORTH CAROLINA

Well Number	Date	Casing Elevation (feet)	Depth to Water (feet)	GW Elevation (feet)	Concentration (mg/L)									
					Benzene	Chloro-benzene	Dichloro-difluoromethane	1,1,1-TCA	1,1-DCA	PCE	TCE	cis-1,2-DCE	1,1-DCE	Vinyl Chloride
MW3	11/16/04	729.67	15.48	714.19	<0.0005	<0.0005	<0.0005	<0.0005	**0.0017**	<0.0005	<0.0005	**0.074**	**0.0033**	<0.0005
MW3	01/25/05	729.67	15.44	714.23	NA	<0.001	<0.001	<0.001	**0.0024**	<0.001	<0.001	**0.012**	**0.0073**	<0.001
MW3	04/03/05	729.67	14.41	715.26	NA	<0.001	<0.001	<0.001	**0.0019**	<0.001	**0.0012**	**0.015**	**0.0076**	<0.001
MW4	09/21/01	730.47	15.49	714.98	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.00085**	<0.0005	<0.0005
MW4	10/30/01	730.47	15.89	714.58	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
MW4	05/16/02	730.47	14.74	715.73	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	08/23/02	730.47	16.09	714.38	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	10/24/02	730.47	14.83	715.64	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	11/26/02	730.47	13.70	716.77	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	05/22/03	730.47	10.84	719.63	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	11/24/03	730.47	13.00	717.47	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	05/11/04	730.47	12.78	717.69	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	11/16/04	730.47	13.24	717.23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	01/25/05	730.47	13.05	717.42	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW4	04/04/05	730.47	11.48	718.99	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.0077**	<0.001	<0.001
MW5	08/23/02	727.41	17.05	710.36	<0.0005	<0.0005	<0.0005	<0.0005	**0.0025**	<0.0005	**0.13**	**0.0039**	**0.033**	<0.0005
MW5	10/24/02	727.41	16.09	711.32	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW5	11/26/02	727.41	15.27	712.14	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	**0.032**	<0.0025	**0.0075**	<0.0025
MW5	05/22/03	727.41	12.37	715.04	<0.0005	<0.0005	<0.0005	<0.0005	**0.0029**	<0.0005	**0.093**	**0.0021**	**0.0021**	<0.0005
MW5	11/24/03	727.41	14.71	712.70	<0.0005	<0.0005	<0.0005	<0.0005	**0.0031**	<0.0005	**0.088**	<0.0005	**0.017**	<0.0005
MW5	05/11/04	727.41	14.78	712.63	<0.0005	<0.0005	<0.0005	<0.0005	**0.0018**	<0.0005	**0.12**	**0.0042**	**0.03**	<0.0005
MW5	11/16/04	727.41	15.03	712.38	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.076**	<0.0005	**0.019**	<0.0005
MW5	12/08/04	727.41	14.85	712.56	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW5	12/16/04	727.41	16.53*	710.88	NA	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.067**	<0.0005	**0.018**	<0.0005
MW5	12/17/04	727.41	16.82	710.59	NA	<0.001	<0.001	<0.001	**0.0016**	<0.001	**0.089**	**0.0025**	**0.016**	<0.001
MW5	12/20/04	727.41	16.37	711.04	NA	<0.001	<0.001	<0.001	**0.0018**	<0.001	**0.086**	**0.0023**	**0.017**	<0.001
MW5	01/25/05	727.41	15.02	712.39	NA	<0.001	<0.001	<0.001	**0.0022**	<0.001	**0.096**	**0.0025**	**0.028**	<0.001
MW5	02/23/05	727.41	14.83	712.58	NA	<0.001	<0.001	<0.001	**0.0017**	<0.001	**0.087**	**0.0023**	**0.024**	<0.001
MW5	04/03/05	727.41	13.63	713.78	NA	<0.001	<0.001	<0.001	**0.0019**	<0.001	**0.099**	**0.0024**	**0.028**	<0.001
MW6	08/23/02	730.73	18.12	712.61	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
MW6	10/24/02	730.73	16.91	713.82	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW6	11/26/02	730.73	15.84	714.89	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

TABLE 1 CUMULATIVE GROUNDWATER ANALYTICAL DATA
FORMER KAISER FLUID TECHNOLOGIES, 530 EAST SUGAR CREEK ROAD, CHARLOTTE, NORTH CAROLINA

Well Number	Date	Casing Elevation (feet)	Depth to Water (feet)	GW Elevation (feet)	Concentration (mg/L)									
					Benzene	Chloro-benzene	Dichloro-difluoromethane	1,1,1-TCA	1,1-DCA	PCE	TCE	cis-1,2-DCE	1,1-DCE	Vinyl Chloride
MW6	05/22/03	730.73	13.24	717.49	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW6	11/24/03	730.73	15.42	715.31	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW6	05/11/04	730.73	15.19	715.54	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW6	11/16/04	730.73	15.48	715.25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW6	01/25/05	730.73	15.41	715.32	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW6	04/03/05	730.73	13.87	716.86	NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
MW7	08/23/02	728.59	16.55	712.04	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.022**	<0.0005	<0.0005
MW7	10/24/02	728.59	15.42	713.17	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW7	11/26/02	728.59	14.32	714.27	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW7	05/22/03	728.59	11.84	716.75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW7	11/24/03	728.59	13.58	715.01	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW7	05/11/04	728.59	13.30	715.29	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW7	11/16/04	728.59	13.79	714.80	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW7	01/25/05	728.59	13.84	714.75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW7	04/03/05	728.59	12.51	716.08	NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.03**	<0.001	**0.0022**
MW8	08/23/02	730.67	17.65	713.02	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.0034**	<0.0005
MW8	10/24/02	730.67	16.43	714.24	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW8	11/26/02	730.67	15.28	715.39	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW8	05/22/03	730.67	11.66	719.01	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW8	11/24/03	730.67	14.64	716.03	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW8	05/11/04	730.67	14.56	716.11	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW8	11/16/04	730.67	14.90	715.77	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW8	01/25/05	730.67	14.75	715.92	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW8	04/03/05	730.67	13.19	717.48	NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.013**	<0.001
MW9	08/23/02	730.77	18.26	712.51	<0.0005	<0.0005	<0.0005	<0.0005	**0.0037**	<0.0005	<0.0005	**0.005**	**0.0065**	<0.0005
MW9	10/24/02	730.77	17.21	713.56	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW9	11/26/02	730.77	16.18	714.59	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW9	05/22/03	730.77	13.06	717.71	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW9	11/24/03	730.77	15.55	715.22	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW9	05/11/04	730.77	15.60	715.17	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW9	11/16/04	730.77	15.93	714.84	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW9	01/25/05	730.77	15.85	714.92	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

TABLE 1 CUMULATIVE GROUNDWATER ANALYTICAL DATA
FORMER KAISER FLUID TECHNOLOGIES, 530 EAST SUGAR CREEK ROAD, CHARLOTTE, NORTH CAROLINA

Well Number	Date	Casing Elevation (feet)	Depth to Water (feet)	GW Elevation (feet)	Concentration (mg/L)									
					Benzene	Chloro-benzene	Dichloro-difluoromethane	1,1,1-TCA	1,1-DCA	PCE	TCE	cis-1,2-DCE	1,1-DCE	Vinyl Chloride
MW9	04/03/05	730.77	14.52	716.25	NA	<0.001	<0.001	<0.001	**0.0088**	<0.001	**0.0019**	**0.014**	**0.012**	<0.001
MW10	10/11/04	725.05	15.10	709.95	NA	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	**0.022**	<0.0005	**0.0054**	<0.0005
MW10	11/16/04	725.05	15.30	709.75	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW10	01/25/05	725.05	15.50	709.55	NA	<0.001	<0.001	<0.001	**0.0046**	<0.001	**0.011**	**0.0047**	**0.0065**	<0.001
MW10	04/03/05	725.05	14.33	710.72	NA	<0.001	<0.001	**0.0016**	**0.0032**	<0.001	**0.024**	**0.0031**	**0.007**	<0.001
MW11	04/04/05	724.48	12.22	712.26	NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
RW1	10/11/04	728.66	14.72	713.94	NA	<0.025	<0.025	**0.42**	<0.025	<0.025	**0.075**	<0.025	**0.31**	<0.025
RW1	11/16/04	728.66	15.16	713.50	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
RW1	12/13/04	728.66	19.16*	709.50	NA	<0.0005	<0.0005	**1.2**	**0.0059**	**0.014**	**0.064**	NA	**0.80**	<0.0005
RW1	12/16/04	728.66	20.96*	707.70	NA	<0.001	<0.001	**0.36**	**0.0013**	**0.0027**	**0.036**	**0.0013**	**0.19**	<0.001
RW1	12/20/04	728.66	16.80*	711.86	NA	<0.0005	<0.0005	**0.58**	<0.0005	<0.0005	**0.044**	<0.0005	**0.36**	<0.0005
RW1	01/25/05	728.66	15.57	713.09	NA	<0.0005	<0.0005	**1.6**	**0.0095**	**0.011**	**0.082**	<0.0005	**0.72**	<0.0005
RW1	02/23/05	728.66	15.36	713.30	NA	<0.01	<0.01	**1.3**	**0.010**	**0.010**	**0.12**	<0.01	**0.65**	<0.01
RW1	04/03/05	728.66	14.15	714.51	NA	<0.005	<0.005	**0.61**	**0.006**	<0.005	**0.072**	<0.005	**0.32**	<0.005
RW1A	10/11/04	728.52	14.92	713.60	NA	<0.250	<0.250	<0.250	<0.250	<0.250	**4.0**	<0.250	<0.250	<0.250
RW1A	11/16/04	728.52	15.09	713.43	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
RW1A	12/13/04	728.52	15.85*	712.67	NA	<0.0005	<0.0005	**0.007**	<0.0005	<0.0005	**0.15**	NA	**0.0063**	<0.0005
RW1A	12/16/04	728.52	16.96*	711.56	NA	<0.001	<0.001	**0.0057**	<0.001	<0.001	**0.11**	**0.0014**	**0.0072**	<0.001
RW1A	12/20/04	728.52	16.00*	712.52	NA	<0.001	<0.001	**0.0035**	<0.001	<0.001	**0.036**	<0.001	**0.0043**	<0.001
RW1A	01/25/05	728.52	15.47	713.05	NA	<0.001	<0.001	**0.038**	<0.001	**0.0013**	**0.42**	**0.0033**	**0.034**	<0.001
RW1A	02/23/05	728.52	15.24	713.28	NA	<0.001	<0.001	**0.032**	**0.0019**	**0.0014**	**0.61**	**0.0048**	**0.033**	<0.001
RW1A	04/03/05	728.52	14.06	714.46	NA	<0.005	<0.005	**0.029**	<0.005	<0.005	**0.71**	**0.0056**	**0.032**	<0.005
RW2	10/11/04	727.41	14.04	713.37	NA	<0.005	<0.005	**0.015**	<0.005	<0.005	**0.12**	<0.005	**0.025**	<0.005
RW2	11/16/04	727.41	14.71	712.70	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
RW2	12/16/04	727.41	16.97*	710.44	NA	<0.001	<0.001	**0.0058**	<0.001	<0.001	**0.065**	**0.0025**	**0.0067**	<0.001
RW2	12/17/04	727.41	18.74	708.67	NA	<0.001	<0.001	**0.0096**	**0.0011**	<0.001	**0.12**	**0.0026**	**0.016**	<0.001
RW2	12/20/04	727.41	16.22	711.19	NA	<0.001	<0.001	**0.013**	<0.001	<0.001	**0.091**	**0.0021**	**0.02**	<0.001
RW2	01/25/05	727.41	14.66	712.75	NA	<0.001	<0.001	**0.023**	<0.001	<0.001	**0.17**	**0.0026**	**0.043**	<0.001
RW2	02/23/05	727.41	14.47	712.94	NA	<0.001	<0.001	**0.015**	<0.001	<0.001	**0.11**	**0.0025**	**0.039**	<0.001
RW2	04/03/05	727.41	13.24	714.17	NA	<0.001	<0.001	**0.017**	<0.001	<0.001	**0.12**	**0.0023**	**0.041**	<0.001

TABLE 1 CUMULATIVE GROUNDWATER ANALYTICAL DATA
FORMER KAISER FLUID TECHNOLOGIES, 530 EAST SUGAR CREEK ROAD, CHARLOTTE, NORTH CAROLINA

Well Number	Date	Casing Elevation (feet)	Depth to Water (feet)	GW Elevation (feet)	Concentration (mg/L)									
					Benzene	Chloro-benzene	Dichloro-difluoromethane	1,1,1-TCA	1,1-DCA	PCE	TCE	cis-1,2-DCE	1,1-DCE	Vinyl Chloride
RW2	11/08/05	727.41	15.60	711.81	NA	<0.001	<0.001	**0.022**	<0.001	<0.001	**0.075**	**0.0012**	<0.001	<0.001
RW-2	06/01/06	727.41	14.81	712.60	NA	<0.001	<0.001	0.026	<0.001	<0.001	0.042	0.0017	0.018	<0.001
RW3	11/18/04	729.99	16.59	713.40	NA	<0.001	<0.001	**0.25**	**0.0075**	**0.008**	**4.2**	NA	**0.2**	<0.001
RW3	12/13/04	729.99	18.58*	711.41	NA	<0.005	<0.005	**0.034**	<0.005	<0.005	**1.5**	NA	**0.034**	<0.005
RW3	12/16/04	729.99	20.14*	709.85	NA	<0.001	<0.001	**0.025**	**0.0018**	**0.0013**	**0.8**	**0.0053**	**0.02**	<0.001
RW3	12/20/04	729.99	17.58*	712.41	NA	<0.005	<0.005	**0.021**	<0.005	<0.005	**0.9**	**0.0055**	**0.025**	<0.005
RW3	01/25/05	729.99	16.53	713.46	NA	<0.005	<0.001	**0.095**	<0.005	<0.005	**1.8**	**0.026**	**0.052**	<0.005
RW3	02/23/05	729.99	16.31	713.68	NA	<0.02	<0.02	**0.15**	<0.02	<0.02	**3.9**	**0.031**	**0.071**	<0.02
RW3	04/03/05	729.99	15.18	714.81	NA	<0.02	<0.02	**0.10**	<0.02	<0.02	**2.4**	**0.037**	**0.051**	<0.02
RW4	11/18/04	729.96	16.90	713.06	NA	<0.01	<0.01	**0.074**	<0.01	<0.01	**1.80**	NA	**0.018**	<0.01
RW4	12/13/04	729.96	22.06*	707.90	NA	<0.005	<0.005	**0.034**	<0.005	<0.005	**0.92**	NA	**0.018**	<0.005
RW4	12/16/04	729.96	23.12*	706.84	NA	<0.001	<0.001	**0.0079**	<0.001	<0.001	**0.32**	**0.0015**	**0.0055**	<0.001
RW4	12/20/04	729.96	20.69*	709.27	NA	<0.005	<0.005	**0.013**	<0.005	<0.005	**0.42**	<0.005	**0.011**	<0.005
RW4	01/25/05	729.96	16.36	713.60	NA	<0.005	<0.005	**0.025**	<0.005	<0.005	**0.47**	<0.005	**0.014**	<0.005
RW4	02/23/05	729.96	16.47	713.49	NA	<0.002	<0.002	**0.019**	<0.002	<0.002	**0.42**	**0.003**	**0.0097**	<0.002
RW4	04/04/05	729.96	14.79	715.17	NA	<0.005	<0.005	**0.02**	<0.005	<0.005	**0.48**	<0.005	**0.014**	<0.005
BW-1	11/08/05	727.56	15.83	711.73	NA	<0.001	<0.001	**0.016**	**0.011**	<0.001	**0.16**	**0.024**	**0.011**	<0.001
BW-1	11/22/05	727.56	15.52	712.04	NA	<0.001	<0.001	**0.027**	**0.0012**	<0.001	**0.32**	<0.001	**0.02**	<0.001
BW-1	11/22/05	727.56	15.52	712.04	NA	<0.001	<0.001	**0.046**	**0.021**	**0.0014**	**0.60**	**0.0078**	**0.036**	<0.001
BW-1	12/20/05	727.56	14.19	713.37	--	--	--	--	--	--	--	--	--	--
BW-1	06/01/06	727.56	15.10	712.46	--	--	--	--	--	--	--	--	--	--
BW-2	12/20/05	727.56	14.30	713.26	NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
BW-2	06/01/06	727.56	15.31	712.25	--	--	--	--	--	--	--	--	--	--
15A NCAC 2L Groundwater Standards					0.001	0.05	1.4	0.2	0.7	0.0007	0.0028	0.07	0.007	0.000015

GW Groundwater.
NCAC North Carolina Administrative Code
TCA Trichloroethane.
DCA Dichloroethane
DCE Dichloroethene

TABLE 1 CUMULATIVE GROUNDWATER ANALYTICAL DATA
FORMER KAISER FLUID TECHNOLOGIES, 530 EAST SUGAR CREEK ROAD, CHARLOTTE, NORTH CAROLINA

Well Number	Date	Casing Elevation (feet)	Depth to Water (feet)	GW Elevation (feet)	Concentration (mg/L)									
					Benzene	Chloro-benzene	Dichloro-difluoromethane	1,1,1-TCA	1,1-DCA	PCE	TCE	cis-1,2-DCE	1,1-DCE	Vinyl Chloride

PCE Tetrachloroethene
TCE Trichloroethene.
NA Not Analyzed.
NM Not Measured.
NR Not reported.
NS Not Sampled.
mg/L Milligrams per liter.
< Less than the laboratory reporting limits.

Choloromethane - 0.0049 mg/L in MW5 sample collected 5/11/04. (15A NCAC 2L standard = 0.0026 mg/L)

Carbon tetrachloride - 0.0011 mg/L (12/13/04), 0.0067 mg/L (2/23/05) in RW1A, 0.024 mg/L RW3 (2/23/05) in RW3, 0.2 mg/L (2/23/05) in RW1. (15A NCAC 2L standard = 0.0003 mg/L)

Methylene chloride - 0.058 mg/L (11/18/04) and 0.012 mg/L (12/20/04) in RW4 and 0.010 mg/L (12/20/04) in RW1A. (15A NCAC 2L standard = 0.005 mg/L)

High vacuum dual-phase extraction event conducted 12/10/04-12/20/04. Wells RW1, RW1A, RW3, and RW4 used for extraction.

* well gauged and grab sample collected during recharge period after shutdown of dual-phase extraction

TABLE 2 **ZVI-WELL CONSTRUCTION DETAILS**
FORMER KAISER FLUID TECHNOLOGIES, 530 EAST SUGAR CREEK ROAD, CHARLOTTE, NORTH CAROLINA

Well ID	Well Installation Date	Top-of-Casing Elevation (feet)	Casing Material	Casing Diameter (inches)	Screened Interval (ft bgs)	Slot Size (inches)	Filter Pack Interval (ft bgs)	Filter Pack Interval
ZVI-Well	4/19/06	NM	PVC	2	15-20	0.010	10-22	ZVI/Fine Sand

NM Not Measured.
PVC Polyvinyl chloride.
ft bgs Feet below ground surface.
ZVI Zero Valent Iron

TABLE 3 ZVI-WELL AND RW-2 GROUNDWATER ANALYTICAL RESULTS
FORMER KAISER FLUID TECHNOLOGIES, 530 EAST SUGAR CREEK ROAD, CHARLOTTE, NORTH CAROLINA

		Concentration (mg/L)									
Well Number	Sampling Date	Chloro-benzene	Dichloro-difluoromethane	Chloroethane	1,1,1-TCA	1,1-DCA	PCE	TCE	cis-1,2-DCE	1,1-DCE	Vinyl Chloride
ZVI-Well	5/2/2006	<0.001	<0.001	0.0047	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ZVI-Well	6/1/006	<0.001	<0.001	0.0017	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
RW-2	6/1/006	<0.001	<0.001	<0.001	0.026	<0.001	<0.001	0.042	0.0017	0.018	<0.001
15A NCAC 2L Groundwater Standards		0.05	1.4	2.68	0.2	0.7	0.0007	0.0028	0.07	0.007	0.000015

GW	Groundwater
NCAC	North Carolina Administrative Code
TCA	Trichloroethane.
DCA	Dichloroethane
DCE	Dichloroethene
PCE	Tetrachloroethene
TCE	Trichloroethene.
mg/L	Milligrams per liter.
<	Less than the laboratory reporting limits.

ETIC ENGINEERING

LOG OF SOIL BORING: **BW-1**

COORDINATES: N551882.62 :E1464569.62

ELEVATION TOP OF CASING: 727.56

CASING BELOW SURFACE:

DRILLING COMPANY: Saedacco

LICENSE NUMBER: 2675

CLIENT	SITE NUMBER	LOCATION
Rockwell Collins	TMKFT	530 East Sugar Creek Road Charlotte, NC

DRILLING AND SAMPLING METHODS: Diamond core; 120lb hammer sample every 5 ft. 6" O.D. augers, overdrilled with 12" O.D. augers. Diamond core for 0-19 ft bgs. Refusal @ 19 feet bgs. Drill new boring with 12" HSA to refusal at 15 ft bgs. Air rotary from 15 to 29 ft bgs, diamond core from 29 to 36 feet bgs, air rotary from 36-47' bgs. Upper 19 feet based on initial boring, located 2 feet west of well BW-1. 8" conductor casing installed from 0 to 25 feet bgs.

				START TIME	FINISH TIME
WATER LEVEL		▼ 15.83			
TIME				---	---
DATE		11/8/05		START DATE	FINISH DATE
REFERENCE		TOC		11/1/05	11/2/05

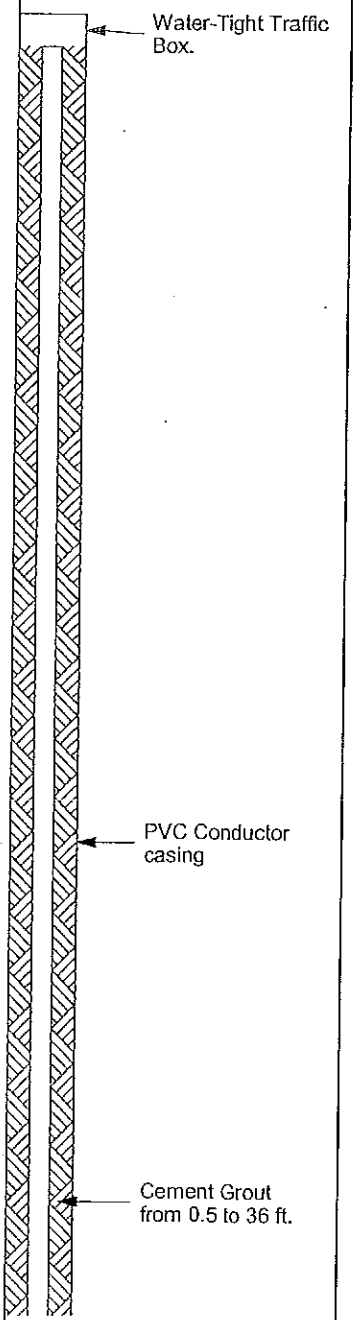
SURFACE CONDITIONS: Asphalt

DESCRIPTION BY: L. Pawlak and K. Brandt

INCHES DRIVEN	INCHES RECOVER	BLOWS / 6" SAMPLER	OVA READING	DEPTH (feet)	GRAPHIC LOG	DESCRIPTION
				0	CL	CLAY: Yellowish red (5Y 4/6) to dark red (2.5YR 4/6), firm, low to medium plasticity, dry to damp.
				3	ML	SANDY SILT with CLAY: Dark yellowish brown (10YR 4/4), low plasticity, friable.
				4		SILT with SAND: Light olive brown (2.5Y 5/4) to olive yellow (2.5Y 6/6), non-plastic to low plasticity, some clay, minor angular to sub-angular gravel up to 4 cm.
30	18	30 24 50	0.0	6	ML	@ 5.75 ft bgs, decrease in silt, increase in clay, low to medium plasticity, dry, significant iron oxidation, small black organics, vertical vein of whitish plastic clay up to 2 cm thick from 6 - 6.5 ft bgs.
				9	ML	
11	11	40 50	0.1	10		SILT with CLAY: Minor gravel and some slough. Weathered Bedrock: Gley (5GY 1/7), angular to subangular rock fragments, iron oxidation. @ 10.75 ft bgs, smaller rock fragments, less iron oxidation, dry.
14	14	30 30 50	0.2	15		@ 15.25 ft bgs, olive brown (2.5Y 4/3) to olive (5Y 4/3,) rock breaks into disks, friable, dry, white clay veins. @ 16 ft bgs, pinkish red (10YR 5/6) clay veins, blocky rock fragments up to 5 cm, dry, increased iron oxidation.

AIR SAMPLE | WATER SAMPLE | SOIL SAMPLE | RECOVERED

DETAILS



LOG OF SOIL BORING BORING LOGS.GPJ ETIC.GDT 6/12/06

ETIC ENGINEERING

CLIENT	SITE NUMBER	LOCATION
Rockwell Collins	TMKFT	530 East Sugar Creek Road Charlotte, NC

LOG OF SOIL BORING: **BW-1**

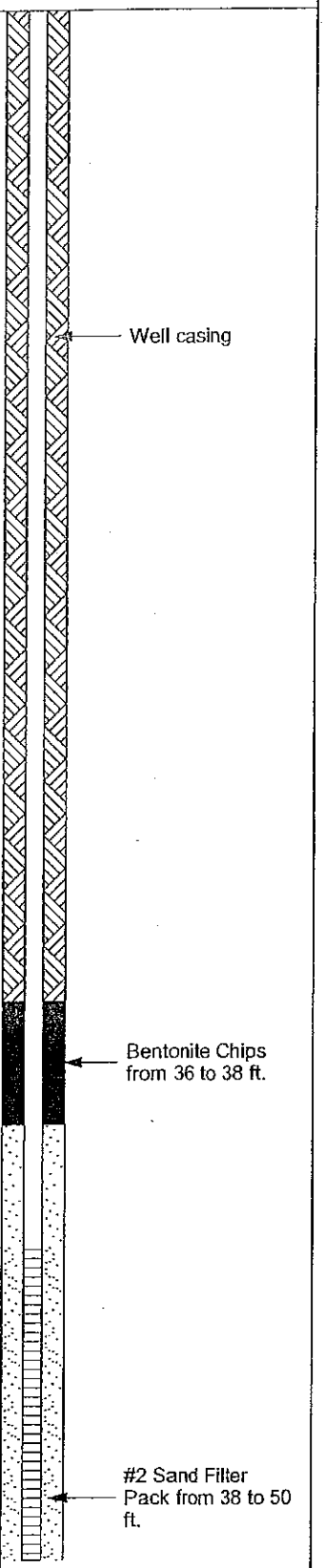
INCHES DRIVEN	INCHES RECOVER	BLOWS / 6" SAMPLER	OVA READING	DEPTH (feet)	AIR SAMPLE	WATER SAMPLE	SOIL SAMPLE	RECOVERED	GRAPHIC LOG
				21					
				22					
				23					
				24					
				25					
				26					
				27					
				28					
				29					
48	36	-		30					
				31					
				32					
				33					
16		-		34					
				35					
				36					
				37					
				38					
				39					
				40					
				41					
				42					
				43					
				44					
				45					

@ 25 ft bgs, rock chips up to 6 cm, some quartz and feldspar, iron oxidation.

@ 29 ft bgs, begin drilling with diamond core and 8.5 ft long core barrel. Core moderately fractured (FD-5), moderately-closely spaced (SP4 - SP5), clean - no film/fill in fractures (T0), slightly rough - small asperities (R4), iron oxidation.

@ 31.5 ft bgs, angular to subangular fragments up to 3 cm, significant fragments are very weathered, friable. Low grade metamorphic assemblages (chlorite, biotite/horneblende), dry fractures (M3).

@ 34 ft bgs, diamond core jammed with weathered bedrock, pull out core barrel and clean. Appoximately 1 - 1.5 ft of rock recovery. Longest core segment is ~0.6 ft, moderately to intensely fractured (FD6 - FD7), small angular fragments up to 5 cm, fractures moderately to closely spaced (SP4 - SP5), dry (M3), slightly rough to rough fracture surfaces (R2 - R4).
@ 35 ft bgs, longer core segments, 0.3 - 0.4 ft, undulating fracture surfaces.
@ 35.5 to 36 ft bgs, becomes intensely fractured, soil present on some fracture surfaces, moderately thin film in fractures (T2).
@ 36 ft bgs, air rotary to 47 ft bgs. Mixture of weathered and unweathered rock chips.



LOG OF SOIL BORING BORING LOGS.GPJ ETIC.GDT 6/12/06

ETIC ENGINEERING

CLIENT	SITE NUMBER	LOCATION
Rockwell Collins	TMKFT	530 East Sugar Creek Road Charlotte, NC

LOG OF SOIL BORING:

BW-1

INCHES DRIVEN	INCHES RECOVER	BLOWS / 6" SAMPLER	OVA READING	DEPTH (feet)	AIR SAMPLE	WATER SAMPLE	SOIL SAMPLE	RECOVERED	GRAPHIC LOG	
				46						Rock chips with quartz up to 3 - 4 cm. Chips slightly less weathered.
				47						@ 47 ft bgs, driller indicates difficulty advancing with air rotary. Diamond core from 47 to 50 ft bgs. Longest segment is 0.5 ft, moderately to intensely fractured (FD5 - FD7), closely spaced to very closely spaced (SP5 - SP6). Fracture surfaces are oxidized and show some chemical and mechanical weathering, slighly rough to smooth surfaces (R4 - R5), dry and light fractures (M1).
				48						
				49						
				50						Borehole total depth 50 feet bgs.
				51						
				52						
				53						
				54						
				55						
				56						
				57						
				58						
				59						
				60						
				61						
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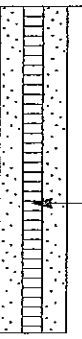
				65						
				66						
				67						
				68						
				69						
				70						



2 in. I.D. 0.010 in. Slot, Schedule 40 PVC Screen from 40 to 50 ft.

LOG OF SOIL BORING BORING LOGS.GPJ ETIC.GDT 6/12/06

ETIC ENGINEERING

LOG OF SOIL BORING: **BW-2**

COORDINATES: N551888.18 :E1464573.91

ELEVATION TOP OF CASING: 727.56

CASING BELOW SURFACE:

DRILLING COMPANY: Saedacco

LICENSE NUMBER: 2675

CLIENT	SITE NUMBER	LOCATION
Rockwell Collins	TMKFT	530 East Sugar Creek Road Charlotte, NC

DRILLING AND SAMPLING METHODS: Air rotary with tri-cone bit to 22 ft bgs. Air hammer from 22 to 50 ft bgs. Diamond core from 50 to 82 ft bgs. 8" conductor casing set from 0 to 50 ft bgs.

				START	FINISH
WATER LEVEL		▼ 14.30			
TIME				TIME ---	TIME ---
DATE		12/20/05			
REFERENCE		TOC		DATE 12/15/05	DATE 12/18/05

SURFACE CONDITIONS: Asphalt

DESCRIPTION BY: L. Pawlak and Tim McKinsey (Schnabel Engineering)

INCHES DRIVEN	INCHES RECOVER	BLOWS / 6" SAMPLER	OVA READING	DEPTH (feet)	AIR SAMPLE	WATER SAMPLE	SOIL SAMPLE	RECOVERED	GRAPHIC LOG	DESCRIPTION	DETAILS
				0						Asphalt. Weathered Bedrock present below asphalt.	
				1						@ 1.5 ft bgs, greenish rock powder.	
				2							
				3							
				4							
				5						@ 5 ft bgs, brown to light brown rock powder.	8 in diameter conductor casing to 50 ft bgs.
				6							
				7							
				8							
				9							
				10							2 in diameter blank casing to 76 ft bgs.
				11							
				12							
				13							
				14							
				15							
				16							
				17							
				18						@ 18 ft bgs, green rock powder.	
				19							
				20							

LOG OF SOIL BORING BORING LOGS.GPJ ETIC.GDT 6/12/06

ETIC ENGINEERING

CLIENT	SITE NUMBER	LOCATION
Rockwell Collins	TMKFT	530 East Sugar Creek Road Charlotte, NC

LOG OF SOIL BORING: **BW-2**

INCHES DRIVEN	INCHES RECOVER	BLOWS / 6" SAMPLER	OVA READING	DEPTH (feet)	AIR SAMPLE	WATER SAMPLE	SOIL SAMPLE RECOVERED	GRAPHIC LOG	
				21					
				22					@ 22 ft bgs, air hammer with 10" pneumatic hammer.
				23					
				24					
				25					@ 25 ft bgs, light brown rock chips.
				26					
				27					
				28					
				29					
				30					
				31					
				32					
				33					
				34					
				35					
				36					
				37					
				38					@ 38 ft bgs, green rock chips, fresh surfaces, minor weathered surfaces / fracture surfaces.
				39					
				40					
				41					
				42					@ 42 ft bgs, mixture of weathered and unweathered rock chips, weathered chips have limonite patches.
				43					
				44					
				45					

8 in diameter conductor casing to 50 ft bgs.

Cement grout from 0 to 73 ft bgs.

2 in diameter blank casing to 76 ft bgs.

LOG OF SOIL BORING BORING LOGS.GPJ ETIC.GDT 6/12/06

ETIC ENGINEERING

CLIENT	SITE NUMBER	LOCATION
Rockwell Collins	TMKFT	530 East Sugar Creek Road Charlotte, NC

LOG OF SOIL BORING:

BW-2

INCHES DRIVEN	INCHES RECOVER	BLOWS / 6" SAMPLER	OVA READING	DEPTH (feet)	AIR SAMPLE	WATER SAMPLE	SOIL SAMPLE	RECOVERED	GRAPHIC LOG	
				46						@ 45 to 46 ft bgs, small pieces of quartz and/or sodium feldspar present with rock chips, fresh surfaces, minor weathered surfaces.
				47						@ 47 ft bgs, reddish clay with rock chips, soft; may be recirculated from above by air hammer.
				48						
				49						@ 49 ft bgs, angular chips, fresh surfaces, friable chips with weathered surfaces.
60	48	-		50						@ 50 ft bgs, greenish, moderately to intensely fractured (FD5 - FD7), distinct fracture surfaces with small pitted areas up to ~ 1 mm (possible mineral dissolution). Iron oxidation and patches of red (2.5Y 5/8) silty clay on weathered surfaces from 50 to 51 ft bgs.
				51						
				52						
				53						@ 53 to 54 ft bgs, large vertical fracture present in core sample. Fracture surfaces slightly rough (R4), dry to damp fractures (M3 - M4), very thin to moderately thin film in fractures (T1 - T2), longest core segment is 0.4 ft, moderately fractured (FD5).
				54						
				55						@ 55 to 56 ft bgs, ~ 0.5 ft of intact core recovered, moderately fractured (FD5).
24	18	-		56						@ 56 ft bgs, core barrel jammed with broken rock.
				57						Air hammer from 56 to 58 ft bgs to clean hole.
				58						@ 58 to 63 ft bgs, longest core segment is 1.6 ft, slightly fractured (FD3), some fractures visible in core, no breaks along fractures.
60	54	-		59						@ 58 to 58.5 ft bgs, small pyrite or marcasite flecks.
				60						@ 59 to 60 ft bgs, greenish color, metamorphic minerals (chlorite, actinolite).
				61						
				62						
				63						@ 63 to 68 ft bgs, increased weathering and fractures. From 63 to 65 ft bgs, longest segment is ~ 0.6 ft, moderately fractured (FD5), inclined and horizontal fractures.
60	50	-		64						
				65						@ 65 to 66 ft bgs, core intensely fractured (FD7), fractures closely to very closely spaced (SP5 - SP6).
				66						
				67						@ 67 to 68 ft bgs, significant iron oxidation, muscovite present, rough fracture surfaces (R2).
				68						Full recovery from 68 to 72 ft bgs, moderately to intensely fractured (FD6 - FD7), closely to very closely spaced (SP5 - SP6), slightly rough to rough surfaces (R2 - R4).
60	60	-		69						
				70						

LOG OF SOIL BORING BORING LOGS.GPJ ETIC.GDT 6/12/06

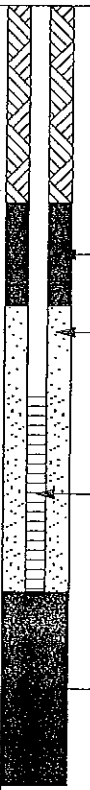
ETIC ENGINEERING

CLIENT	SITE NUMBER	LOCATION
Rockwell Collins	TMKFT	530 East Sugar Creek Road Charlotte, NC

LOG OF SOIL BORING:

BW-2

INCHES DRIVEN	INCHES RECOVER	BLOWS / 6" SAMPLER	OVA READING	DEPTH (feet)	AIR SAMPLE	WATER SAMPLE	SOIL SAMPLE RECOVERED	GRAPHIC LOG	
				71					@ 71 to 72 ft bgs, angular pieces up to 6.5 cm.
				72					
60	54	-		73					@ 73 ft bgs, competent and almost fractureless core. Evidence of moderately to totally healed fractures (HL0 - HL2), longest segment is ~ 3 ft, very slightly to slightly fractured (FD1 - FD2), widely spaced fractures (SP3). Biotite visible on freshly broken surfaces, flecks of pyrite visible with 10X hand lens.
				74					
				75					
				76					
60	54	-		77					@77 to 82 ft bgs, 1.5 to 2 ft of competent rock; longest segment is 1.1 to 1.2 ft, slightly fractured (FD2), widely spaced fractures (SP3), moderately to totally healed (HL0 - HL2), slightly to moderately rough surfaces (R3 - R4). @ 77.5 to 78 ft bgs, recrystallized (healed) fractures or veins composed of quartz, biotite/hornblende, muscovite. @ 79 to 82 ft bgs, core is moderately fractured (FD5), moderately to closely spaced fractures (SP4 - SP5), slightly rough to rough surfaces (R2 - R4), fractured vein ~ 0.5 ft thick; thin inclined healed fracture present @ 81.5 to 82 ft bgs.
				78					
				79					
				80					
				81					
				82					Borehole total depth 82 feet bgs.
				83					
				84					
				85					
				86					
				87					
				88					
				89					
				90					
				91					
				92					
				93					
				94					
				95					



Bentonite seal from 73 to 74.4 ft bgs.

2 sand (20/30) filter pack from 74.4 to 79 ft bgs

0.010 size screen from 76 to 79 ft bgs

Bentonite plug from 79 to 82 ft bgs.

LOG OF SOIL BORING BORING LOGS.GPJ ETIC.GDT 6/12/06

TABLE OF CONTENTS

Section	Page
TABLE OF CONTENTS	J-i
J.1 INTRODUCTION	J-1
J.2 CONCEPTUAL SITE MODEL	J-2
J.3 NUMERICAL MODEL CODE AND MATHEMATICAL FORMULATION	J-2
J.4 GROUNDWATER FLOW MODEL DEVELOPMENT	J-5
J.4.1. MODEL DOMAIN	J-5
J.4.2. BOUNDARY AND INITIAL CONDITIONS	J-6
J.4.3 INITIAL AQUIFER PROPERTIES	J-6
J.4.4.. GROUNDWATER FLOW CALIBRATION	J-7
J.5 CHEMICAL FATE AND TRANSPORT MODEL	J-9
J.5.1. BOUNDARY CONDITIONS	J-9
J.5.2. TRANSPORT PARAMETERS	J-10
J.6 MODEL SIMULATIONS	J-12
J.7 REFERENCES	J-14

APPENDIX FIGURES

FIGURE J-1 Groundwater Elevations (April 2005) and TCE Isoconcentration Contours Pre-HVDPE Event (August-November 2004)

FIGURE J-2 Site Vicinity and Model Domain

FIGURE J-3 Model Discretization

FIGURE J-4 Properties Zones for Groundwater Flow Calibration

FIGURE J-5 Calibration Results. Water Elevations at MW-1, MW-3, RW-2, and MW-5

FIGURE J-6 Calibration Results. Water Elevations at MW-6, MW-8, MW-9, and MW-10

FIGURE J-7 Average Conditions, Steady State Flow for TCE Transport

FIGURE J-8 Input TCE Injection Rate

FIGURE J-9 Comparison of Model-Simulated and Field TCE Isoconcentrations Pre-HVDPE Event

FIGURE J-10 Simulated TCE Concentration After Source Removal Relative to Initial Concentration at RW-2

FIGURE J-11 Simulated TCE Concentration After Source Removal at Several Locations Along the Center Line of the TCE Plume

APPENDIX TABLES

Table J-1 Model Domain and Grid Discretization

Table J-2 Fractured Media Flow Parameters After Calibration

Table J-3 Matrix Flow Parameters After Calibration

Table J-4 Fractured Media Transport Parameters After Calibration

Table J-5 Matrix Transport Parameters After Calibration

J.1 INTRODUCTION

Recent source reduction activities, consisting of excavation of impacted soils within the former release area (corresponding to historical presence of a settling tank), backfilling of excavation with clean soils, and inclusion of a 3-foot thick zero valent iron (ZVI)/sand reaction zone along the downgradient edge of the excavation backfill have served to limit trichloroethylene (TCE) mass flux away from the former TCE source area at the former Kaiser Fluid Technologies (KFT) site in Charlotte, North Carolina. This has been corroborated by two rounds of groundwater sampling (yielding non-detect levels of TCE) in a monitoring well (ZVI-Well) installed within the reaction zone and along the downgradient edge of the excavation backfill material.

As part of the negotiated approach to remediation and to substantiate the groundwater sampling results referenced above, the North Carolina Department of Environment and Natural Resources (NCDENR) expressed interest in using mathematical modeling to support the premise that bulk source removal via excavation and biological treatment of residual TCE (via ZVI) necessarily results in a reduction over time of TCE mass and concentrations at locations immediately downgradient of the excavation/remediation area. To this end, a three-dimensional numerical model was developed to simulate groundwater flow and chemical transport at the KFT site. The purpose of the numerical model was to evaluate the TCE concentration trends over time at various locations downgradient of the excavation (points of interest) identified through discussions with the NCDENR. Of these points of interest, one location corresponds to the approximate location of existing monitoring well RW-2, located approximately 20 feet downgradient of the northern edge of the area of excavation/remedial activities at former settling tank. Decline in TCE concentration relative to initial concentration in well RW-2 were simulated. Additionally, as requested by the NCDENR, decline in TCE concentration over time at other locations downgradient of RW-2 were also simulated.

The numerical models used for the above simulations were the Lawrence Berkeley National Laboratory (LBNL) unsaturated flow model TOUGH2 (Pruess et al., 1999) and the related chemical transport code T2R3D (Wu et al., 1996). The approach and related data pertaining to construction, calibration, and application of these models is the subject of this appendix. Divided into seven sections, this appendix includes the following:

- Section J.1, the introduction, presents the purpose and scope for the modeling study.
- Section J.2 presents an overview of the conceptual site model development.
- Section J.3 presents the rationale for numerical model code selection and related mathematical formulation.
- Section J.4 summarizes the development of the flow model and the associated calibration results.
- Section J.5 presents the transport model and the associated calibration results.
- Section J.6 presents the simulation results following source removal.
- Section J.7 lists the references cited in this appendix.

J.2 CONCEPTUAL SITE MODEL

Regionally, the groundwater system is essentially a two-part system, which consists of an uppermost layer of saprolite, alluvium, and soil (fill material) (collectively referred as regolith) and the underlying bedrock. Specifically, the subsurface at the site is characterized by silts and clays from just beneath the surface to depths ranging from 5 to 14 feet below ground surface (bgs). Beneath these soils are the variably fractured and weathered bedrock (saprolite) extending to approximate depths of 22 to 31 feet bgs. Fractured, unweathered bedrock was encountered in boreholes in the vicinity of the former settling tank. The unweathered bedrock was characterized as hard rock that could not be penetrated by an auger.

Groundwater flow and associated dissolved halogenated volatile organic compound (HVOC) migration occurs primarily as horizontal flow through fractures and along the saprolite/bedrock interfaces. The groundwater flow direction has previously been inferred to be to the northwest based on groundwater elevations. However, supplemental investigations have delineated the orientation and extent of the TCE plume, which is oriented in a more northerly direction. This plume orientation is attributed to the alignment of the fractures within the saprolite that forms the water-bearing zone.

Based on the field data, it is evident that the northwesterly overall hydraulic gradient is governed by and reflects the regional gradient; however, the actual flow path followed by TCE has a more predominant northward component, following the local-scale fracture patterns within the water-bearing saprolite (Figure J-1). This site-specific flow pattern is further supported by groundwater drawdown data collected during the December 2004 High Vacuum Dual-Phase Extraction (HVDPE) event (ETIC 2005).

J.3 NUMERICAL MODEL CODE AND MATHEMATICAL FORMULATION

In modeling the above conceptualization, the challenge is to adequately account for both types of spatial domains; fractured and matrix pore systems. To this end, model code selection was based on the need to simulate future transport of TCE in a combined fractured and matrix pore system and to meet the modeling objectives. As previously indicated, the objective of the model simulations was to quantify the trend in TCE concentrations over time at RW-2 and at other locations downgradient of the excavation area following remedial activities (bulk removal of the TCE source and biological treatment of residual source material).

Based on the site conceptual model, technical requirements of the selected model are the ability to numerically simulate the following items:

- Porous and fractured media: Field investigations indicate the presence of fractures within the saprolite (ETIC, 2005). The need for a dual permeability model is further emphasized by field observations that indicate two components of groundwater flow. The first flow component is the groundwater flow occurring within the matrix pore

space of the saprolite, which is evidenced by the northwesterly groundwater gradient. The second flow component is the groundwater flow within the fractures of the saprolite as evidenced by the northerly migration of TCE in groundwater.

- Unconfined groundwater flow and saturated conditions: Because of the absence of solid information regarding groundwater flow controls (e.g., constant water level at rivers or creeks, groundwater divides, etc), calibration of the groundwater flow model required the use of pumping information that pertained to unconfined groundwater flow. Additionally, modeling of flow and TCE fate and transport under saturated conditions was required.
- Heterogeneous and variably anisotropic hydraulic properties: The asymmetrical drawdown pattern observed during the HVDPE event is indicative of anisotropic groundwater flow conditions, such as would be found in the fractured rock observed at the site.
- Contaminant advection, dispersion, adsorption, and matrix diffusion: As in most commercially available codes, the selected numerical model should be able to simulate TCE migration subjected to contaminant advection, dispersion, and adsorption processes. Additionally, it was desired that the numerical model be capable of handling matrix diffusion. Matrix diffusion of constituents into rock is a function of porosity, fracture spacing, and degradation constants. This process accounts for diffusion into the matrix pore space from the fractures and out of the matrix pore space into the fractures depending on the relative concentrations within these media. Field data show that the approximate forty-year-old TCE plume is contained within the site boundaries. Matrix diffusion is an important mechanism by which migration of the TCE plume has been contained. Additionally, the limited rebound of TCE concentrations at some well locations after the HVDPE event was an indicator of the importance of matrix diffusion at the site.
- Time-varying boundary conditions: Time-varying boundary conditions were required for calibration of the flow model using water levels at different monitoring wells and drawdown during the HVDPE event.
- Space- and time-varying TCE sources (point or area sources and concentrations): Modeling of contaminant boundary conditions by mass injection at several cells within the model at and around the residual source area was required.

Based on the above requirements, the numerical models TOUGH2 and T2R3D were selected to model flow and transport, respectively. TOUGH2 (Transport Of Unsaturated Groundwater and Heat) is a three-dimensional simulator for non-isothermal flows of multi-component, multiphase fluids in porous and fractured media. The results presented in this study were obtained using TOUGH2's module EOS9. The EOS9 module uses Richard's equation approximation for the physical processes of flow in saturated and unsaturated fractured and porous media. T2R3D is a modular mass transport modeling system that can simulate changes in groundwater concentrations of contaminants while considering advection, dispersion, diffusion, and basic chemical reactions. T2R3D is distinctive in that it includes additional provisions to handle matrix diffusion.

The simulator TOUGH/EOS 9 (saturated-unsaturated flow) is based on the following assumptions:

- Darcy's Law is extended to account for multiphase flow;
- All the dependent variables are volumetric averages over a representative elementary volume (REV);
- Effects of mechanical stress are neglected;
- The gas phase is treated as a passive bystander at constant pressure; and
- Isothermal conditions are assumed.

The integral finite difference (IFD) method is used to discretize the mass balance equations. Time is discretized fully implicitlyas a first order finite difference. The flux of each phase, $\overline{f_\alpha}$, is related to the pressure gradient in terms of an extension of Darcy's law:

$$\overline{f_\alpha} = \rho_\alpha \overrightarrow{v_\alpha} = -\rho_\alpha \frac{\bar{k} k_{r\alpha}}{\mu_\alpha} \left(\nabla P_\alpha - \rho_\alpha \vec{g} \right) \tag{4}$$

where $\overrightarrow{v_\alpha}$ is the volumetric flux of phase a, $\bar{k}$ is the intrinsic permeability tensor, $k_{r\alpha}$ is the relative permeability of phase a and g is the gravitational vector (the vertical coordinate is oriented positive downward). Water flow is described by Richard's equation for unsaturated flow. The functional form determined by van Genuchten (1980) is used to derive the relative permeability of water.

$$k_{rl} = \sqrt{S^*} \left\{ 1 - \left(1 - \left[S^* \right]^{1/m} \right)^m \right\}^2 \tag{5}$$

$$S^* = \frac{S_l - S_{lr}}{1 - S_{lr}} \tag{6}$$

Here, S_{lr} is the residual water saturation and m is the van Genuchten shape parameter.

T2R3D is a transport module for the TOUGH2 family of codes. The objective of this module is to provide a numerical tool to handle tracer transport in a non-isothermal multiphase flow environment, including fracture-matrix interaction. The numerical method for this transport module is based on the integral finite difference scheme, as in the TOUGH2 code. The major assumptions of the transport module are:

- Tracer exists and is transported only within the liquid phase;
- Transport mechanisms include molecular diffusion and hydrodynamic dispersion in the liquid phase, in addition to advection;
- First order decay is assumed; and
- Linear adsorption on rock grains are considered.

J.4 GROUNDWATER FLOW MODEL DEVELOPMENT

J.4.1. Model Domain

The groundwater flow model domain and numerical grid were constructed using WinGridder (Pan, 2003), an interactive grid generator for the TOUGH2 numerical model. The aerial model domain encompasses approximately 26.32 acres of the site and the surrounding area (Figure J-2). The model grid was set up using three levels of refinement. A relatively fine grid, 10 meters (32.8 feet) grid block size, was used for the area with available data (flow data area). The flow data area extends 500 feet in the South East – North West direction and 400 feet in the South West – North East direction. The model grid is further refined in the area covering the observed TCE plume (plume area). The grid block size in the plume area ranges from 2 to 5 meters (6.6 to 16.4 feet). In order to avoid boundary effects, the grid was extended in the lateral and downgradient directions. For the area outside the flow data area, the model grid was set up using a uniform 40 meters (131 feet) grid spacing (Figure J-3). Because the conceptual model indicates anisotropic conditions, one of the principal axes of the grid was aligned along the centerline of the TCE plume. Vertically, the model consisted of two layers: weathered saprolite (regolith) and bedrock. The upper system layer is discretized into 8 numerical layers and extends from the water table down to a depth between 22 and 31 feet bgs. The lower system layer extends below the regolith to 60 feet bgs. Simulation of fractured aquifers using dual-permeability approach involves discretization of the solution domain into two continua called the matrix and the fracture.

Table J-1 Model Domain and Grid Discretization

System	Hydrogeologic Description	Approx. Depth [ft bgs]	Model Thickness [ft]	Model Description	Vertical Discretization	Horizontal Discretization
Regolith	Fractured and weathered saprolite	22 to 31	7-15	Modeling only the saturated portion. Water Table assumed at 15 ft bgs	8 numerical layers	3 Levels of refinement. 2217 Elements per layer
Bedrock	Unweathered bedrock/hard rock	60	29-38	Porosity and fracture spacing decreasing with depth	7 numerical layers	3 Levels of refinement. 2217 Elements per layer

J.4.2. Boundary and Initial Conditions

Boundary conditions are applied to a numerical model to represent the groundwater entry into and exit out of the model domain. To simulate groundwater inflow and outflow relative to the model domain, constant-head cells were used. The following assumptions were made in selecting the boundary conditions of the model.

- The upgradient and downgradient boundaries were treated as prescribed time-dependent head boundaries.

  Rationale: The hydraulic head at the site area varies seasonally, but this seasonal variation is consistently the same at the majority of wells. The upgradient head is assumed based on water levels at monitoring wells MW-2 and MW-4. The head at this boundary was calculated by linear interpolation based on recorded water levels at wells MW-2 and MW-4. The downgradient head boundaries were estimated based on the recorded heads at the site (10 monitoring wells) by extrapolation.

- No groundwater flow condition through the lateral boundaries of the model was assumed.

  Rationale: Lateral boundaries were positioned along lines intersecting observed head contours at approximately 90 degrees.

J.4.3. Initial Aquifer Properties

Aquifer properties represent geologic factors that control groundwater flow within the model domain. With the dual-continuum approach used in this modeling study, a set of values for properties such as permeability, density, and fracture geometry were needed for each of the two media of fracture and matrix systems.

Fracture properties of the regolith (saprolite) were initially estimated using the recorded drawdown at wells MW-5, RW-2, and MW-1 during the HVDPE event. The HVDPE event consisted of 1-hour individual well tests on four source area wells RW-1, RW-1A, RW-3, and RW-4 to measure the relationship between applied vacuum and vapor flow rate (ETIC 2005). The individual well tests were followed by a 10-day combined well HVDPE event on wells RW-1, RW-1A, RW-3, and RW-4 at maximum extraction capacity. The HVDPE event is described in detail in the *Supplemental Investigation and Remediation Report* (ETIC 2005). Drawdown vs. time data at wells MW5, RW2, and MW1 were analyzed using Neuman's solution for unconfined water flow toward a pumping well (Fetter, 1994; Neuman, 1975). A mean value for fracture hydraulic conductivity of 0.723 meters per day (m/d) and porosity of 0.0056 were obtained. Matrix permeability was assumed to be between two to three orders of magnitude smaller than fracture permeability. For the first layer (regolith) and second layer (bedrock), initial values for matrix porosity of 0.35 and 0.02, respectively, were assumed.

J.4.4. Groundwater Flow Calibration

The groundwater model flow calibration was accomplished using the numerical code iTOUGH2 (Finsterle, 2000). iTOUGH2 provides inverse modeling capabilities for the TOUGH2 family of codes. The inverse modeling code iTOUGH2 essentially examines the impact of input parameters on selected model outputs, and uses this information for automatic model calibration. The model calibration was performed using aquifer parameter values obtained via Neuman's solution (see Section J.4.4) as initial estimates.

For purposes of the iTOUGH2 flow model calibration, the fractured medium is considered anisotropic and the flow domain is divided into 7 different properties zones (Figure J-4). The data used for the calibration includes:

- Measured head at 10 monitoring wells (MW1-MW10) between August 2002 and April 2005.
- Measured head at 10 monitoring wells (MW1-MW10) and four remediation wells (RW1-RW4), during the 10-day HVDPE event in December 2004.

Hydrographs comparing calibrated model results to field-observed data during the HVDPE event are presented on Figures J-5 and J-6. The agreement between computed hydrographs and measured water levels is considered qualitatively good. Tables J-2 and J-3 display the results of the calibration. Observed heads at wells (MW-1 and RW-2) near the extraction wells proved difficult to match because the HVDPE event was modeled as a conventional pumping test by ignoring negative pressures at and in the vicinity of the extraction wells. An unsurprising result of the calibration process was that starting from an isotropic permeability field (initial estimate), the resulting anisotropy ratio for horizontal permeability was estimated to be approximately 100 in the Plume Area.

Table J-2 Fractured Media Flow Parameters After Calibration

Property Zone	Description	Saprolite Fracture Permeability [m/s]	Saprolite Fracture Porosity	Bedrock Fracture Permeability [m/s]	Bedrock Fracture Porosity
1	Plume Area (source)	$kx=kz = 2.465 \times 10^{-5}$ $ky = 1.988 \times 10^{-7}$	0.0058	$kx=kz = 7.184 \times 10^{-6}$ $ky = 6.574 \times 10^{-8}$	0.0054
2	Plume Area (middle section)	$kx=kz = 3.214 \times 10^{-5}$ $ky = 3.018 \times 10^{-7}$	0.0065	$kx=kz = 7.184 \times 10^{-6}$ $ky = 6.574 \times 10^{-8}$	0.0054
3	Plume Area (leading edge)	$kx=kz = 3.773 \times 10^{-5}$ $ky = 2.397 \times 10^{-7}$	0.0063	$kx=kz = 7.184 \times 10^{-6}$ $ky = 6.574 \times 10^{-8}$	0.0054
4	Plume Area (right and downgradient)	$kx=kz = 2.465 \times 10^{-5}$ $ky = 1.988 \times 10^{-7}$	0.0058	$kx=kz = 7.184 \times 10^{-6}$ $ky = 6.574 \times 10^{-8}$	0.0054
5	Plume Area (left and upgradient)	$kx=kz = 2.465 \times 10^{-5}$ $ky = 1.988 \times 10^{-7}$	0.0058	$kx=kz = 7.184 \times 10^{-6}$ $ky = 6.574 \times 10^{-8}$	0.0054
6	Flow Data Area	$kx=kz = 1.479 \times 10^{-6}$ $ky = 7.420 \times 10^{-7}$	0.0095	$kx=kz = 1.479 \times 10^{-6}$ $ky = 7.420 \times 10^{-7}$	0.0095
7	Outside Area	$kx=kz = 1.479 \times 10^{-6}$ $ky = 7.420 \times 10^{-7}$	0.0095	$kx=kz = 1.479 \times 10^{-6}$ $ky = 7.420 \times 10^{-7}$	0.0095

Table J-3 Matrix Flow Parameters After Calibration

Property Zone	Description	Saprolite Matrix Permeability [m/s]	Saprolite Matrix Porosity	Bedrock Matrix Permeability [m/s]	Bedrock Matrix Porosity
1 thru 7	Homogeneous and isotropic	$k = 3.976 \times 10^{-9}$	0.35	$k = 3.976 \times 10^{-9}$	0.01

J.5 TCE FATE AND TRANSPORT MODEL

The chemical fate and transport model used for model simulations was based on T2R3D. This code makes use of TOUGH2-EOS9 output with respect to the groundwater flow model in order to solve the chemical transport equations. The model domain and groundwater boundary conditions are the same for both TOUGH2-EOS9 and T2R3D.

The approach to modeling TCE transport was based on:

1) Representation of TCE source release to groundwater over a 40-year period, which approximately corresponds to the timeframe between the initiation of historical operations and the HVDPE application at the KFT site;

2) Calibration of the solute transport model to the existing TCE plume defined by field data to be entirely contained within the site boundaries;

3) Forward simulations of TCE transport into the future, reflecting removal/treatment of the TCE source and observation of TCE breakthrough (i.e., concentration change over time) 20 feet downgradient of the remediation zone; and

4) Prediction of attenuation in TCE concentrations at four additional locations, approximately 40 feet, 80 feet, 120 feet, and 160 feet, respectively downgradient of the remediation zone along the center line of the TCE plume.

The calibrated groundwater flow model was used to simulate the migration of TCE in fractured and porous media from the residual source area (i.e., the former settling tank area). Model simulations of TCE migration into the future assume a steady-state groundwater flow field (see Figure J-7).

J.5.1. Boundary Conditions

To introduce TCE mass into the model, generation source terms were conservatively assigned to the area corresponding to historically higher TCE concentrations in groundwater. This area coincides with the area at and around the former settling tank, identified as a historical source (ETIC, 2005). In the numerical model, TCE source was assumed to be released at an average rate of 0.585 kilogram per year (kg/year) over 15 grid cells located immediately below the water table at and around the former settling tank (see Figure J-8 for actual mass injection rates for various time periods). During a period of 40 years, the total amount of TCE injected in the numerical model was 23.4 kg. This amount is consistent with a preliminary estimate of the traceable mass in the fractured saprolite. A traceable amount of 22.13 kg was estimated by assuming that (1) the observed TCE isocontours (Figure J-1) represent concentrations in the fractures and (2) the concentrations in matrix are 10% of those in the fractures (Tang et al., 1981).

J.5.2. Transport Parameters

The transport parameters used in the model were estimated from site-specific information and literature data; the parameter values were further refined during the model calibration process. Constituents dissolved in groundwater will migrate by advection in the direction of flow. However, other natural processes can modify the movement of TCE causing the concentrations to change or causing TCE to move at rates different from the rate of groundwater flow. Major processes affecting contaminant movement are advection and hydrodynamic dispersion. In the case of fractured media (dual continuum), matrix diffusion also plays a significant role. Processes such as biodegradation, adsorption, and hydroloysis were conservatively ignored in model simulations herein.

A primary factor affecting contaminant movement is advection, which is the transport of dissolved constituents with the velocity and direction of groundwater flow. Transport by advection at the site is governed by fractured flow. Hydrodynamic dispersion occurs due to mechanical mixing of moving water and molecular diffusion of dissolved chemicals. Dispersion will cause the constituent plume to spread, resulting in lower solute concentrations away from the plume center. Hydrodynamic dispersion, D_L, is usually difficult to accurately quantify in the field and is usually calculated using a factor called the dynamic dispersivity (a_L). For one-dimensional flow, hydrodynamic dispersion is represented by the following equation (Fetter, 1994):

$$D_L = a_L v_x + D^* \tag{1}$$

where v_x is the average linear velocity and D^* is the molecular diffusion.

Matrix diffusion is the process by which solute, flowing in distinct fractures, penetrates into the surrounding rock and is transported, through a connected system of pores or micro-fractures, into the rock matrix. Matrix diffusion of constituents into rock is a function of rock porosity, fracture spacing, and degradation constants. This concept accounts for back diffusion (release of constituents) into groundwater during remediation. The diffusion coefficient for an isotropic matrix depends on matrix tortuosity, $\tau(>1)$, and the molecular diffusivity D_w of a solute in free water (Zhou et al., 2005):

$$D_m = D_w / \tau \tag{2}$$

Because matrix tortuosity is a function of matrix porosity (ϕ_m) based on Archie's Law (Bowing and Grathwohl, 2001), we have

$$D_m = \phi_m^{n-1} D_w \tag{3}$$

where n is an empirical parameter, which is generally larger than 2.0 for materials of low porosity. For this study, the matrix diffusion coefficient was initially estimated using $D_m = \phi_m D_w$. Assuming a TCE water diffusion coefficient of 8.3 $\times 10^{-10}$ m^2/s and a matrix porosity of 0.35, the initial estimate for TCE matrix diffusion coefficient was 2.9×10^{-10}.

J.5.3. Solute Transport Model Calibration

The solute transport model was calibrated to the TCE concentrations (pre-HVDPE event observed isoconcentration contours) assuming that the release started 40 years prior to November 2004 and continued until this date (see Figure J-8 for injection rates). The objective of the fate and transport modeling calibration was to match, as closely as possible, the know distribution of TCE. The calibration strategy was to vary the dispersivity, matrix diffusion, and mass released until modeled concentrations matched measured values as closely as possible. For this simulation, it was assumed that the flow field is constant in time (steady-state groundwater flow conditions), no adsorption takes place, and that there is no biodegradation in the dissolved phase.

Table J-4 Fractured Media Transport Parameters After Calibration

Property Zone	Description	Saprolite Fracture Dispersivity [m]	Matrix Diffusion D_m	Bedrock Fracture Dispersivity [m]	Matrix Diffusion D_m
1	Plume Area (source)	$a_L = 0.05$ $a_T = 0.001$	3.2×10^{-9}	$a_L = 0.0$ $a_T = 0.0$	3.2×10^{-10}
2	Plume Area (middle section)	$a_L = 0.05$ $a_T = 0.001$	3.2×10^{-9}	$a_L = 0.0$ $a_T = 0.0$	3.2×10^{-10}
3	Plume Area (leading edge)	$a_L = 0.5$ $a_T = 0.1$	3.2×10^{-9}	$a_L = 0.0$ $a_T = 0.0$	3.2×10^{-10}
4	Plume Area (west and downgradient)	$a_L = 0.5$ $a_T = 0.1$	3.2×10^{-9}	$a_L = 0.0$ $a_T = 0.0$	3.2×10^{-10}
5	Plume Area (east and upgradient)	$a_L = 0.5$ $a_T = 0.1$	3.2×10^{-9}	$a_L = 0.0$ $a_T = 0.0$	3.2×10^{-10}
6	Flow Data Area	$a_L = 0.5$ $a_T = 0.1$	3.2×10^{-9}	$a_L = 0.0$ $a_T = 0.0$	3.2×10^{-10}

Property Zone	Description	Saprolite Fracture Dispersivity [m]	Matrix Diffusion D_m	Bedrock Fracture Dispersivity [m]	Matrix Diffusion D_m
7	Outside Area	a_L= 0.5 a_T= 0.1	3.2×10^{-9}	a_L= 0.0 a_T= 0.0	3.2×10^{-10}

Table J-5 Matrix Transport Parameters After Calibration

Property Zone	Description	Saprolite Fracture Dispersivity [m]	Matrix Diffusion D_m	Bedrock Fracture Dispersivity [m]	Matrix Diffusion D_m
1 thru 7	Homogeneous	a_L= 0.05 a_T= 0.001	-	a_L= 0.0 a_T= 0.0	-

The final (post-calibration) parameter values by zone for the fractured and matrix components of the model are summarized in Tables J-4 and J-5, respectively. The results of the calibration efforts in the form of simulated versus observed TCE isocontours concentrations are shown on Figure J-9. As indicated, the model-simulated extent of the existing TCE plume closely approximates that observed in the field. The simulated plume is slightly larger than the field-measured plume, imposing additional conservatism to the model simulations discussed below.

J.6 MODEL SIMULATIONS

The calibrated groundwater flow and transport model was used for simulation of the decline in TCE concentrations after the source removal. In performing forward simulations of TCE transport into the future following source removal, the TCE source term in the model was removed (reflecting removal of source and biological treatment of residual TCE) and the distribution of TCE reflected by the calibrated plume (see Figure J-9) was incorporated as the initial condition in the model simulations.

The model was simulated over a 100-year period, yielding concentration breakthrough curves for TCE at well RW-2, located 20 feet to the north of the excavation/remediation area (see Figure J-10). Additionally, breakthrough TCE concentrations over time were simulated at four additional locations (points of interest), 40 feet, 80 feet, 120 feet, and 160 feet respectively along centerline of plume northward (downgradient) of the remediation area and are depicted on Figure J-11. As expected, source removal efforts served to reduce TCE concentrations downgradient of the remediation area within a short period (to a concentration approximately one-fifth of initial concentrations in approximately 20 years) at RW-2; concentrations in this well were predicted to continue to decline toward 2L standards. Also, TCE simulation results at the four other locations indicate that concentrations would initially rise gradually to a level around or less than 100 micrograms per liter and then decline gradually toward the 2L standard. The initial increase in concentration is attributed to potential transport of TCE from upgradient areas (with higher TCE initial concentrations). The rapid decline following this initial rise in concentration is attributed to the flux of groundwater (which does not contain TCE) through this area following this potential initial transport of TCE from upgradient areas. However, it should be noted that the magnitude of actual increase in TCE concentration will be significantly lower than what was predicted by the model because the model does not incorporate the processes of adsorption and biodegradation. These processes would serve to reduce the mass flux of TCE from upgradient areas into the points of interest. Additionally, processes such as biodegradation, which serve to reduce the mass of TCE in groundwater, would also contribute to accelerated decline in TCE concentrations over time. It is important to note, however, that even with the exclusion of these processes in the modeled simulations, the model simulations indicate that TCE concentrations downgradient of the area targeted by recent remediation efforts will continue to decline to below 2L standards over time.