Final Report:
Independent Design Review
Celanese Fiber Operations
Superfund Site
Shelby, North Carolina
EPA Region 4

Solid Waste and
Emergency Response
(5203P)

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ABBREVIATIONS

ESD	Explanation of Significant Differences
GRUB	Glycol Recovery Unit Distillation Bottoms
IDR	Independent Design Reviews
IT	inner tier
MNA	monitored natural attenuation
NCDENR	North Carolina Department of Environment and Natural Resources
OT	outer tier
OU	operable units
P&T	pump and treat
ROD	Record of Decision
RP	responsible party
RSE	remediation system evaluations
TCE	trichloroethene

PREFACE

This report was prepared part of a pilot project conducted by EPA's Office of Superfund Remediation and Technology Innovation (OSRTI). The objective of this pilot project is to conduct independent, expert reviews of soil and ground water remedies that are jointly funded by EPA and the associated State agency. The reviews are ideally conducted during the pre-design, design, or redesign stage so that independent perspectives on the remedy are provided before costs are incurred for implementing and operating the remedies. The project contacts are as follows:

Organization	Key Contact	Contact Information
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1.0 INTRODUCTION

1.1 PURPOSE

During fiscal years 2000 and 2001 independent reviews called remediation system evaluations (RSEs) were conducted at 20 operating Fund-lead pump and treat (P&T) sites (i.e., those sites with P&T systems funded and managed by Superfund and the states). Due to the opportunities for system optimization that arose from those RSEs, OSRTI has incorporated RSEs into a larger post-construction complete strategy for Fund-lead remedies as documented in *OSWER Directive No. 9283.1-25, Action Plan for Ground Water Remedy Optimization*. OSRTI has since commissioned RSEs at additional Fund-lead sites with P&T systems.

Lessons learned from the RSEs conducted to date indicated potential value in conducting independent reviews during the pre-design, design, or redesign stage of a remedy so that the independent perspective can be considered before a remedy is implemented and operated. In addition, there is potential for the same type of process to benefit responsible party (RP) sites. As a result, OSRTI's Technology Innovation and Field Services Division is conducting pilot Independent Design Reviews (IDRs) at Fund-lead and RP sites that are nominated by the EPA Regions. These sites are typically at one of the following stages:

- Pre-design – The Region is in the process of determining the remedy for the site. The Remedial Investigation is typically completed and the site team is evaluating the feasibility of several remedial options.

- Design Stage – The Region has selected a remedy and documented it in a Record of Decision (ROD). The Region is at any phase of the Remedial Design stage.

- Redesign Stage – The Region has selected, designed, and may have implemented a remedy but the remedy is being reconsidered. Based on data collected to date, the Region is considering new remedial options or is designing a new remedy for the site.

An IDR involves a team of expert hydrogeologists and engineers that are independent of the site, conducting a third-party evaluation of remedy selection or remedy design. It is a broad evaluation that considers the goals of the remedy, site conceptual model, available site data, performance considerations, protectiveness, cost-effectiveness, and closure strategy. The evaluation includes reviewing site documents, potentially visiting the site for one day, and compiling a report that includes recommendations. Recommendations with cost and cost savings estimates are provided in the following categories:

- Site strategy
- Initial recommendations
- Next-step recommendations

The recommendations are intended to help the site team identify opportunities for improvements. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed prior to implementation of the recommendation. Note that the recommendations are based on an independent evaluation by the IDR team, and represent the opinions of the IDR team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the Region and other site stakeholders.

The Celanese Fiber Operations Superfund site (the "Celanese site", or "site") was selected by EPA OSRTI based on a nomination from EPA Region 4. The Celanese site is located in Shelby, North Carolina. Operation of the P&T system was discontinued on a trial basis for two years to evaluate monitored natural attenuation as a potential ground water remedy. The system has not been restarted. EPA Region 4 is requesting a third-party review to help determine if the system should be restarted, if a modified system should be restarted, or if another type of ground water remedial approach is warranted. This report provides a brief background on the site, a summary of observations made from the document review, and recommendations regarding future modifications to the existing remediation system (including associated investigation activities). The cost impacts of the recommendations are also discussed.

1.2 TEAM COMPOSITION

The IDR team consists of the following individuals:

Name	Affiliation	Phone	Email
Doug Sutton	GeoTrans, Inc.	732-409-0344	dsutton@geotransinc.com
Kathy Yager* (not present)	U.S. EPA OSRTI	617-918-8362	yager.kathleen@epa.gov

** Project coordinator(s)*

1.3 DOCUMENTS REVIEWED

The following documents were reviewed during the IDR process. The reader is directed to these documents for additional site information that is not provided in this IDR report.

- 3rd Five-Year Review – August 2001
- 4th Five-Year Review – August 2006
- Explanation of Significant Differences – April 2004
- OU1 Semi-Annual Report January 2007 to June 2007 – September 2007
- OU1 Semi-Annual Report July 2007 to December 2007 – March 2008
- Institutional Controls/Watering Agreements
- Conceptual Site Model Report – September 2007
- Risk Assessment – August 2007

- Access Database through April 17, 2008
- Region 4 Comments on OU1 Semi-Annual Report – June 4, 2007
- Draft Region 4 Response to Comments Dated August 14, 2007 – September 2007
- Region 4 Comments to Status Update and Conceptual Path Forward – August 9, 2007
- North Carolina Department of Environment and Natural Resources (NCDENR) Comments to Draft Risk Assessment – September 19, 2007
- NCDENR Comments to Conceptual Site Model Report – December 5, 2007
- NCDENR Comments to OU1 Semi-Annual Report July 2007 to December 2007 – April 14, 2008

1.4 PERSONS CONTACTED

The following individuals associated with the site were present for the visit:

Name	Affiliation
Beth Walden	EPA Region 4 (Remedial Project Manager)
David Jenkins	EPA Region 4 (Hydrogeologist)
David Mattison	NCDENR
Steve Simpson	Celanese
Everett Glover	AECOM (Celanese Contractor)
Bryon Dahlgren	AECOM
Joe Harrigan	AECOM

1.5 BASIC SITE INFORMATION AND SCOPE OF IDR

The Celanese site began operation in 1960 and currently operates as a polyester and engineering plastics production facility. CNA Holdings, Inc., a subsidiary of Celanese, retains management of environmental matters for the corporation and is responsible for environmental work regarding the site. The Celanese site is approximately 450 acres located six miles south of Shelby, North Carolina in south-central Cleveland County. The site is bordered to the west by Highway 198 and Lavender Road to the south. The site consists of a main plant production area, wastewater treatment area, former waste disposal areas, and recreational/wooded areas. The plant production area is covered with buildings and paved or graveled areas. Toward the wastewater treatment area, the site consists of grassy areas and roads. The recreation area is wooded and has no structures present. The site is currently fenced and has controlled access points. Current land

use surrounding the site includes mainly rural residential areas and agricultural. A site location map is presented in Figure 3-1 of the Conceptual Site Model Report (see Attachment A).

The site has been divided into two operable units: OU1 addresses contaminated ground water, and OU2 addresses contaminated soil and source materials. This independent review focuses on ground water contamination associated with OU1 and only considers impacted soils as they would potentially affect OU1 as a continuing source of contamination for ground water. The OU1 remedy consists of two P&T systems. The inner tier (IT) system addresses contamination in the immediate vicinity of the former source areas and was shutdown on a trial basis in accordance with a 2004 Explanation of Significant Differences (ESD) to evaluate monitored natural attenuation (MNA) in the absence of remedy pumping. The outer tier (OT) system addresses the plume near the downgradient property boundary and was shutdown in accordance with the National Priority List delisting process in 1998.

This independent review aims to determine if the IT P&T system should be restarted, if a modified system should be restarted, or if another type of ground water remedial approach is warranted.

2.0 FINDINGS

The IDR team reports the following findings from the document review that are pertinent for the recommendations that have been developed as part of the IDR process and described in Section 3.0 of this report.

2.1 FINDINGS RELATED TO SITE CONCEPTUAL MODEL

Hydrogeology

Site geology consists primarily of low permeable saprolite overlying bedrock. The saprolite is generally thickest beneath the plant and thins toward the east and in the vicinity of the adjacent streams. In some locations the saprolite has pinched out and the creeks flow across the bedrock. Ground water occurs in the saprolite under water table conditions and in fractures in the bedrock. The direction of groundwater movement in the shallow saprolite zone is to the east, northeast, and southeast from upgradient areas along NC 198 toward discharge areas along unnamed tributaries of Buffalo Creek and is shown on Figure 3 of the Semi-Annual Report January to June 2007 (see Attachment A). Direction of groundwater movement in the deeper saprolite and upper bedrock zone is in the same general direction. Figure 6 of the Semi-Annual Report January to June 2007 and Figures 4-2, 4-3, and 4-4 of the Conceptual Site Model Report (see Attachment A) present cross-sections of the site prepared by the site contractor. The figures from the two reports generally agree, but there are a few discrepancies, including the zone in which monitoring well O-59 is screened and the presence of a transition zone between the saprolite and bedrock. The Site Conceptual Model Report indicates that this transition zone likely has a higher hydraulic conductivity than the saprolite or bedrock.

The bedrock fracturing reportedly decreases in intensity with depth below the top of rock. In the saprolite, groundwater generally parallels the ground surface slope. This is also the case in shallow bedrock. In the deeper bedrock, below the elevation of local creek bottoms, groundwater flow becomes more regional, although discharge to the major creeks appears still dominant. The potentiometric surface in the saprolitic aquifer slopes to the northeast, east, and southeast toward Buffalo Creek. Based on a generalized hydraulic gradient of 0.036 feet/foot, an average hydraulic conductivity of 5.13×10^{-4} centimeters per second (cm/sec) from slug tests, and an effective porosity of 0.3, the groundwater seepage velocity was calculated by the site team at 0.17 feet/day (63 feet/year) in the saprolite. The hydraulic conductivity at some locations is as high as 10 feet per day based on slug tests and pumping tests.

Extent of Contamination

The site investigation began in 1981 and determined that the burn pits and Glycol Recovery Unit distillation bottoms (GRUB) disposal areas located near the center of the property were the probable source of groundwater contamination. These areas are shown in Figure 3-3 of the Conceptual Site Model Report. The groundwater contaminants include ethylene glycol,

trichloroethene (TCE), diethylene oxide, DOWTHERM™A constituents (1,1-biphenyl and biphenyl ether), and others (several volatile organic compounds, metals, and phenols in much less extent).

The remedial action objective for the former GRUB disposal pits was reportedly to remove the GRUB plus 1 foot of soil on all sides, and was not intended to be a clean closure in the disposal area. This resulted in leaving contaminated soil in place above the groundwater table. Approximately 4,549 tons of GRUB sludge, stained soils, and associated contaminated soils were excavated and incinerated from the source areas in 1991. Additionally, approximately 3,259 tons of burn pit materials and plastic chips and 39 cubic yards of stream sediment were excavated. The incinerator ash, burn pit material, plastic chips, and stream sediments were solidified with 10% to 20% by weight of cement and backfilled into the excavated former GRUB and burn pit areas. OU-2 was delisted in April 1998.

After OU1 was operational, localized areas of impact were identified at well F-55 (ethylene glycol and DOWTHERM™A) and at wells TD-3/TD-4 (TCE). The Conceptual Site Model Report states that these are interpreted as localized issues not related to the source area identified for remediation under OU1 and OU2. These locations are located in the downgradient portion of the process area, upgradient of the waste disposal areas addressed by OU1 and OU2.

Ground water contaminants with ongoing detections at the site include but are not limited to the following:

- ethylene glycol
- diethylene oxide (i.e., 1,4-dioxane)
- 1,1-biphenyl
- biphenyl ether
- TCE

In addition, iron, manganese, and arsenic are found in elevated concentrations, presumably due to the reducing ground water conditions at the site caused by the presence of ethylene glycol.

In July 2007, ethylene glycol was detected above the standard of 14,000 µg/L at the following three wells:

- F-55 at 6,680,000 µg/L
- IT-6 at 1,011,000 µg/L (average between two samples)
- V-23 at 8,280,000 µg/L

IT-6 and V-23 are located in the vicinity of the former burn pits and GRUB disposal area. F-55 is located in the saprolite upgradient of these locations in the downgradient portion of the process area. Ethylene glycol is not detected in downgradient wells HH-48 and HH-77. Ethylene glycol has a very low organic carbon partitioning coefficient; therefore, sorption to soil and associated transport retardation is expected to be negligible. Ethylene glycol degrades rapidly in aerobic environments and can also degrade in anaerobic environments.

Data from 2006 and 2007 indicate that diethylene oxide is present in many of the site monitoring wells above the standard of 7 µg/L with the highest concentrations occurring in monitoring wells in the saprolite in the vicinity of the former burn pits and GRUB disposal area at a maximum concentration of approximately 3,120 µg/L. From this location, it appears that the plume may split into two or three arms with contamination migrating to the northeast near monitoring wells AA-54, KK-55, P-58, PZ-12, to the east near monitoring wells II-65, and to the southeast near monitoring wells OT-2R, OT-3, NN-105, and T-58. In all three areas, it appears that concentrations are the highest in deep saprolite or shallow bedrock. The pathways to the northeast and east may be one larger plume, but it is difficult to tell given the absence of monitoring points between these two pathways in the deep saprolite or shallow bedrock. A separate diethylene oxide plume appears to originate from the F-55 and G-50 area that migrates south toward I-57. Diethylene oxide is not detected in downgradient wells HH-48 and HH-77. Figure 1 illustrates the apparent diethylene oxide migration pathways. Diethylene oxide has a very low organic carbon partitioning coefficient; therefore, sorption to soil and associated transport retardation is expected to be negligible. In addition, diethylene oxide does not readily degrade; therefore, diethylene oxide is expected to behave essentially as a conservative tracer with no sorption or degradation.

Diethylene oxide appears to be present in the bedrock and deep bedrock based on sampling results for the LL, MM, and NN clusters between 2004 and 2006. However, these detections of diethylene oxide in these clusters may be the result of pulling down contamination while installing the wells. Each of these three well clusters was installed in February 2004 through shallower zones with elevated diethylene oxide concentrations, and the first round of sampling was conducted in June 2004. Another round of sampling was conducted in August 2004 and a third round of sampling was conducted in September 2006. For all three clusters, all wells (with the exception of NN-105) have shown consistent and substantial declines that are much faster than would be expected from an established plume at this distance from the source area at this site. Based on the reported slow recovery of these wells during sampling, it is apparent that these wells have limited flow of water through them and it is reasonable that contamination brought down during the drilling process is slowly being flushed from the vicinity of the well screen.

Sampling for 1,1-biphenyl and biphenyl ether appears to be limited to F-55 and wells and the PEW wells, which are in the general vicinity of F-55. The concentrations for 1,1-biphenyl are highest in F-55 and are approximately one order of magnitude above the standard.

TCE is primarily detected in two different locations: a presumed but unidentified source area near monitoring wells TD-3 and TD-4 in the process area and approximately 1,000 feet downgradient of the site at HH-48 (saprolite) and HH-77 (shallow bedrock). The concentrations at TD-3 and TD-4 in July 2007 were 416 µg/L and 2,280 µg/L, respectively. TCE in TD-3 has been generally declining since it was first detected in 1998, and TCE concentrations in TD-4 generally increased since 2001 and appear to have begun declining since 2006. The concentrations at HH-48 and HH-77 in July 2007 were 85.9 µg/L and 360 µg/L, respectively. TCE has been present in HH-48 at comparable concentrations since 1989, and TCE concentrations have generally increased at HH-77 to the present value since 1989. TCE at other site monitoring wells was not detected (at an appropriate detection limit), was detected below standards, or was detected slightly above standards. For example, TCE was detected at PEW-4

and CC-33 at 15.7 µg/L and 3.8 µg/L, respectively, relative to a standard of 2.8 µg/L. TD-4 is screened near the bottom of the saprolite and has a higher TCE concentration than TD-3, which is screened approximately 30 feet above TD-4. TCE is not vertically delineated in this area. TCE degradation products (cis-1,2-dichloroethene and vinyl chloride) are either not detected or are detected at very low concentrations at both the TD-3/4 cluster and the HH cluster indicating that there is little or no TCE degradation occurring in or upgradient of these areas.

Potential Receptors

Potential complete exposure pathways for humans to contaminated ground water identified in RI/FS included ingestion of contaminated groundwater downgradient of the site. In 1996, 100% of adjacent offsite residents considered to be potentially at risk were connected to the Cleveland County water system and all individual domestic wells were abandoned. Although this might eliminate current ground water receptors, a potential pathway for future ground water receptors might still exist.

Potential ecological receptors for contaminated ground water are the unnamed tributaries to Buffalo Creek that run along the northern and southern portions of the site.

Remedy Objectives

The ROD objectives of the ground water remedy are to

- Control migration of contaminated water
- Remove contaminated water
- Treat and discharge the extracted water
- Attain North Carolina 2L Ground Water Quality Standards

The following table presents the North Carolina 2L Ground Water Quality Standards for constituents identified in the ROD and for constituents identified subsequent to the ROD.

Constituent	Standard
Inorganics:	
Barium	2,000 µg/L
Chromium	50 µg/L
Iron	300 µg/L
Lead	15 µg/L
Manganese	50 µg/L
Nickel	100 µg/L
Selenium	50 µg/L
Organics	
Acetone	700 µg/L
Benzene	1 µg/L
1,1-Biphenyl	350 µg/L
bis(2-ethylhexyl) phthalate	2.5 µg/L
Carbon tetrachloride	0.269 µg/L

Constituent	Standard
Chlordane	0.1 µg/L
Chlorobenzene	50 µg/L
Chloroform	70 µg/L
Chloromethane	2.6 µg/L
Diethylene oxide (1,4-dioxane)	7 µg/L
1,1-Dichloroethane	70 µg/L
1,1-Dichloroethene	7 µg/L
cis-1,2-Dichloroethene	70 µg/L
trans-1,2-Dichloroethene	100 µg/L
Ethylene glycol	14,000 µg/L
Methylene chloride	4.6 µg/L
2-Methylnaphthalene	14 µg/L
Naphthalene	21 µg/L
Phenol	300 µg/L
Tetrachloroethene (PCE)	0.7 µg/L
Trichloroethene (TCE)	2.8 µg/L
Vinyl chloride	0.015 µg/L

Additionally, a Class C surface water standard for secondary recreation of 110 µg/L of diethylene oxide has been established by NCDENR for streams adjacent to the site.

Description of Remedy

The ground water remedy consists of two P&T systems: an inner tier (IT) system designed to address contamination near the former GRUB disposal area and burn pits and an outer tier (OT) system designed to control plume migration near the downgradient property boundary.

The IT system consists of nine extraction wells that are each 2 inches in diameter and completed in the shallow saprolite. The extracted water is pumped to an equalization tank and is then treated by an activated sludge sequencing bioreactor, air stripping, and carbon adsorption. The treated water is discharged to the facility's water treatment plant NPDES permitted outfall. The IT system was temporarily shutdown in April 2004, in accordance with an ESD, to evaluate the potential for MNA in the absence of remedy pumping.

The OT system consists of 10 extraction wells that are each 6 inches in diameter and completed in the deep saprolite and shallow bedrock. The extracted water is pumped to an equalization tank and is then treated by air stripping and carbon adsorption. The treated water is discharged to the facility's water treatment plant NPDES permitted outfall. The OT system was shutdown in accordance with the National Priority List delisting process in 1998.

Monitoring Program

The ground water monitoring program includes quarterly sampling from several wells for constituents of concern and for MNA parameters. Results are reported semi-annually. Tables 1

and 2 from the semi-annual reports outline the monitoring program. These tables are included in Attachment A of this report for reference.

2.2 FINDINGS RELATED TO EXISTING REMEDY

Contaminant Fate and Transport

The contaminant fate and transport for three pertinent site contaminants (ethylene glycol, TCE, and diethylene oxide) are discussed in this section. The discussion is limited to these parameters because they are the likely drivers for site remediation. Understanding the fate and transport of these contaminants depends heavily on an understanding of the ground water flow at the site. The site contractor prepared a ground water model to help understand ground water flow at the site. Findings regarding hydraulic data and this numerical model are discussed first.

Hydraulic Data and Ground Water Flow Model

The ground water flow model was calibrated using the water level data from October 2005. This data set for the shallow saprolite indicates a hydraulic head gradient of 0.015 feet per foot below the process building, 0.03 feet per foot from the treatment ponds to the downgradient edge of the property (and also on the northern and southern edges of the process area), and 0.023 feet per foot from the western boundary to the eastern boundary. Ground water beneath the process area and immediately to the east of the process area appears to flow to the north, east, and south. The hydraulic head gradient for the deep saprolite is relatively similar, and the hydraulic head gradient for the shallow bedrock is relatively uniform at 0.017 feet per foot. Vertical ground water flow seems to be downward from the saprolite to the bedrock near the process building and is almost absent at downgradient locations.

The ground water flow model appears to generally simulate these ground water flow patterns in the shallow saprolite, deep saprolite, and shallow bedrock. The model calibration statistics are reasonable, and a sensitivity analysis was conducted. However, there are some limitations to the model development that might affect how it is used for forecasting and/or understanding ground water flow at the site.

- Hydraulic conductivity zones and values appear to vary significantly over relatively small distances. Furthermore, the hydraulic conductivity zones and values do not appear to agree with the slug or pump test results. For example, in the shallow saprolite, the area among the ponds was assigned a hydraulic conductivity of 0.3 feet per day, but the slug test results for O-25, N-29, and W-33 (which are in this area) were 1 foot per day, 2 feet per day, and 8 feet per day, respectively. Therefore, one would expect the model to have a higher hydraulic conductivity in this area. Similarly, in the deep saprolite hydraulic conductivities of 5.3 feet per day (OT-1 pump test) and 10 feet per day (Q-33 slug test) are located in model zones with a hydraulic conductivity of 1.6 feet per day.

- The low hydraulic conductivity from the IT wells may be the result of well fouling or well construction. These wells operated as 2-inch extraction wells that had a relatively low yield. It is likely that they had some degree of iron fouling given the high levels of

iron in the aquifer in that vicinity. In addition, extraction wells are typically larger in diameter, so the small diameter calls into question the quality of the well construction. If significant well fouling is present, the aquifer hydraulic conductivity in this area may be higher than that measured by the slug tests.

- The simulated contours appear to be substantially more complex than the contours interpreted from actual measurements suggesting that the use of many hydraulic conductivity zones in a single layer with large ranges in hydraulic conductivity (e.g., 0.2 feet per day to 50 feet per day), are complicating the contours in an attempt to match water levels at individual wells.

- The conceptual model includes a transition zone between the saprolite and bedrock that is likely higher in hydraulic conductivity than the saprolite or bedrock. This zone could therefore be considered a preferential pathway for contamination. The zone is observed in several monitoring wells and is depicted as continuous across the site, but the hydraulic conductivity of the zone has not been tested, and the zone is included in the deep saprolite zone in the model rather than as a distinct zone that may have a higher hydraulic conductivity.

- The model was only calibrated against the water levels from October 2005 using recharge and stream discharge as the primary stresses. A ground water flow model would ideally be calibrated under multiple stresses (e.g., pumping and non-pumping conditions). Given that a P&T system was active at this site, it would seem feasible to also calibrate the model against a set of water levels from a time when the system was operating to demonstrate that the chosen parameters also apply under a different pumping scenario. It would also be appropriate to conduct extended aquifer tests using system extraction wells to refine hydraulic conductivity estimates.

- The model report does not discuss the conductance used for the river and drain boundary conditions in the model. These parameters can significantly change how much water is discharged from the aquifer to the rivers and drains, and combined with recharge and the constant head boundaries, are the only parameters in the absence of pumping that help determine the calibrated value of the hydraulic conductivity. The conductance of the streams close to the site relative to that of the other streams and Buffalo Creek could control how much of the ground water from the site discharges to the tributaries that are close to the site versus Buffalo Creek. Given that the rivers are the ultimate discharge point for all water in the model, which river receives the majority of the water and contamination will control how far the plume spreads before discharging to surface water.

- The model report cites that optimal parameter settings for some hydraulic conductivity zones were not selected because it caused the simulated values for the layers 4 and 5 to deviate from actual values. However, in another part of the report, it is stated that the measured values, particularly in layer 5, may not be reliable.

In summary, based on the model developed, it is difficult to accept the modeling results without some reservation. For example, although the calibrated value for a wide portion of the modeling domain is 2 feet per day and this parameter is relatively sensitive to change in this value, this hydraulic conductivity value is dependent on the value of the recharge selected and the conductance of the river/stream beds. A different recharge rate and/or a different riverbed conductance could result in a reasonable change in this calibrated parameter.

Diethylene Oxide

Based on water level measurements and stream gauge measurements it is readily apparent that the core interval of diethylene oxide migrating in the deep saprolite/shallow bedrock discharges to the stream that runs north/south through the eastern edge of the Celanese property. The elevations of the screen intervals for contaminated wells AA-54, PZ-12, and P-58 are over 720 feet above mean sea level, and the screen interval for contaminated well II-65 is between 700 and 705 feet above mean sea level. The stream elevation is approximately 700 feet above mean sea level near II-65 and diethylene oxide is consistently observed in surface water where the diethylene oxide plume is expected to discharge. Diethylene oxide concentrations in surface water have been as high as 67.5 µg/L, which is below the surface water standard for the site of 110 µg/L. There is a general upward gradient from bedrock to saprolite at the MM/AA cluster location, and there is generally an upward gradient from shallow bedrock to saprolite at the II cluster. There is a downward gradient in bedrock at the LL cluster, so additional information at this location or downgradient of this location would be beneficial to demonstrate ultimate discharge of the plume to the stream. Additional monitoring over time is likely needed to confirm decreasing concentrations in bedrock wells to support the case that the observed bedrock contamination is associated with well installation.

To the southeast of the site, the highest diethylene oxide concentrations suggest migration toward and along the stream that runs through residential area with ground water restrictions. It is unclear how far the diethylene oxide migrates before discharging to the stream and if the plume is still present on the far side of the ground water restriction area. Sampling results indicate that diethylene oxide contamination has not migrated to HH-48 and HH-47 suggesting that these wells are not in a primary migration pathway for contaminants migrating from the GRUB area.

Ethylene Glycol

In contrast to the diethylene oxide, ethylene glycol appears to be relatively localized in the source area. This is likely due to the relatively rapid degradation of ethylene glycol; however, it may also be due, in part, to the extent of the sampling for ethylene glycol. Ten of the monitoring wells along the preferential pathway for diethylene oxide have not been sampled for ethylene glycol.

TCE

The interpreted TCE plume also differs from that of diethylene oxide plume. With the exception of HH-48 and HH-77, the presence of TCE appears limited compared to that of diethylene oxide. Unlike ethylene glycol, this is not likely due to TCE degradation because TCE degradation

products are not present in significant concentrations at any of the sampled monitoring wells. The apparent limited extent of TCE may partially be due to retardation of TCE since it has the potential to adsorb to soil more strongly than diethylene oxide, but it would be unlikely for the TCE retardation factor to be more than a factor of 2 at this site given the expected low organic carbon fraction of the soil. The relatively limited sampling for TCE may be a factor. Seven of the wells sampled along the preferential pathway marked by diethylene oxide have not been sampled for TCE, and another four were sampled as far back as 2001 or earlier. It is unclear when the TCE release occurred. TCE was first detected in a sample collected from TD-3 in 1998 but was not detected in TD-4 until 2001. By contrast diethylene oxide was present in some downgradient locations by 1998. The limited extent of the TCE plume, may be, in part, due to a relatively later release compared to that for diethylene oxide.

It is unclear if the TCE identified at HH-48 and HH-77 result from a release to ground water from the Celanese process area. The following are arguments for and against the TCE at HH-48 and HH-77 being linked to the Celanese process area.

Arguments against a link

The TCE detected at HH-48 was detected as early as 1988. It is unclear when or where the TCE release occurred that resulted in the contamination at TD-3. The first sample collected from TD-3 was collected in 1998. Evidence for a relatively late release is that TCE was not detected in TD-4 in 1998. It was first detected in TD-4 in 2001. Therefore, TCE contamination was identified far downgradient of the site 10 years prior to the first TCE samples onsite and before detections were present in TD-4.

Diethylene oxide, which is more mobile than TCE and likely released in greater quantities has not been detected in HH-48 and HH-77. These two wells appear to straddle the general vertical zone where diethylene oxide would be detected if it was migrating in this direction. The absence of diethylene oxide in these two wells suggests that these wells are not along the preferred path for contaminant transport at this site and that the TCE might be better explained by a local source.

Given that the TCE source is upgradient of the diethylene oxide source, it is expected that TCE would follow the same migration pathways as the diethylene oxide. Based on diethylene oxide sample results, the deep saprolite/shallow bedrock/transition zone is likely the preferential pathway for contaminant transport at the site. As such, it is unlikely that TCE would have migrated vertically into and through bedrock to the HH wells faster than it would through the transition zone. In addition, TCE concentrations at the HH wells first appeared the HH-48 in the saprolite before appearing in HH-77 in the bedrock, lending further evidence for a localized TCE source at the surface that migrated deeper over time rather than migrating upward from bedrock.

Potential Data Gaps or Uncertainties

There are concentrations onsite that are high enough to explain the observed concentrations at HH-48 and HH-77. Although the detected TCE concentrations in TD-3

and TD-4 are on the order of 1 to 2 mg/L, these wells are not necessarily at the source area, and areas onsite with higher concentrations are likely.

There are very few, if any, samples collected from the transition zone between the source area and HH-48 and HH-77.

A set of realistic transport parameters for the site can result in sufficiently fast transport times for TCE to have reached HH-48 by 1988. For example, a hydraulic gradient of 0.02, a hydraulic conductivity as low as 5 feet per day in the transition zone, and a porosity of 0.2 would yield an unretarded transport velocity of approximately 180 feet per year. This would allow TCE to reach from the TD-3/TD-4 location to the HH-48/HH-77 location within 20 years. The facility began operation in 1960.

Remedy Effectiveness

The IT system appears to have had minimal effectiveness when operating. The wells were small diameter and had very low yield relative to the estimated amount of water flowing through that portion of the aquifer. As a result, the mass recovery and source control offered by the system were likely negligible. The Fourth Five-Year Review indicated that the IT system pumped approximately 1.6 million gallons over a three year period, which translates to an average extraction rate of 1 gallon per minute. By contrast, using a hydraulic conductivity of 2 feet per day (global hydraulic conductivity value from the model), a hydraulic gradient of 0.02, a saturated thickness of approximately 50 feet, and a source area width of at least 500 feet, the amount of water flowing through the system would be approximately 5 gallons per minute. Typically, extraction should exceed this flow rate by a factor of two or more, and in this case, the extraction is lower by a factor of five.

It is difficult to evaluate the effectiveness of the OT system because little water quality data and system operational parameters are available to evaluate the hydraulic control it provided. The diethylene oxide plume has migrated beyond the OT system, but this may have occurred prior to system installation and operation. The OT system was apparently sufficiently effective to be delisted in 1998, but this is before diethylene oxide was identified as a potential contaminant of concern.

The evaluation of an MNA remedy depends on the constituent of concern being evaluated. With respect to diethylene oxide, MNA does not appear to be a viable remedy because the contaminant does not readily degrade and has demonstrated the ability to migrate over 1,000 feet from the source area at concentrations that are 50 times greater than the cleanup standard.

With respect to TCE, there is insufficient information to evaluate MNA because many of the critical monitoring wells (i.e., those marked by diethylene oxide transport and along ground water flow paths) have not been sampled for TCE. Finally, there is a lack of information regarding TCE distribution in the source area and between HH-48 and HH-77. The concentrations at TD-3 have declined and the concentrations at TD-4 appear to have peaked, but little is known about the locations of these wells relative to the source of TCE. A shift in the ground water flow direction may be the cause for the change in concentrations in these wells.

Alternatively, the TCE source may have attenuated and the TCE at these wells is migrating from these points to locations downgradient. Regardless, there is little evidence for degradation of TCE near TD-3/TD-4 and at HH-48/HH-77. If additional sampling of key wells substantially increases the known TCE plume extent, then it is likely that MNA would not be a suitable remedy for TCE. On the other hand, if sampling confirms a limited TCE extent, then MNA may be appropriate for the TD-3/TD-4 TCE plume once the source has been addressed.

With respect to ethylene glycol, it is likely that MNA is an appropriate remedy due to the potential for this compound to degrade; however, sampling of key monitoring wells is lacking. It is unclear if aerobic degradation of ethylene glycol could lead reduced dissolved oxygen concentrations in nearby streams and/or if increased metals concentrations from reducing conditions caused by ethylene glycol degradation could lead to metals exceeding surface water standards.

3.0 RECOMMENDATIONS

3.1 SUGGESTED ADDITIONAL CHARACTERIZATION

Diethylene oxide has migrated further and at higher levels above standards than any other contaminant onsite, and the plume is not delineated horizontally. The ground water flow model suggests that all ground water discharges to streams in the vicinity of the site, but given the limitations to model calibration at this complex site, additional information is needed to confirm this fate of the diethylene oxide and consequently delineate the extent of the plume. Additionally, the southeastern portion of the diethylene oxide plume appears to run parallel with a stream running through a residential area. It is likely that diethylene oxide is discharging to this stream, but additional information is needed to help confirm the extent of the plume along this stream. Based on the results, it may be necessary to expand the restrictions regarding ground water use in the area, particularly if it is found that the diethylene oxide continues to migrate in the subsurface further downstream than the area currently covered by ground water use restrictions.

Suggested Characterization Efforts to the Northeast to Delineate Diethylene Oxide

The north/south running stream (gauged at locations SW-3 and SW-7) is the likely discharge point for diethylene oxide migrating to the north and east of the site. However, the steep topography and thick brush leading down to the stream and up the valley on the opposite side make it impractical to install monitoring wells to delineate the plume with water quality data alone. Therefore, it is practical to attempt to delineate the plume by demonstrating that it discharges to this stream and therefore does not continue migrating through the subsurface to another discharge point further downgradient. Sufficient evidence is discussed in section 2.2 of this report to demonstrate that this stream is the discharge point for the diethylene oxide; however, a few data gaps remain. The following is suggested:

- Continue sampling bedrock wells in the LL, MM, and NN clusters to confirm continued decreasing trends and supporting evidence that observed contamination in bedrock is associated with well installation rather than significant vertical migration. If continued monitoring cannot support this hypothesis, then additional data will be needed to determine the fate of diethylene oxide observed in deep bedrock because some of these deep wells are almost 200 feet deeper than the stream bed.

- Install a bedrock monitoring well at the II cluster location to vertically delineate the plume and to demonstrate an upward gradient within bedrock at this location given that there appears to be a downward gradient at the LL cluster. To the degree possible, measures should be taken to minimize the potential for pulling down contamination while drilling. A telescoping well may be appropriate with a total depth of approximately 120 feet below ground surface. The well should be sampled and analyzed for site contaminants and water levels should be measured and compared with other locations to

evaluate the vertical hydraulic gradient. The cost for installing this well might be $45,000, including work plans and contractor oversight.

- Install one or two new stream gauges upstream of SW-3 and include stream gauge measurements from existing and new stream gauges in development of potentiometric surface maps and potentiometric surface cross-sections.

Suggested Characterization Efforts to the Southeast

The diethylene oxide plume to the southeast (i.e., near OT-2R) would be best delineated by several monitoring wells placed within and potentially downgradient of the residential area with restricted ground water use. Given that ground water in this area is expected to discharge to the stream, an alternative approach to delineation could be to collect and analyze samples from ground water along the stream bank to determine where diethylene oxide is discharging to the stream and at what distance downstream the diethylene oxide concentrations become undetectable. A sampling methodology should be developed to ensure that ground water, and not surface water, is sampled. If the results are inconclusive, delineation with monitoring wells would be needed. In addition, if the plume extends beyond the current ground water restriction area, potable well sampling and use restrictions would likely need to be expanded downgradient.

Assuming ground water sampling at 10 stream bank locations and surface water sampling at 5 locations, the cost for delineation activities might be approximately $25,000, including planning.

Suggested Sampling for Delineation of Other Constituents

The distributions of TCE and ethylene glycol at the site are not well understood due to a lack of sampling from appropriate locations. The diethylene oxide plume helps highlight preferential pathways for contaminant migration, and many of the wells with elevated diethylene oxide concentrations have not been sampled for TCE or ethylene glycol. The following existing monitoring wells should be sampled and analyzed for TCE (and volatile organic compounds), DOWTHERM™ A, ethylene glycol, dissolved oxygen, oxygen demand, and metals because elevated diethylene oxide concentrations are present or because they are transition zone wells.

- F-55
- G-50
- I-57
- M-44
- P-58
- Z-78
- W-23
- AA-54
- BB-18
- DD-58R
- GG-39
- II-65
- KK-55

- LL-110
- LL-175
- LL-295
- MM-128
- MM-170
- MM-280
- NN-105
- NN-240
- PZ-3
- PZ-4
- PZ-12
- PZ-13
- OT-1R
- OT-2R
- OT-3
- The new deep well installed at the II cluster.

Assuming six wells can be sampled by a two person crew for $2,000 per day and analysis costs of $250 per sample, this additional sampling could likely be accomplished for under $25,000 per event. A minimum of two events would be suggested.

Suggested Characterization for the TCE Source Zone

The TCE source zone has not been identified, and the plume is not vertically delineated beneath TD-4. A source zone investigation utilizing existing information and direct-push sampling is recommended to identify the source area and determine if it is practical to remove. It is also recommended that two new bedrock monitoring wells (one below and one approximately 100 feet downgradient and deeper than TD-4) be installed and sampled to vertically delineate TCE in this area. The TRIAD approach with dynamic work planning and field-based decisions should be considered when planning and executing all aspects of this characterization to minimize the number of field events and to provide for timely characterization. Assuming a file review, three-day direct-push event, plus installation and sampling of two monitoring wells, the cost for these activities would likely be approximately $50,000, including planning.

Based on the results from the above activities, the site team should revisit the site conceptual model and evaluate if additional important data gaps are missing with respect to the TCE source and migration pathways. If additional data gaps are missing, additional characterization may be required prior to selecting an appropriate remedial measure.

A number of limitations were mentioned with regard to the ground water flow model, but it is unclear if these limitations should be addressed to reliably use the model for evaluating contaminant fate and transport. Some of the limitations are fundamental, including the presence, extent, and parameters of the transition zone as well as the conductance of the river and drain boundary conditions. It is unclear if sufficient information is present to help accurately adjust the model accordingly. Additional information would likely be required, and even if the model were

updated, it is likely that ultimate decisions regarding contaminant fate and transport and site remedy would be based on continuing water quality data. An updated model may be appropriate for evaluating a P&T capture zone or to design an extraction system, but this is not an immediate concern for the site.

3.2 SUGGESTED REMEDIAL STRATEGY (FROM A TECHNICAL PERSPECTIVE)

Selecting an appropriate remedial measure for the site is highly dependent on the results of the recommended characterization, on the interpretation of regulations by the site team, and on the development of appropriate standards for diethylene oxide. Remedy selection is discussed in context of each of the three primary contaminants, beginning with diethylene oxide.

Diethylene Oxide

Diethylene oxide is a difficult contaminant to address. It cannot readily be removed via air stripping or carbon adsorption and is generally resistant to bioremediation in typical subsurface conditions or in typical bioreactors. To date, the discharge of diethylene oxide plume to nearby streams has not resulted in an exceedance of the surface water criteria, but diethylene oxide remains in the subsurface above the 7 µg/L ground water criteria which serves as an ARAR for this site. There are two predominant remediation options for this constituent. One is to identify and remove the remaining source material and allow the existing plume to attenuate. The other is to declare source removal impractical and to capture the core of the plume, allowing the toe of the plume to attenuate. Some combination of source removal and ground water extraction may also be appropriate to allow aquifer restoration in a timely manner.

The GRUB area was reportedly used as far back as the mid to late 1960s, and the earliest diethylene oxide sampling (in 1998) suggests that plume had migrated at least as far as the OT system. Assuming diethylene oxide reached ground water in 1970 and the plume reached its current extent by 1998, suggests that transport took less than 30 years. It is reasonable to conclude that in the absence of a continuing source cleanup via natural flushing and dispersion will take substantially longer than initial plume transport.

Figure 2 provides a flow chart to illustrate the potential process for arriving at a remedy for diethylene oxide. Consistent with current findings in literature, this flow chart assumes that in-situ remediation will not be appropriate for providing reliable plume control. Source removal, source control, and active plume remediation are considered as is the potential need to expand institutional controls for ground water usage in the vicinity of the site is also indicated.

Long-term source control or active plume remediation with ground water extraction and treatment has the limitation of needing to provide cost-effective treatment. The facility's activated sludge treatment plant provides some treatment of diethylene oxide through cometabolism with tetrahydrofuran, which is reportedly present in the facility's waste water. However, it is unclear if this degree of treatment would be sufficient to meet standards. In addition, use of the facility's activated sludge system would require the system to continue operating for the duration of the source control remedy, which would very likely be longer than 30 years. If additional treatment for diethylene oxide is needed, the most successful and reliable

currently available treatment process is advanced oxidation. This is typically implemented with UV/oxidation or with oxidation from reacting ozone and hydrogen peroxide. The implementation of either of these approaches would highly depend on the quality of the extracted water. The performance of these technologies is greatly influenced by the presence of iron and solids, pH, total organic carbon, and other parameters. In addition, if bromide is present then there is potential to create bromate (a carcinogen) as a byproduct. These complications associated with long-term water treatment are further motivating factors for identifying and removing the source material in an attempt to avoid ground water extraction and treatment.

TCE

Additional sampling for TCE may indicate that it has an attenuating source and a plume of limited extent that is controlled by degradation associated with reducing conditions from the ethylene glycol plume. Alternatively, additional sampling may indicate a continuing source and preferential pathways that allow TCE to migrate from the site. If the former is true, then TCE may be appropriately addressed by continued monitoring to document the declining source and the controlled plume. If the latter is true, then source area remediation or some form of plume control may be appropriate. The form of plume control would depend on how the site team chooses to address the other contaminants. For example, if the site team chooses to control diethylene oxide migration with a P&T system, then the TCE could likely also be controlled with the same system.

Regardless of the source, the TCE in the vicinity of the HH cluster should be delineated as it may extend downgradient of the restricted ground water use area. However, if the source is determined to be local to the HH cluster (rather than site-related), these delineation activities would presumably not be the responsibility of Celanese. The results from the suggested sampling of existing wells and from the TCE source investigation should provide adequate information to conclude if the source is site-related or local to the HH cluster.

Ethylene Glycol

Additional sampling for ethylene glycol may confirm that this constituent is degrading sufficiently to limit plume migration. Further sampling may also indicate that the reducing conditions fostered by the ethylene glycol are instrumental in controlling or helping to control the TCE plume. Alternatively, additional monitoring may suggest that degradation of the organic carbon associated with the ethylene glycol may eventually adversely affect the dissolved oxygen content or metals concentrations in nearby streams.

3.3 POTENTIAL SCHEDULE

It is recommended that additional testing and study for potential remedies be postponed until the results from the above-noted sampling are available and the site conceptual model updated. The following schedule might apply:

Conduct the suggested characterization	By 12/31/09
Report findings and update site conceptual model	By 3/1/10
Update/expand institutional controls as needed	By 3/31/10
Select a ground water remedy (source remediation, source control, and the potential the need for active plume remediation)	By 6/30/10
Design and plan for the ground water remedy	By 12/30/10
Implement the ground water remedy	Begin by 3/31/11
Evaluate effectiveness and modify remedy accordingly	Ongoing

ATTACHMENT A:
FIGURES

Figure 1. Migration Pathways Based on Diethylene Oxide Concentrations >70 µg/L
Figure 2. Flow chart Illustrating Potential Process for Arriving at a Remedy for Diethylene Oxide

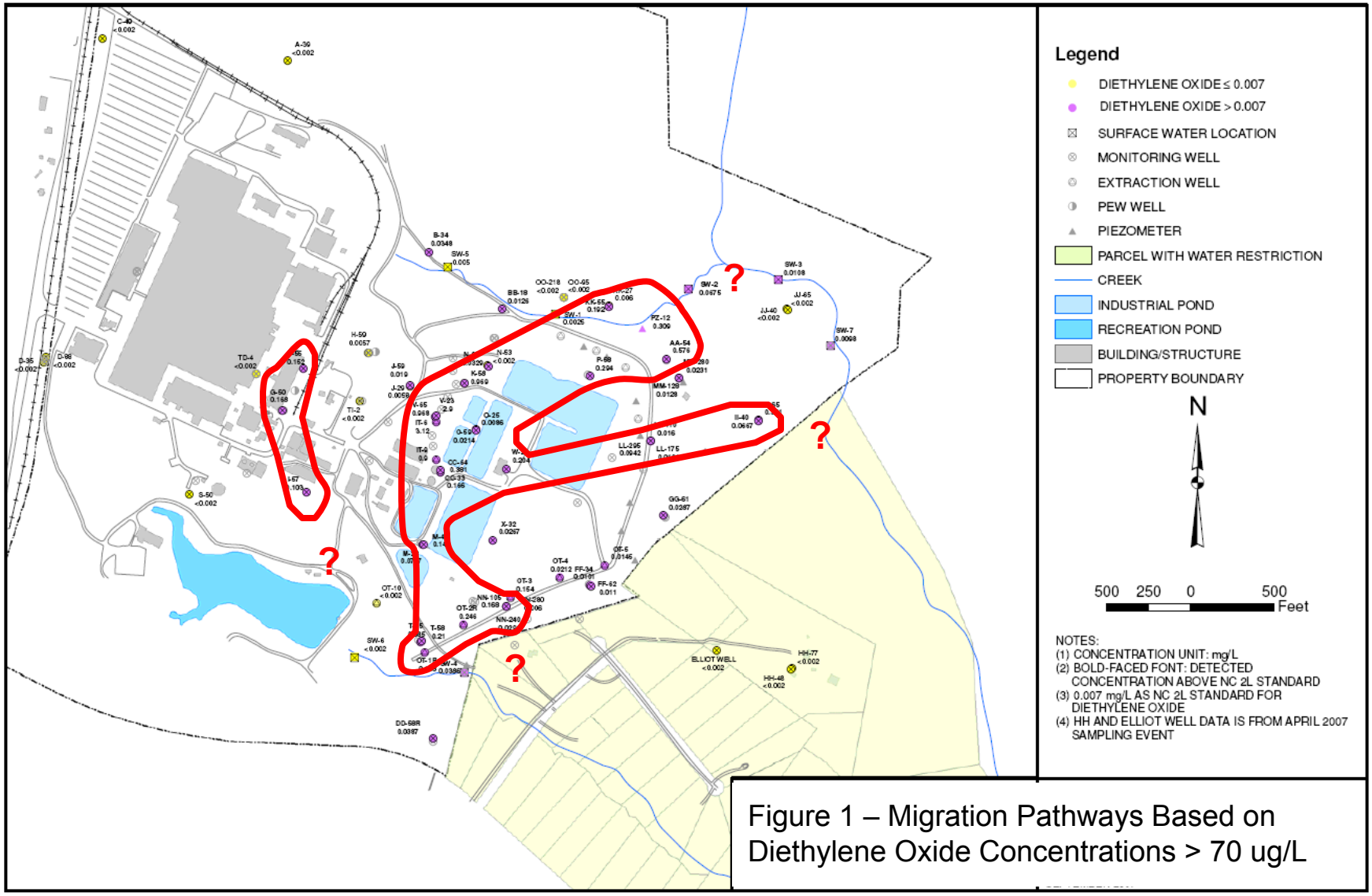


Figure 1 – Migration Pathways Based on Diethylene Oxide Concentrations > 70 ug/L

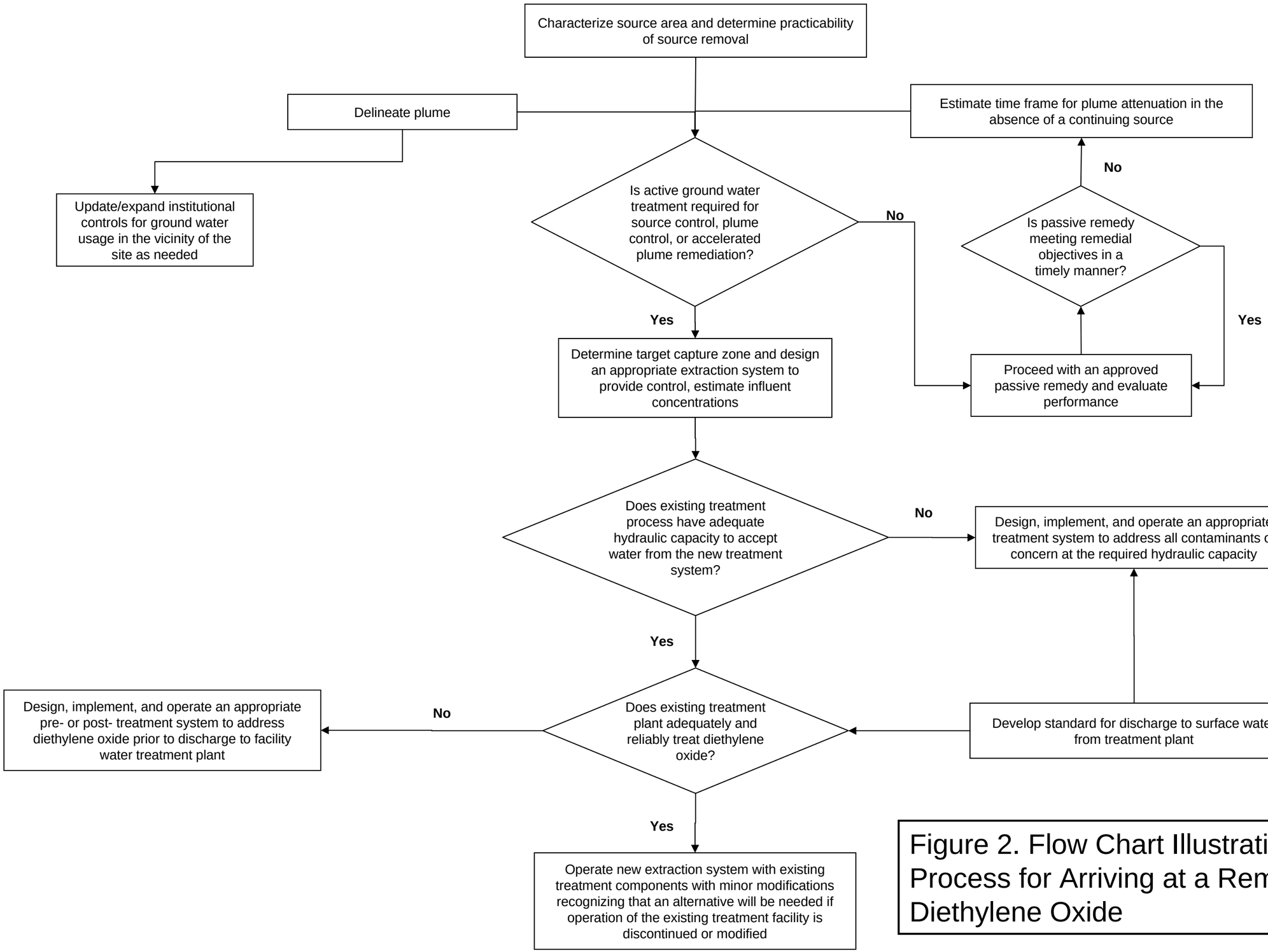
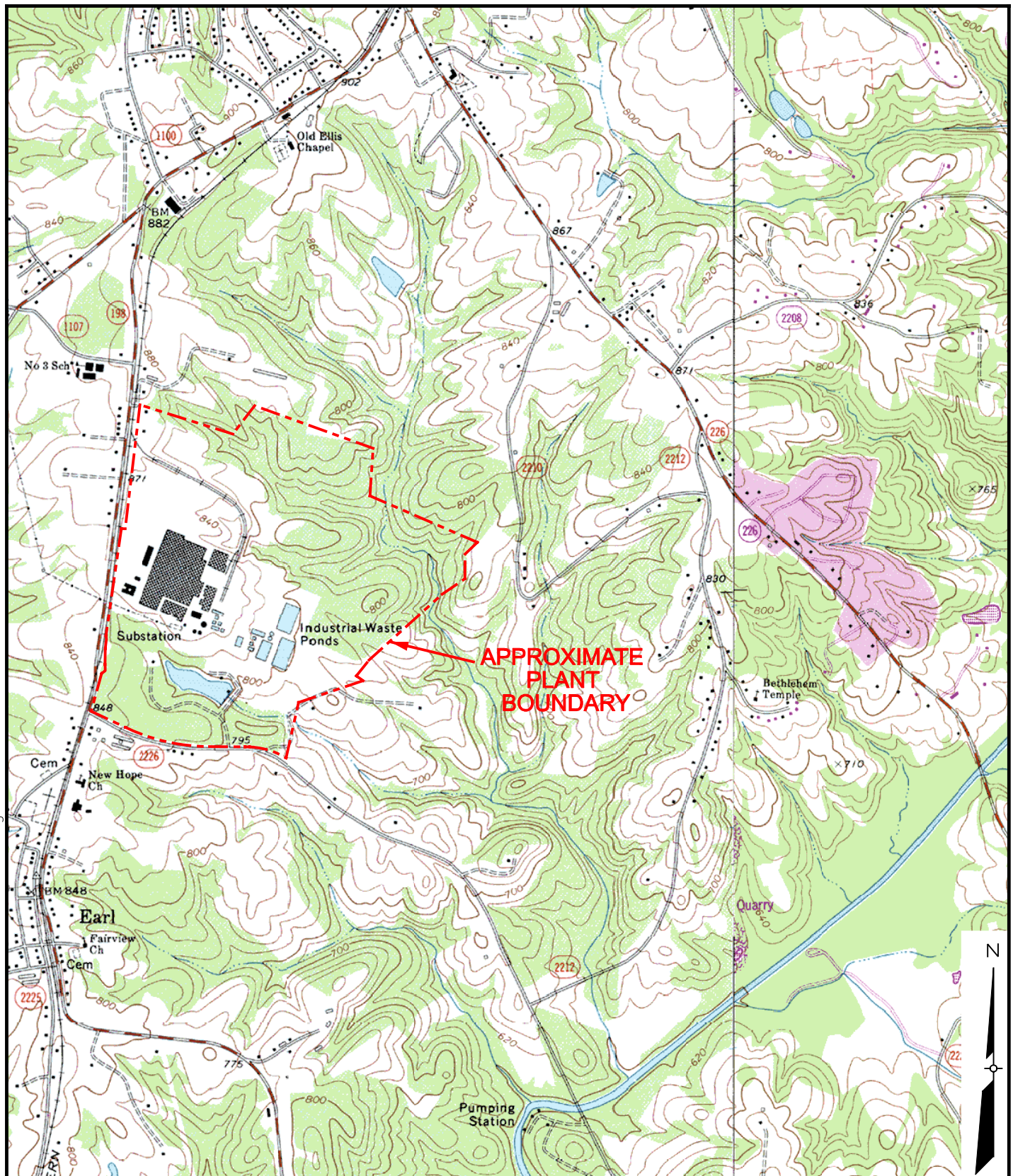


Figure 2. Flow Chart Illustrating Potential Process for Arriving at a Remedy for Diethylene Oxide

ATTACHMENT B:
FIGURES AND TABLES FROM THE CONCEPTUAL SITE MODEL REPORT AND SEMI-ANNUAL REPORTS

Figure 3-1	Site Location Map
Figure 6	Hydrogeological Cross Section A-A´, January 2007
Figure 4-2	Cross Section A-A´
Figure 4-3	Cross Section B-B´
Figure 4-4	Cross Section C-C´
Figure 3-3	Contamination Source Locations and OU-2 Excavation Extent Map
Table 1	Quarterly Groundwater Sampling Plan ─ CERCLA Parameters
Table 2	Quarterly Groundwater Sampling Plan ─ MNA Parameters



SOURCE: USGS 7.5 MIN. QUADRANGLEs
BLACKSBURG NORTH, NC - 1971
GROVER, NC - 1993

0' 2000' 4000'
SCALE

EarthTech
A Tyco International Ltd. Company

FIGURE 3-1
SITE LOCATION MAP

CNA HOLDINGS, INC./TICONA
SHELBY, NORTH CAROLINA

SEPTEMBER 2007 79750

9/7/2007

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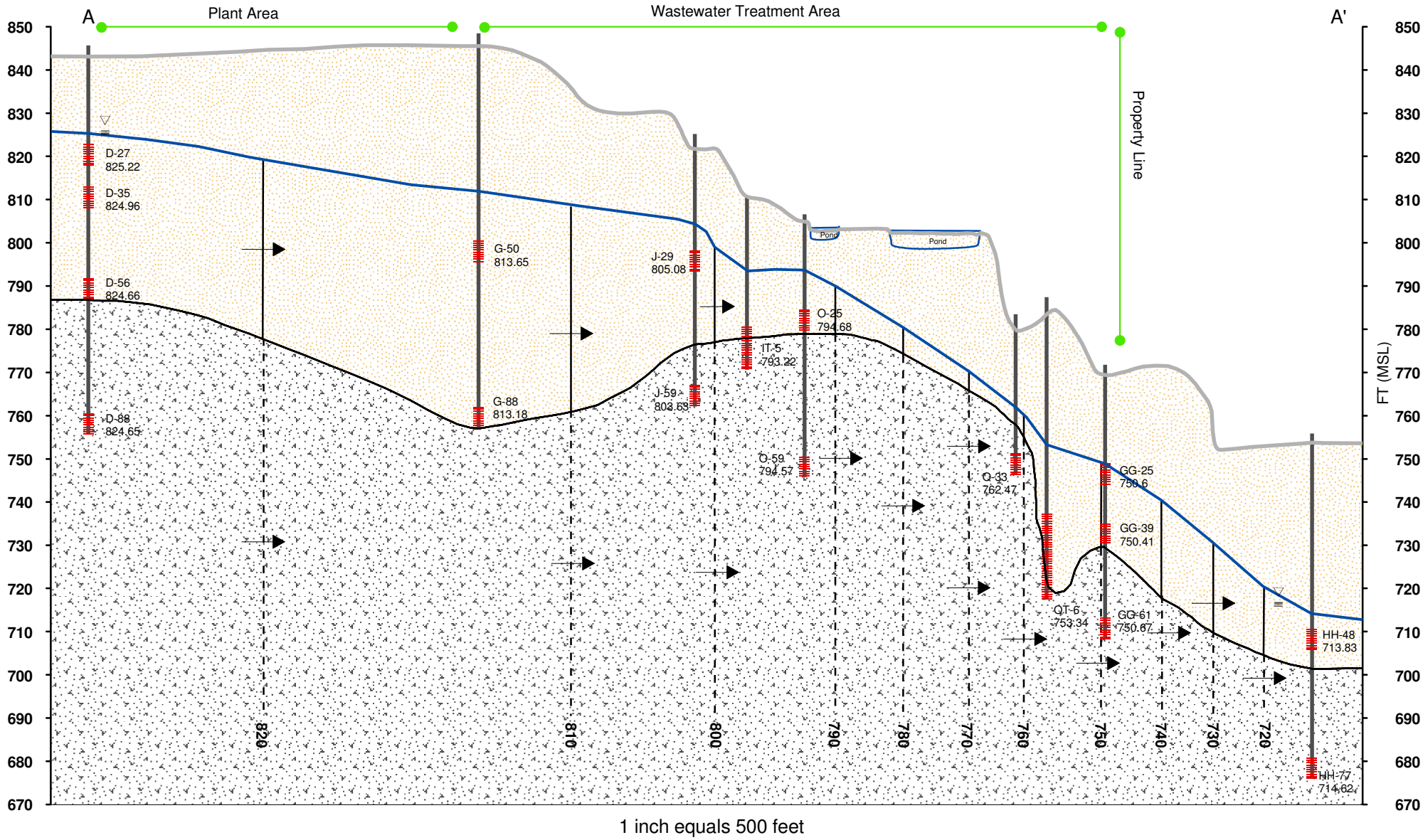

1 inch equals 500 feet

Line of equal fluid potential (1 msl) (dashed where inferred)

Potentiometric Surface

Inferred direction of groundwater movement

Screen

Saprolite

Bedrock

EarthTech

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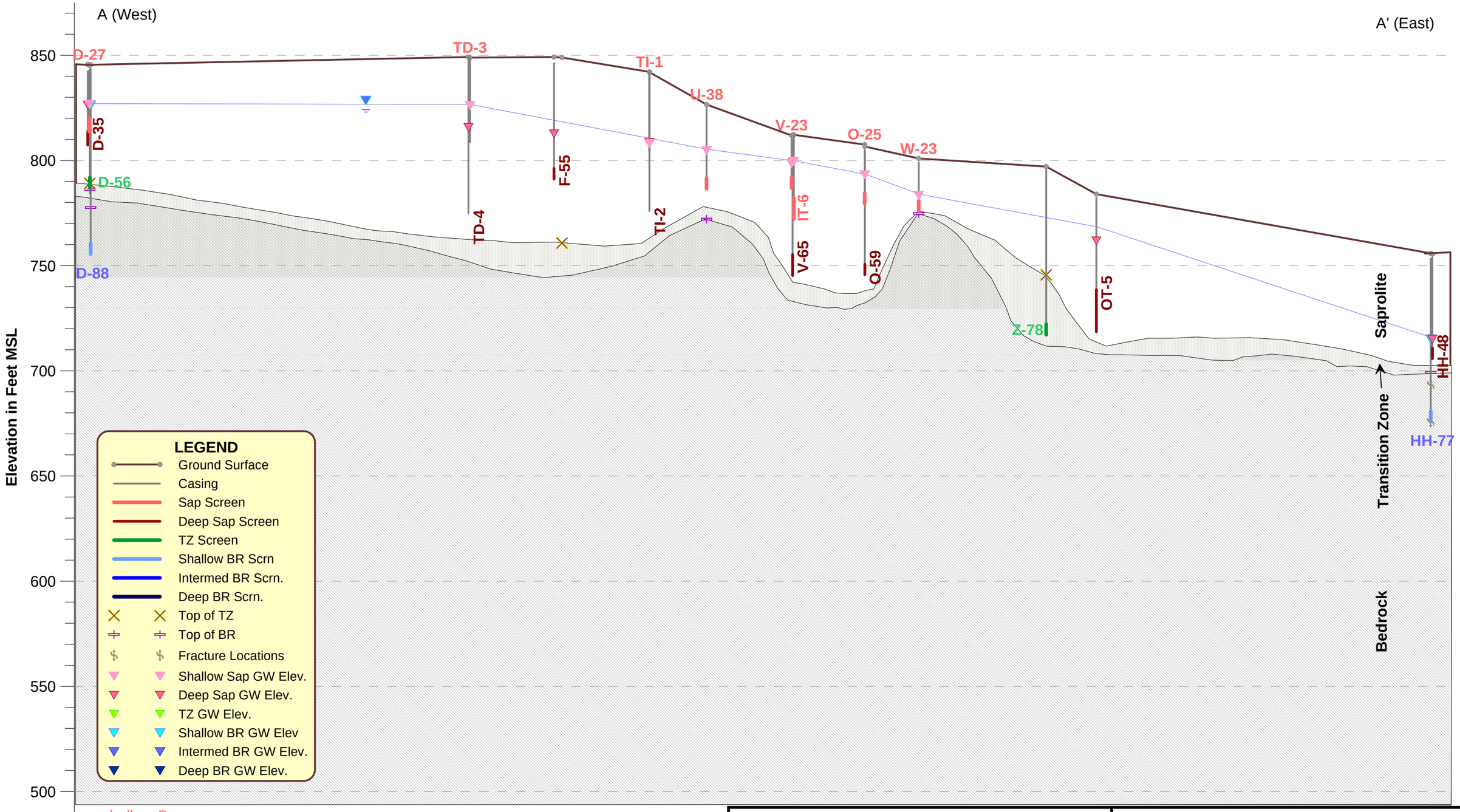
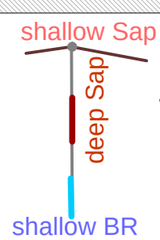
FIGURE 6
HYDROGEOLOGICAL CROSS SECTION A-A'
JANUARY 2007
CNA Holdings, Inc./Ticona
Shelby, North Carolina

SEPTEMBER 2007

79750





Well ID placement

NOTES:

(1) Groundwater elevations measured in January 2007

(2) TD-3, TD-4, TI-1, and TI-2 well screen intervals not identified

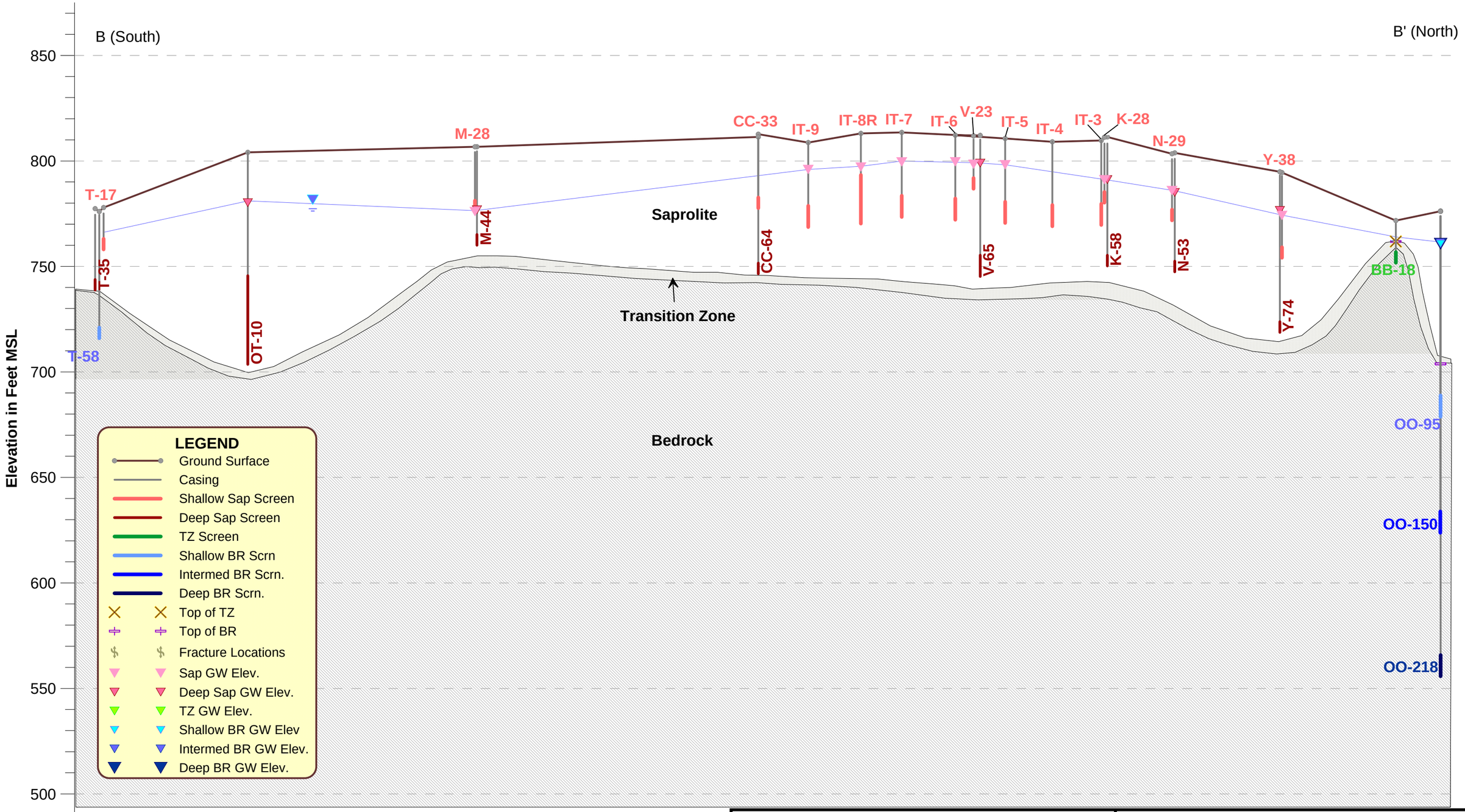
EARTH TECH

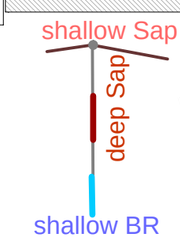
A tyco INTERNATIONAL LTD. COMPANY

FIGURE 4-2
CROSS SECTION A-A'

CNA Holdings, Inc./Ticona
Shelby, North Carolina

September 2007 79750





Well ID placement

NOTES:
(1) Groundwater Elevations measured in January 2007

EARTH TECH
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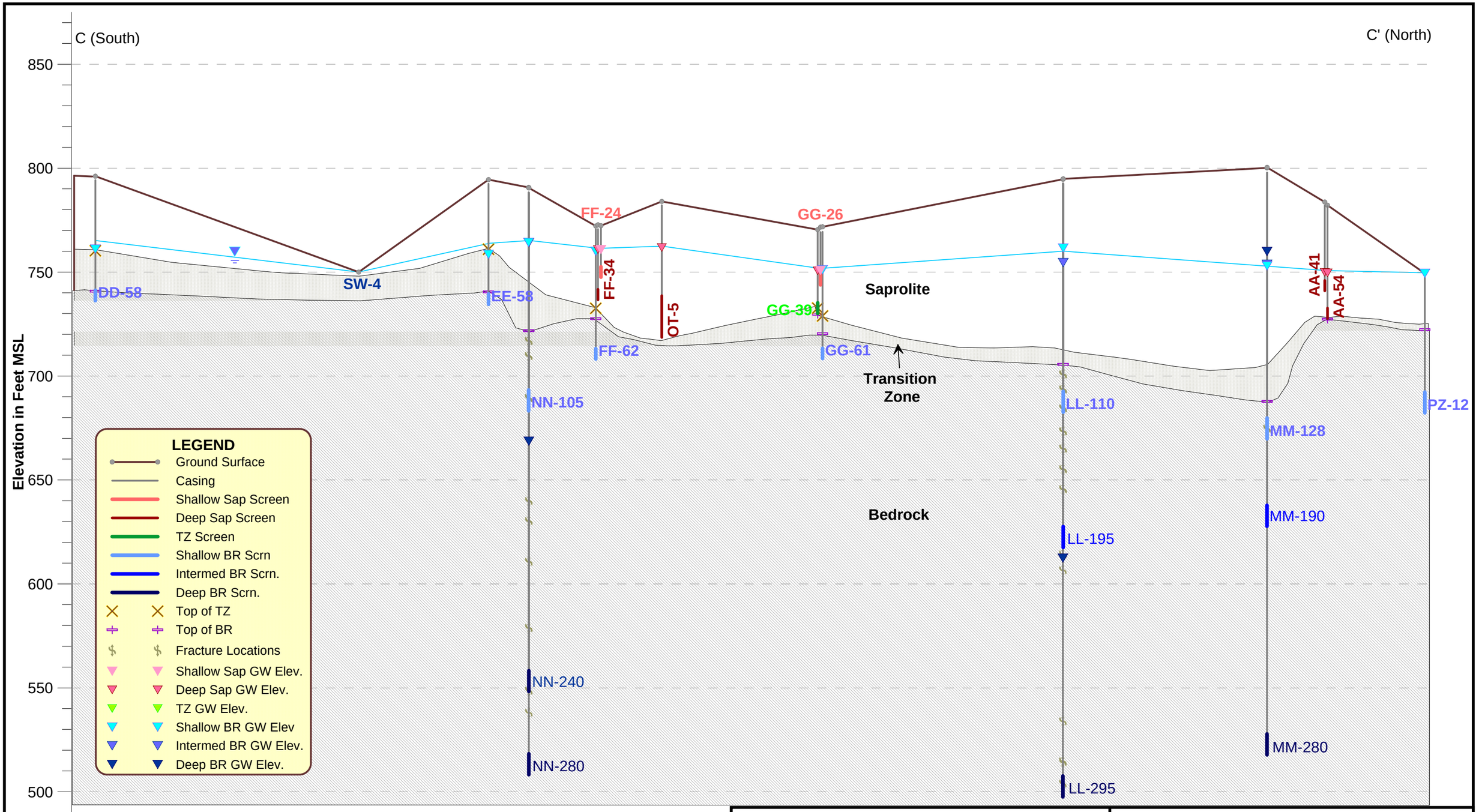
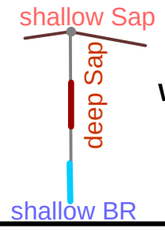
FIGURE 4-3
CROSS SECTION B-B'

CNA Holdings, Inc./Ticona
Shelby, North Carolina

September 2007 79750





Well ID placement

NOTES:
(1) Groundwater Elevations measured in January 2007

E A R T H T E C H
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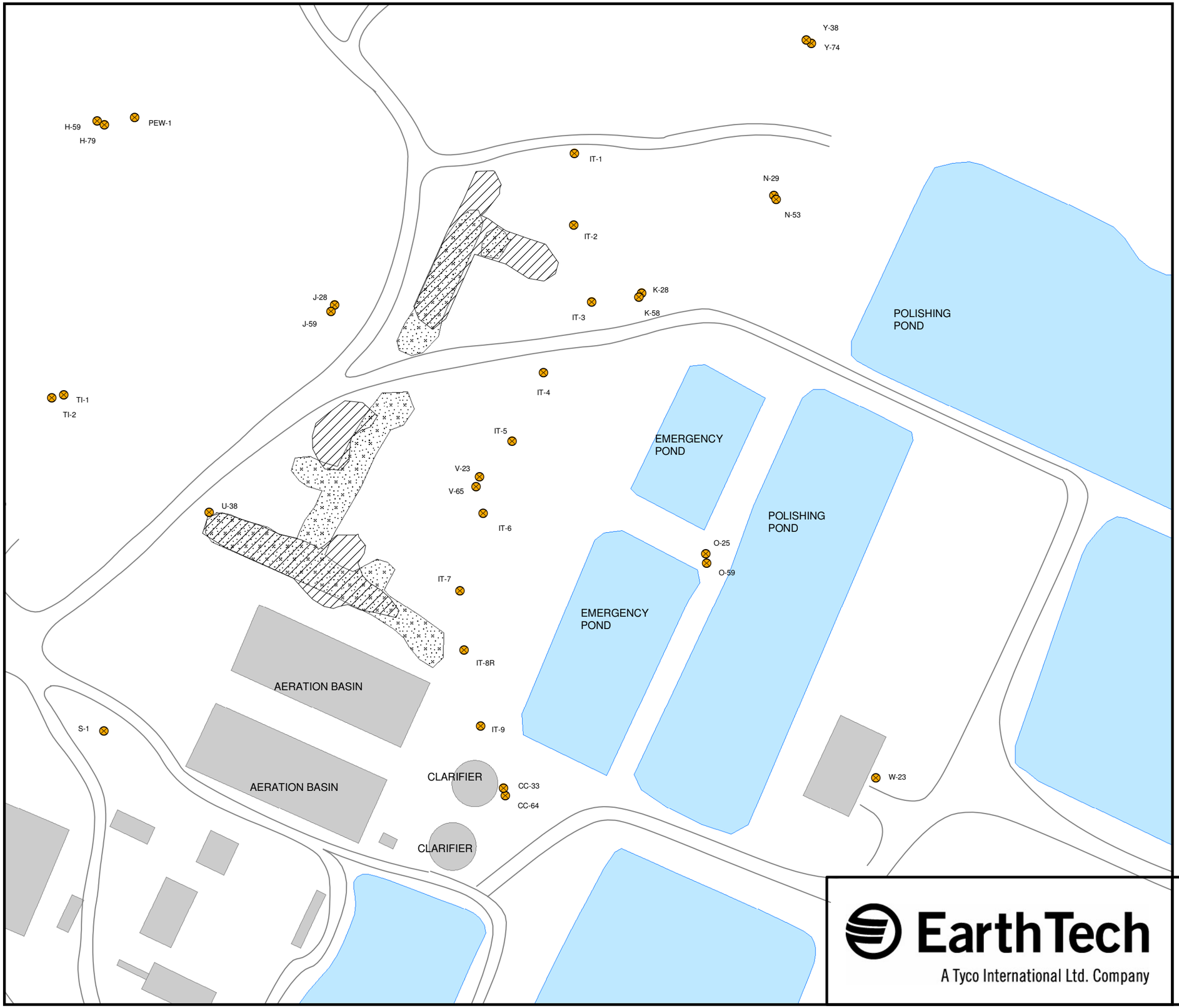
Figure 4-4
CROSS SECTION C-C'

CNA Holdings, Inc./Ticona
Shelby, North Carolina

September 2007 79750



Legend

- WELL LOCATION
- PROPERTY BOUNDARY
- OU1 BURN AREA
- OU1 GRUB AREA

N

100 50 0 100 Feet

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FIGURE 3-3
CONTAMINATION SOURCE LOCATIONS
AND OU-2 EXCAVATION EXTENT MAP

CNA Holdings, Inc./Ticona
Shelby, North Carolina

SEPTEMBER 2007

79750

Table 1
Quarterly Groundwater Sampling Plan - CERCLA Parameters
CNA Holdings/Ticona Facility - Shelby, North Carolina
Earth Tech Project No. 79750

	January 2007					April 2007					July 2007					October 2007				
	TOC	VOCs	SVOCs	Field Parameters[1]	QC Sample	TOC	VOCs	SVOCs	Field Parameters[1]	QC Sample	TOC	VOCs	SVOCs	Field Parameters[1]	QC Sample	TOC	VOCs	SVOCs	Field Parameters[1]	QC Sample
C-49		X		X								X		X						
F-55		X	X	X	MS/D			X		DUP		X	X	X				X		
J-29		X	X	X																
K-28	X	X		X	DUP	X			X		X	X		X	DUP	X			X	
P-58		X		X								X		X						
T-35		X		X								X		X						
V-23	X	X		X	DUP, MS/D	X			X		X	X		X		X			X	
AA-54		X		X								X		X						
CC-33		X		X								X		X						
EE-58		X		X								X		X						
FF-34		X		X								X		X						
FF-62		X		X								X		X						
GG-61		X		X								X		X						
HH-48		X		X	EB							X		X	EB					
HH-77		X		X								X		X						
TD-3		X		X			X		X			X		X			X		X	
TD-4		X		X			X		X			X		X			X		X	
PEW-1		X	X	X				X				X	X	X	MS/D			X		
PEW-3		X	X	X	FB			X				X	X	X				X		
PEW-4		X	X	X				X				X	X	X				X		
ITCI	Inner Tier Shut Off					Inner Tier Shut Off					Inner Tier Shut Off					Inner Tier Shut Off				
ITEF	Inner Tier Shut Off					Inner Tier Shut Off					Inner Tier Shut Off					Inner Tier Shut Off				
OTCI	Outer Tier Shut Off					Outer Tier Shut Off					Outer Tier Shut Off					Outer Tier Shut Off				
OTEF	Outer Tier Shut Off					Outer Tier Shut Off					Outer Tier Shut Off					Outer Tier Shut Off				

[1] - Field Parameters - depth to groundwater, dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperature, turbidity

TOC - total organic carbon
VOCs - volatile organic compounds
SVOCs - semi-volatile organic compounds
QC - quality control
DUP - duplicate
EB - equipment blank
FB - field blank
MS/D - matrixspike/matrix spike duplicate

Table 2
Quarterly Groundwater Sampling Plan - MNA Parameters
CNA Holdings/Ticona Facility - Shelby, North Carolina
Earth Tech Project No. 79750

	January 2007					April 2007					July 2007					October 2007				
	TOC	Ethylene Glycol	MNA Parameters[1]	Field Parameters[2]	QC Sample	TOC	Ethylene Glycol	MNA Parameters[1]	Field Parameters[2]	QC Sample	TOC	Ethylene Glycol	MNA Parameters[1]	Field Parameters[2]	QC Sample	TOC	Ethylene Glycol	MNA Parameters[1]	Field Parameters[2]	QC Sample
IT-1	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
IT-2	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
IT-3	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
IT-4	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
IT-5	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
IT-6	X	X	X	X		X	X	X	X		X	X	X	X	DUP	X	X	X	X	
IT-7	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
IT-8R	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
IT-9	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
F-55	X	X	X	X		X	X	X	X	DUP	X	X	X	X		X	X	X	X	
G-50	X	X	X	X							X	X	X	X						
G-88	X	X	X	X							X	X	X	X						
J-29	X	X	X	X		X	X	X	X	DUP	X	X	X	X	MS/D	X	X	X	X	
K-28		X	X	X		X	X	X	X	DUP		X	X	X		X	X	X	X	
N-29	X	X	X	X		X	X		X		X	X	X	X		X	X		X	
O-25	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
Q-33	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
S-1	X	X		X							X	X		X						
TI-1	X	X	X	X		X	X	X	X		X	X	X	X	FB	X	X	X	X	
TI-2	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
U-38	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
V-23		X	X	X	DUP	X	X	X	X			X	X	X		X	X	X	X	
V-65	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
W-23	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
X-32		X		X		X	X	X	X			X		X		X	X	X	X	
CC-33	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
ITCI	Inner Tier Shut Off					Inner Tier Shut Off					Inner Tier Shut Off					Inner Tier Shut Off				
ITEF	Inner Tier Shut Off					Inner Tier Shut Off					Inner Tier Shut Off					Inner Tier Shut Off				
OTCI	Outer Tier Shut Off					Outer Tier Shut Off					Outer Tier Shut Off					Outer Tier Shut Off				
OTEF	Outer Tier Shut Off					Outer Tier Shut Off					Outer Tier Shut Off					Outer Tier Shut Off				

[1] - MNA Parameters - methane, total iron, total manganese, total alkalinity, nitrate-nitrogen, sulfate, ethyl alcohol, acetate

[2] - Field Parameters - depth to groundwater, dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperaturte, turbidity

TOC - total organic carbon
QC - quality control
DUP - duplicate
FB - field blank
MS/D - matrixspike/matrix spike duplicate