

**REVISED COMPREHENSIVE CORRECTIVE ACTION PLAN
ADDRESSING THE SOLVENT RELEASE FROM THE
EGYPTIAN LACQUER MANUFACTURING COMPANY IN
FRANKLIN, TENNESSEE**

TriAD Project Number 07-ELM01-01

Prepared for:

**EGYPTIAN LACQUER MANUFACTURING COMPANY
113 FORT GRANGER DRIVE
FRANKLIN, TENNESSEE 37064**

Prepared by:

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JUNE 23, 2008

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1.0 INTRODUCTION

On behalf of the Egyptian Lacquer Manufacturing Company (“ELMCO”), and through its attorneys Stites & Harbison PLLC, this *Revised Comprehensive Corrective Action Plan* (“RCCAP”) has been prepared by TriAD Environmental Consultants, Inc. (“TriAD”) to address an accidental release of volatile organic solvents that occurred at the ELMCO manufacturing facility located at 113 Fort Granger Drive (the “Site”). More specifically, this RCCAP has been developed to address the contaminated soils and groundwater that remain at and around the Site as a result of a 2007-discovered solvent release from leaking underground pipes that transferred solvents from an aboveground Tank Farm to the manufacturing building at the Site. While the solvent release was immediately stopped upon its discovery in February 2007, and the underground pipelines have since been decommissioned and partly removed, and the aboveground tanks completely removed, the solvents that had been released continue to migrate with groundwater toward and into nearby streams.

ELMCO began voluntarily working with TDEC (through the State Remediation Program within its Division of Solid Waste Management) in early February 2007 to investigate the source of aromatic and ketone solvents that had been found discharging into Liberty Creek and the Harpeth River west and south of the Site, respectively. After discovering on March 2, 2007, that unprotected subsurface elbows in the underground piping on the west side of the former Tank Farm had corroded and leaked, ELMCO promptly assumed responsibility for both investigating and remediating that solvent release source area and for the response actions that TDEC had initiated to manage the solvent releases into the Harpeth River and, especially, Liberty Creek. On June 1, 2007, ELMCO entered into a Consent Agreement and Order (the “Order”, Case No. 07-R0134) with TDEC to address the release. The Order required ELMCO to prepare and submit to TDEC corrective action plans to address the contaminated source area soils, the contaminated groundwater, and contaminated soils that TDEC contractors had stockpiled during their initial efforts to excavate and interceptor trench near Liberty Creek. In compliance with the Order, ELMCO developed and submitted the required

corrective action plans and, following or in advance of TDEC approval, implemented them. Of necessity, the corrective action plans have involved additional investigations and monitoring, and these efforts have generated further information concerning the nature, extent, and effects of the contaminants in soil, groundwater, and air which must be factored into the corrective action efforts.

The most substantive work plan prepared and submitted by ELMCO pursuant to the Order was the *Groundwater Corrective Action Plan* (“GCAP”), dated August 28, 2007. Following extensive public review and comment, TDEC issued on November 20, 2007, a Notice of Deficiency (“NOD”) to ELMCO that identified several deficiencies in the GCAP and the course of action that ELMCO must take to correct those deficiencies. Pursuant to that NOD, ELMCO submitted to TDEC an air monitoring plan (prepared by EnSafe and dated December 14, 2007) to evaluate the contaminant levels in ambient air to which the persons living, working, or otherwise occupying structures near the solvent seep discharges into Liberty Creek and the Harpeth River might have long-term exposure. Also pursuant to the NOD, ELMCO submitted to TDEC an Investigative Workplan (prepared by TriAD and dated December 20, 2007) that described (1) additional groundwater investigations to further delineate groundwater contamination, (2) confirmation subsurface soil sampling in the known source area at the south end of the former Tank Farm to determine the effectiveness of previous *in situ* soil treatment, (3) confirmation subsurface soil sampling under the former Tank Farm to determine the presence or absence of additional soil source areas, and (4) further site characterization to demonstrate that natural attenuation processes are occurring as suggested in the GCAP. While implementation of both of these work plans was delayed by property access issues, both were subsequently implemented. ELMCO’s implementation of items (1) and (4) from the December 20, 2007, Investigative Workplan was reported in TriAD’s March 25, 2008, letter “Report of Additional Solvent Release Investigations”. Then, following the April 2008 removal of the solvents and aboveground tanks that were in the Tank Farm, ELMCO implemented the efforts described in items (2) and (3) above. The performance and results of these confirmation subsurface soil investigations were

reported in two TriAD letter reports – an initial report dated May 30, 2008, and a final report dated June 10, 2008.

The NOD also required ELMCO to submit “a revised Corrective Action Plan” to TDEC within 30 days from the submittal date of the “Site Investigation Report” that reported the results from implementation of the Investigative Workplan. This due date was interpreted to be April 24, 2008, 30 days from the March 25, 2008 letter “Report of Additional Solvent Release Investigations”. However, ELMCO requested – in an April 23, 2008, letter from Stites & Harbison PLLC – that the due date for the revised CAP be extended until June 23, 2008. This request was verbally granted on April 24, 2008, and the schedule extension was documented in a May 7, 2008, letter from TDEC to Stites & Harbison PLLC.

Pursuant to the November 20, 2007, NOD, the revised CAP was to include the following items: (1) Corrective Measures Study, (2) Proposed remedy, (3) Time line for site remediation, (4) Contingency provisions, and (5) Long-term groundwater monitoring plan. In Stites & Harbison’s April 23, 2008, letter, ELMCO requested the 60-day extension to try to ensure time to:

1. Address not only the contaminated groundwater but also any remaining contaminated soils in the source area at the former Tank Farm, the operation and ultimate closure of the Interceptor Trench near Liberty Creek, the management of the piles of excavated soil and rock that are staged south of (and originate from) the Interceptor Trench, and any residual soil contamination that exists in the soils in the Liberty Creek floodplain area – It was particularly noted that the confirmation subsurface soil investigations in the treated source area and under the Tank Farm were scheduled for May 2008.

2. Include a more thorough assessment of the risks to which persons may be exposed to the contaminated soil, groundwater, and surface water, and especially to

breathable vapors that may be created from such contaminated soil and water – It was noted that the risks have to be clearly identified because the purpose of corrective action is to ameliorate such risks. It was also noted that the long-term air monitoring plan that had just been implemented was going to collect some key information in this area.

3. Allow for a more thorough assessment of the groundwater monitoring and other data that had been collected and reported in the March 25, 2008, letter “Report of Additional Solvent Release Investigations” – It was also noted that the quarterly groundwater monitoring that was scheduled for May 2008 would provide valuable additional information to be factored into the planned risk assessment and corrective action planning efforts.

4. Consider in the corrective action planning effort the improved access to the interceptor trench and soil pile area to be provided by the culvert crossing of Liberty Creek that TDEC was planning to install.

Subsequent discussions with TDEC officials also convinced ELMCO that a formal assessment of both human health and ecological risks needed to be performed and the results factored into the corrective action planning effort.

It is important to remember that this RCCAP is based on available data and related assumptions. As described in Section 4.0, there are data gaps and investigative efforts that have yet to be accomplished. Also, as described in Sections 8.0 and 9.0, some additional data-gathering steps and/or pilot tests are needed to “flesh out” the recommended corrective measures. Further, it is possible that the routine, ongoing groundwater, seep/surface water, and air monitoring efforts may provide results that will require a change in these planned corrective actions.

2.0 BACKGROUND

The “regulatory” background for ELMCO’s solvent release response is described in Section 1.0. The following sections provide a more physical description of the Site setting, geology, and the release of solvent from the underground pipes at the former tank farm.

2.1 Site Setting

The ELMCO facility, located at 113 Fort Granger Drive in Franklin, Tennessee, is a manufacturer of specialty paints and lacquers, primarily for the pencil industry. These paints and lacquers must be very fast drying to meet industry requirements, and solvent-based paints have been, and still are, the primary means of meeting the fast-drying standards. Since the beginning of operations at their current location in 1978, ELMCO has used a variety of VOC solvents in their manufactured paints and lacquers. These solvents were principally stored in twelve aboveground storage tanks located in the western portion of ELMCO’s property. The twelve tanks, which were removed from the Site in April 2008, were placed on a concrete pad and surrounded by low, concrete-block secondary containment walls. The tanks were connected to the manufacturing building via twelve underground pipelines, which were abandoned and partially removed in February and March 2007. The tank farm was located approximately 350 feet west of the building, at an elevation of approximately 665 feet above mean sea level (MSL). A Site Map, showing the location of the former tank farm, the manufacturing building, and other area features, is presented as Figure 1. [Note: This map identifies the “Site” as the larger area impacted by the solvent release rather than as simply the ELMCO facility.]

For the purposes of this CAP, the geographic features of the land south (to the Harpeth River) and west-northwest (to Liberty Creek) are important. The locations of these features are shown on Figure 1. The topographic relationships between these features are shown on Figures 2 and 3, which are TriAD-generated west-to-east and north-to-

south cross sections showing elevations of the ground surface and other relevant features.

Just west of the former ELMCO tank farm and down a short slope is an abandoned railroad spur siding and, just to its west, the main line of the CSX railroad, which serves downtown Franklin. The abandoned rail spur was owned partly by local landowners and partly by CSX. The CSX-owned portion of the right-of-way ends 140 feet from the former switch points. The railroad main line is approximately 175 feet west of the former tank farm and at about 645 feet above MSL (roughly 20 feet lower than the tank farm).

West of the railroad is found the residential development along Daniels Drive. The single-family homes and duplexes are arranged along both sides of the street and around the cul-de-sac that forms the southern end of Daniels Drive. The nearest residence to the tank farm (124 Daniels Drive) is located approximately 250 feet west. The elevation of Daniels Drive at its high point (near 120 Daniels Drive) is about 650 feet above MSL (roughly 15 feet lower than the former tank farm). The elevation of Daniels Drive at monitoring well MW-5, located at 110 Daniels Drive, and at the cul-de-sac is approximately 640 feet above MSL (roughly 25 feet lower than the former tank farm). The residences at the south end of Daniels Drive, nearest the Harpeth River, are at an elevation of about 630 feet above MSL, or roughly 35 feet lower than the former tank farm.

West of the Daniels Drive residential area, the land slopes down into the valley of Liberty Creek. The valley floor elevation is about 620 feet above MSL. Liberty Creek itself is approximately 750 feet west of the tank farm at an elevation of 611 feet above MSL (measured at the main seep described in Section 3, roughly 55 feet lower than the former tank farm).

To the west of Liberty Creek the land rises out of the creek valley to an elevation of about 635 feet above MSL. Battle Ground Academy Lower School (elementary) is located here, about 850 feet west of the tank farm.

At its nearest point to the tank farm, the Harpeth River is located about 340 feet south-southwest. At that point, the water-level elevation of the river (which varies significantly in response to rain events) has been measured at about 605 feet above MSL (roughly 50 feet lower than the tank farm).

Several underground utility lines serve the area. Water lines are located parallel to Fort Granger Drive and Daniels Drive, although they are not shown on the maps or cross sections included with the CAP. A private sewer line serving ELMCO and the property adjacent to the north runs parallel to and on the east side of the rail spur and CSX line. The private sewer line connects with the municipal sewer near the CSX railroad bridge over the Harpeth River. The private line is located roughly 6 feet underground and is not shown on the maps or cross sections included with this CAP. Municipal sanitary sewer lines are located along Daniels Drive, the Harpeth River, and Liberty Creek. These sewer lines are shown on Figure 1 and, in the case of the line along Liberty Creek, on Figure 2.

Land use in the vicinity of the Site is primarily light industrial and commercial east of the railroad, residential west of the railroad, and undeveloped park land south of the Harpeth River. Fort Granger Park, a municipal park incorporating a Civil War fort, is located adjacent to ELMCO on the south, on the higher ground between ELMCO and the Harpeth River.

2.2 Summary of Solvent Release

VOCs entered the groundwater at the Site as a result of a solvent release from the underground pipelines that connected the former above-ground tank farm to the

manufacturing building. The following subsections describe the solvent release and the physical properties of the principal chemicals of concern, toluene and acetone.

2.2.1 Release Mechanism

Following the discovery of VOCs in water and air samples collected at the Harpeth River and Liberty Creek, ELMCO had tightness testing performed on its underground solvent pipelines in February 2007. This testing detected a possible leak in the acetone line. A detailed investigation of the underground pipes was therefore performed in February and March 2007 by excavating and inspecting (visually and with an Organic Vapor Meter [OVM]) the piping near the tank farm and at nine test pits spaced at 30- to 40-foot intervals between the tank farm and the manufacturing building. As determined from this inspection of the excavated underground pipelines, the pipes were coated with plastic, their connections were wrapped in plastic, and were in excellent condition except at the 90-degree elbows below where the pipes exited the ground at the tank farm end (similar elbows at the building end of the lines were observed to be wrapped and in excellent condition). At the tank-farm pipe elbows all of the pipes were heavily corroded and two of the pipes, those carrying acetone and toluene, were obviously leaking. No quantitative integrity tests were performed on the elbows. High organic vapor readings were found in the soil surrounding the pipe elbows, and soil samples were collected from this area and analyzed for VOCs by US Environmental Protection Agency (EPA) SW846 Method 8260B. The samples were found to be heavily contaminated with VOCs.

In addition to the visual and OVM inspection of the underground pipelines performed by TriAD in March 2007, soil samples were collected from each of the nine test pits, including directly beneath the pipe elbows at the building end. In each test pit, a soil sample was collected from a depth greater than the piping, as close to under the piping as possible, and the collected samples were analyzed for VOCs using Method 8260B. None of these samples contained VOCs above laboratory detection limits, demonstrating that the underground pipelines were not a source of contamination

beyond the leaking elbows at the tank farm. Results of this investigation were reported in TriAD's April 11, 2007, letter "Data Report of Soil Investigation Results".

The discovery of the leaking acetone and toluene pipelines and the large concentrations of those VOCs in the soil samples collected near the leaks matched the principal constituents of water contamination previously documented at groundwater seeps and surface-water sampling points along Liberty Creek and the Harpeth River. It was therefore concluded that releases of solvents from the unprotected, corroded pipe elbows at the tank farm were directly related to the VOCs identified in local surface water. Chemical analysis of the soil and surface water identified toluene and acetone as the principal constituents, with other chemicals (e.g., methyl isobutyl ketone [MIBK], methyl ethyl ketone [MEK], naphthalene, trimethylbenzene, ethylbenzene, xylenes) in minor amounts.

No evidence of other release mechanisms at the ELMCO facility has been found, although such cannot be ruled out with certainty. In October 2006, prior to TriAD's involvement and before the discovery of VOC contamination in Liberty Creek and the Harpeth River, a Phase II environmental site assessment was performed at ELMCO as part of a property transfer due diligence investigation. This investigation, performed by August Mack Environmental of Indianapolis, Indiana, consisted of subsurface soil sampling via 12 soil borings advanced by Geoprobe in several areas of the Site. (A copy of the Phase II report, dated November 2, 2006, was submitted previously to TDEC.) This investigation found significant VOC concentrations only in one soil boring drilled just west of the tank farm in a shallow drainageway (just downgradient of the later-discovered leaking pipe elbows). Although other soil samples collected from other borings contained trace concentrations of VOCs (i.e., less than 0.5 mg/kg total VOCs), the investigation found no evidence of any other release of sufficient quantity to justify further investigation. It is ELMCO's and TriAD's understanding that TDEC has concluded, based on this investigation and TriAD's subsequent efforts, that no further investigations for contaminant releases at the Site are needed.

Prior to ELMCO's ownership of the property, two underground storage tanks were located in the area near the north side of the building. One tank was reportedly used for heating oil (8,500 gallons), one for gasoline (6,500 gallons). The heating oil tank was removed in November 1997, and soil samples collected from the tank pit at that time showed no detectable concentrations of total petroleum hydrocarbons – diesel range organics. A closure report was submitted to TDEC. The gasoline tank was converted by ELMCO to use for process cooling water and is still in place and used for that purpose.

2.2.2 Elimination of Release Mechanism

In February 2007, the solvent pipelines were permanently disconnected from the tank farm by severing the connection from the piping to the tanks at the tank-farm end. In March 2007, the pipes were further separated from the tanks by removing approximately 50 feet of each line from the ground at the tank-farm end. During these operations, the pipes were purged of solvent by vacuuming, nitrogen purging, and water purging. All purged solvent and water was contained and subsequently disposed of off-Site as manifested hazardous waste. Therefore, the source of the solvent release was eliminated as of February and March 2007.

In April 2008, in accordance with TriAD's December 20, 2007, *Investigative Workplan*, the aboveground tanks and remaining aboveground piping were decontaminated, demolished, and removed from the Site. All decontamination fluids were contained and subsequently disposed of off-Site as manifested hazardous waste.

2.2.3 Volume of Release

The volume of solvent released cannot be accurately determined for the following reasons:

- 1) Inventory controls were inadequate to detect a slow release over time. The solvent tanks were vented to the atmosphere, causing some evaporative loss of

the highly volatile solvent compounds. Because the rate of volatilization is dependent on several atmospheric conditions, including temperature and humidity, only very rough estimates can be made regarding atmospheric losses (which were reported to regulatory agencies as required by the facility's air permits). Further, the volume of solvent in each tank was measured using a calibrated stick, with measurements to the nearest inch. Because the liquid expands and contracts with temperature, calculations of tank volumes were necessarily estimates. Resolving differences between volumes purchased, volumes used in manufacturing, volumes estimated lost through volatilization, and volumes measured in the tanks is problematic and does not have the accuracy needed to detect small losses over time.

- 2) The timing of the release is unknown. All that can be established is that the pipe elbows at the tank farm end were corroded and leaking when they were inspected in March 2007. There are no federal or state regulatory requirements for routine underground pipeline tightness testing. Therefore, no testing had been performed on the pipelines between their installation in 1978 and 2007.
- 3) No estimate of the rate of leakage from the pipe elbows can be made. The solvent in the pipes was not under constant pressure, so no accurate calculation can be made of how fast solvent could be "pushed" out of whatever size holes were found in the pipes. The solvent lines were used only occasionally as ELMCO personnel needed solvent for a particular batch of paint or lacquer. When not in use, the solvent pumps were turned off and the pressure on the lines was released. Therefore, any leaks from holes at the pipe elbows would have occurred at variable rates entirely dependent on the pressurization and depressurization of the pipes and the hydrostatic pressure surrounding the pipes.

To produce an estimate of the dissolved contaminant mass in the affected area as of February 2008, the then most recent contaminant distribution, a potentiometric map, and estimated porosities were used. The methodology and results are described in

detail in the *Report of Additional Solvent Release Investigations*, dated March 25, 2008. The resulting total dissolved contaminant masses of the principal constituents were:

Toluene	1,857 pounds (255 gallons)
Acetone	4,767 pounds (726 gallons)

These rough estimates do not include the toluene free product or other VOCs that occur in dissolved phase throughout the plume. The toluene and acetone account for the overwhelming majority of contaminants and are the principal target of any remedial activities performed at the site. Estimates of free-product toluene would be dependent on understanding the specific geometry of the conduits and fractures that allow accumulation of product on a free surface – geometry that is unknown. Further, recent groundwater sampling and work at the interceptor trench near Liberty Creek have failed to find evidence of free product.

An estimate of the contaminant mass in soil at the source area (former tank farm) was calculated based on data collected from Geoprobe investigations of the source area performed in March 2007 and May 2008. Cross sections of the impacted soil are presented as Figures 4 and 5. These calculations resulted in the following estimates of contaminant mass of the two principal constituents:

Toluene	1,234 pounds (170 gallons)
Acetone	21,840 pounds (3,330 gallons)

Combining the totals from the aquifer and from the source area soils yields a mass of 3,091 pounds (425 gallons) of toluene and 26,607 pounds (4,056 gallons) of acetone remaining in the subsurface.

2.2.4 Constituents of Concern

As previously noted in this and other reports, toluene and acetone are by far the most prevalent constituents in the contaminant plume. However, they are not the only constituents. Other constituents detected at the Site, in soil, surface water, and groundwater samples include:

- Benzene
- Di-isopropyl ether
- Ethylbenzene
- Isopropylbenzene (cumene)
- Isopropyl alcohol
- Methyl ethyl ketone (MEK)
- Methyl isobutyl ketone (MIBK, 4-methyl-2-pentanone))
- n-Propylbenzene
- 1,2,3-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- Xylenes
- cis-1,2-Dichloroethane
- Tetrachloroethene
- Methylene chloride
- Naphthalene
- 1-Methylnaphthalene
- 2-Methylnaphthalene

Although detected in samples from time to time, most of these ancillary compounds have been detected sporadically. Some (e.g., naphthalene) have been detected in one medium (e.g., soil) and not in others. Some (e.g., cis-1,2-dichloroethane and tetrachloroethene) were detected only once. The methylnaphthalenes (the only semi-volatile organic compounds on the list), which were detected at trace levels in some

groundwater samples, may represent naturally occurring compounds (bedrock formations in the area are known to be minimally petroliferous, i.e., containing small amounts of petroleum).

The source of most of the listed VOCs could be attributed to the variety of solvents stored at the tank farm at ELMCO over the years. ELMCO used not only toluene and acetone but also blended solvents consisting of several different volatile organics. Over time, different tanks held different products. Although ELMCO specifically and deliberately did not use solvents containing chlorinated compounds or benzene (based on the manufacturer's material safety data sheet), benzene is a common contaminant in shipments of toluene and may have entered the solvent stock without ELMCO's knowledge. Where benzene and toluene are detected together at the Site, benzene is typically present at a concentration of 1 percent or less of the toluene concentration, which would be consistent with the possibility that benzene is a contaminant of the toluene used by ELMCO.

Regardless of the origin of any individual compound, the principal chemicals of concern at and in the vicinity of the Site are toluene and acetone. Any consideration of corrective action must therefore focus on these two VOCs. Other solvent constituents, present in minor concentrations, are also VOCs and it may be presumed that any remedial action taken to address the toluene and acetone will also remediate these associated VOCs.

Toluene is a highly volatile organic compound that is largely insoluble in water. Its water solubility at room temperature is about 535 mg/L. The vapor density of toluene is 3.14, or roughly three times heavier than air. The half-life of toluene in surface water at 25° C is reported to be approximately 2.9 to 5.7 hours (EPA Technical Fact Sheet on: Toluene).

Acetone is a volatile organic compound that is completely soluble in water (water solubility is infinite). The vapor density of acetone is 2.0, or roughly two times heavier than air. The half-life of acetone in surface water at 25° C is reported to be approximately 20 hours (Department of Energy Risk Assessment Information System). Acetone in water in high concentrations may act as a solvent for the toluene, slightly increasing the solubility of toluene.

Neither acetone nor toluene is considered a human carcinogen. In fact, both are considered to be of relatively low toxicity, although toluene is more toxic than acetone. US EPA has recently established revised risk-based exposure concentrations for human populations (Regional Screening Levels [RSLs], May 2008). These RSLs are used by TDEC in screening sites for contamination. The acetone RSL for tap water is 22 mg/L. US EPA has not set a drinking water maximum contaminant level (MCL) for acetone. The toluene RSL for tap water is 2.3 mg/L, with an MCL of 1.0 mg/L.

Benzene is the only human carcinogen that has been consistently detected in water samples from the Site (it has not been detected in soil or air samples at concentrations exceeding detection limits for those media). Benzene's vapor density is 2.8, or heavier than air. The half-life of benzene in flowing surface water is reported to be 2.7 hrs at 20° C (U.S. EPA Technical Fact Sheet on: Benzene). The benzene RSL for tap water is 0.00041 mg/L, with an MCL of 0.005 mg/L.

2.3 Site Geology and Hydrogeology

Based on a review of the published geologic map of the Franklin quadrangle (Geologic Map of the Franklin, Tennessee Quadrangle, Tennessee Division of Geology, 1963) and on data collected during the soil and groundwater investigations at the Site, the following description of Site geology has been assembled. Geologic information is presented on the cross sections in Figures 2 and 3.

Overburden at the Site consists of residual silty, sandy clay derived from weathering of the underlying bedrock. Layers of higher sand or clay content reflect lithologic differences in the bedrock parent material. The overburden ranges from 10 to 35 feet thick at the ELMCO facility, and may be completely absent in areas along the Harpeth River and Liberty Creek, which flow on or near bedrock. Drilling at the ELMCO facility has shown there is no significant groundwater in the overburden; where it occurs at all, groundwater in the overburden is limited to a thin zone at the top of rock, predominantly in bedrock depressions or “cutters.”

The uppermost bedrock unit at the ELMCO facility is the Bigby-Cannon Limestone, particularly the Bigby facies, which is the lowest facies in the formation. The Bigby ranges from 5 to 40 feet thick at ELMCO, thickening to the east. To the west, the Bigby thins gradually, disappearing completely in the valley of Liberty Creek. To the south, the Bigby does not thin, but ends in bluffs along the Harpeth River. The Bigby is a coarse-grained, cross-bedded phosphatic limestone that weathers into an irregular surface known as “cutter and pinnacle” topography. Cutters are linear depressions in the surface of the bedrock, formed by weathering along fractures. Because it readily forms solution features, the Bigby-Cannon Limestone is generally considered a good water-producer, although no water has been encountered in the Bigby at ELMCO, other than minor perched zones at the top of rock.

Beneath the Bigby-Cannon, at a mapped elevation of approximately 630 feet above MSL, is the Hermitage Formation. The Hermitage is a shaly limestone less prone to solution development than the Bigby-Cannon, and as a result is a poor water producer. Boreholes drilled at ELMCO have encountered water flowing along bedding planes in the Hermitage, but there is generally little water, and monitoring wells set in the formation are very low yielding. Liberty Creek and the Harpeth River both flow on the Hermitage.

Based on the geologic map, the limestone formations in the vicinity of the Site dip slightly to the southwest, which is expected based on the Site's position in the southern portion of the Nashville Dome, a broad regional uplift. Examination of the bedrock outcrop along the Harpeth River south of ELMCO indicates a slight dip to the northwest, with a strike to the northeast. While some local variation in dip is likely, the overall degree of dip is low, with near-horizontal conditions predominating.

The bedrock surface at and in the vicinity of the Site is irregular. Data from Geoprobe and air-rotary drilling at ELMCO have indicated a cutter located near the south side of the tank farm that trends east-west, sloping to the west-northwest. The upper bedrock within the cutter is heavily weathered, while the bedrock surface outside of the cutter has exhibited only minor weathering. The position and orientation of bedrock surface irregularities, including cutters, are controlled by fractures. Fractures in the Site vicinity can be observed at small scale in the outcrops of bedrock along the Harpeth River, in the orientation of the bedrock cutter near the former tank farm, and in the orientation of segments of streams, including the Harpeth River. Indeed, the north-northwest orientation of the segment of the Harpeth River nearest the Site roughly mimics the inferred trend of the cutter and fracture system which apparently directs flow of contaminants from ELMCO to Liberty Creek.

Groundwater flow at the Site is primarily through weathered and fractured zones in the top of rock (particularly in the cutter near the tank farm) and through fractures and/or bedding planes (likely enlarged by weathering) in the bedrock. Hydraulic conductivities in the bedrock aquifer have been estimated using data collected from single-well slug tests as described in the *Report of Additional Solvent Release Investigations* (March 25, 2008). These estimates ranged from 6.4×10^{-7} ft/sec at MW-3 to 4.8×10^{-3} ft/sec at MW-1.

A potentiometric map generated from water-level data collected during June 2008 is presented as Figure 6. As shown on the map, water levels are highest in the area near

the solvent release point, which is near the eastern end of a cutter/weathered bedrock feature in which the major portion of the contaminant plume is migrating to Liberty Creek. From this high point, groundwater moves to the west through the soil and fractured rock of the cutter as well as outward in all directions into the bedrock aquifer, working its way along both bedding plane and vertical fractures, where the contaminant plume is dominated by dissolved phase VOCs. Free product solvent has previously been identified in well MW-3, demonstrating that some free product worked its way into fractures in the vicinity of the cutter. No free product has been observed in well MW-3 since it was removed by absorbent booms in March 2008. Well MW-2 is impacted by dissolved-phase contaminants, and February sampling data indicate dissolved-phase contaminants may be impacting MW-1 and MW-5. It is therefore apparent that the cutter is acting as a linear recharge zone for groundwater in the wider bedrock aquifer, which discharges into Liberty Creek and the Harpeth River.

Based on the estimated hydraulic conductivities and the hydraulic gradients shown on the potentiometric map, groundwater flow velocities at the Site are quite variable, ranging from 6×10^{-7} ft/sec to 1.2×10^{-2} ft/sec (roughly 0.05 ft/day to 1,000 ft/day). This wide range is typical of fracture and karst aquifers in which groundwater flow is dominated by secondary porosity. These values are averages and may not represent the maximum and minimum velocities that could be encountered at any given point in the aquifer. For example, the velocity calculated for the weathered rock and soil in the cutter does not account for the presence of fracture/conduit flow observed during construction of the interceptor trench. A more realistic approach would be to assume that the higher velocity calculated for the fractured bedrock (1.2×10^{-2} ft/sec) is also more representative of the faster velocities expected in the weathered rock/cutter zone. It is also important to note that although high velocities may be encountered at any given point, these points may or may not be interconnected in a continuous pathway between the source area and the creek or river that would allow such velocities to be maintained over the entire distance.

3.0 SUMMARY OF RESPONSE ACTIONS PERFORMED

A variety of actions have been taken by ELMCO to investigate and remediate the release of solvent constituents. The following sections describe the principal actions.

3.1 Solvent Capture at Liberty Creek

Beginning February 8, 2007, immediately upon discovery of free-product solvent (primarily toluene) entering Liberty Creek at the main seep, ELMCO responded with efforts to contain the product using absorbent booms and pads. The effort was then taken over by TDEC until March 2, 2007, when ELMCO resumed responsibility. During TDEC's operation, an attempt was made to dig an interception trench on the east side of Liberty Creek. Although this trench succeeded in recovering a small amount of free product, it was not effective at preventing product from entering the creek.

During the spring and summer of 2007, ELMCO's contractor, Ops Contracting Services (OCS) continued collecting free-product using absorbent booms and pads that were changed out as they became saturated with solvent, often on a daily basis. These efforts prevented free product or sheens from migrating down Liberty Creek to the Harpeth River, and continued until late summer 2007, after construction of the second interceptor trench. All recovered product was transported back to ELMCO for classification and then transported and disposed off-site as manifested hazardous waste.

A second interception/recovery trench was constructed in the valley of Liberty Creek during the period July 27 to August 24, 2007. The first trench, constructed under TDEC supervision, was backfilled and the second trench was excavated using trackhoe and hoe-ram equipment in the approximate location shown on Figure 1. A cross section of the trench is presented as Figure 7. The trench is approximately 140 feet long and ranges from approximately 11 to 17 feet deep. Its length and depth were designed to intercept the free-product flow that had been discharging into Liberty Creek. It was excavated into bedrock and, as shown on the cross section, a 1- to 5-foot thick layer of

weathered rock was encountered, thinning to the south. The bottom elevation of the trench ranges from about 611 feet above MSL at the north end to about 607 feet above MSL at the south end. As noted previously, the elevation of the Main Seep in Liberty Creek is approximately 611 feet above MSL, when the stream is flowing (which it was not doing during construction of the trench).

During trench construction, four locations were encountered where groundwater flowed into the excavation. At approximately 20 feet from the north end, a small flow of water entered the trench from the east side at an elevation of about 611 feet above MSL. This water, though apparently contaminated (based on PID and olfactory evidence), did not contain measurable free product. At approximately 87 and 89 feet from the north end, flows of water entered the trench from the east side at elevations of approximately 609 feet and 608 feet above MSL, respectively. Both flows of water were accompanied by free-product toluene. An additional flow of mixed water and free product was encountered at approximately 102 feet from the north end of the trench at an elevation of approximately 607 feet above MSL. No additional free product was encountered in the remaining 38 feet of trench.

As the water level rose in the trench (apparently because of semi-confined conditions in the water-bearing zones), the free-product flows were reduced or eliminated, as had happened at well RW-1 near the tank farm. To facilitate recovery of the free product, at least under the drought conditions experienced in August 2007, it was necessary to keep the water level artificially lowered in the section of trench into which the product could flow. For this reason, dams were constructed across the trench to the north and south of the three product seeps. These dams allowed water to be pumped from the product-generating middle section of the trench to either the northern or southern sections. This water was pumped via an intrinsically safe pump (to eliminate the danger of ignition of the free product toluene) and via a submerged inlet (to eliminate the risk of pumping product with the water). Absorbent booms were also used in the northern trench to capture any entrained free-phase product that might have been discharged.

The pumped water, which contained dissolved-phase acetone and toluene, was then allowed to infiltrate the ground through the sides and bottom of the north or south sections of the trench, to either continue on to Liberty Creek or to return to the central portion of the trench from where it could again be pumped. This intermittent pumping allowed the flow of free product into the trench, where it was separated from the water by means of absorbent booms. The booms were recovered and transported to an authorized hazardous waste management facility for reclamation.

Very soon after operation of the trench began there was a noticeable decrease in free product entering Liberty Creek. Small amounts of product or sheen were intermittently observed during the fall and early winter of 2007, with some occasionally being trapped on the absorbent booms that are, to the date of this report, being maintained in place around the main seep at Liberty Creek. By late winter and early spring of 2008, free product was no longer being observed or trapped in booms at Liberty Creek.

Operation of the trench continued through the fall of 2007. During the winter of 2008 access issues with the property owner arose that resulted in delays in trench operation, and increased rainfall caused significant water-level increases in the trench. Also during the winter, some slumping of the east wall of the central portion of the trench occurred in an area where free product had been observed entering the trench. As water levels declined and TDEC brought in their contractor, periodic trench pumping resumed in April 2008 and continued again with OCS when ELMCO made access arrangements with the property owners. It quickly became evident that the trench, at least with the slumped portion of the east wall, was not producing free product, nor was free product being observed in the creek. After several weeks of intermittent pumping, trench operations were suspended until repairs could be effected. A work plan for such repairs is described in Section 4 of this report. During the suspension of trench operations, crews continue to inspect the booms in place in Liberty Creek and to check for free product accumulation in the trench and creek.

Routine sampling of the groundwater entering the trench has not been performed. However, in November 2007 two samples were collected, one from the central portion and one from the northern portion. These samples showed 320 mg/L toluene and 540 mg/L acetone in the central trench, and 100 mg/L toluene and 240 mg/L acetone in the northern trench.

3.2 Soil Investigation and Remediation at ELMCO

Soil investigation has occurred in phases and has been reported by TriAD in the following documents:

Data Report of Soil Investigation Results, April 11, 2007 (initial tank farm Geoprobe and test pit investigation)

Initial report of Confirmation Soil Investigations Under Former Tank Farm and in BIOX Treatment Area at ELMCO Facility, May 30, 2008 (Geoprobe investigation with boring logs)

Final Report of Confirmation Soil Investigations Under Former Tank Farm and in BIOX Treatment Area at ELMCO Facility, June 10, 2008 (Geoprobe investigation with cross sections)

Additional information regarding soil investigation was presented in the *Groundwater Corrective Action Plan* dated August 28, 2007. Based on the 2007 investigation, which defined the extent of soil contamination at the ELMCO facility and confirmed that the leak from the underground pipe elbows at the Tank Farm was the source of the VOC impact to Liberty Creek, an in-situ soil remediation was designed and implemented. This treatment consisted of injection of a chemical oxidant and biological nutrients. In early June 2007, Geoprobe technology was used to inject into the contaminated soil column a liquid treatment reagent produced by BioManagement Services, Inc. Known as BIOX, the solution included solid peroxides, pH buffers, and nutrients to enhance biological activity. A total of 3,249 gallons of BIOX formulation was injected into the contaminated soil column through 33 injection points spaced roughly 4 feet apart. The injection was performed pursuant to a TDEC-issued Class V Injection permit. A report

of this remedial action was submitted to TDEC in the letter report *Source Area Soils CAP Implementation Report 1*, dated June 22, 2007.

The 2008 soil investigation was designed to achieve two goals; to determine whether soil under the tank farm concrete pad had been impacted by significant quantities of solvent, and to establish whether the BIOX treatment had been effective. The investigation under the tank pad could not be performed until the tanks had been removed, and TDEC approved a schedule of investigation that was linked to the tank removal, which was completed in April 2008. The May 2008 soil investigation revealed three significant findings:

- 1) Soil beneath the former tank farm pad was not significantly impacted by solvent constituents, with the exception of an area under the south edge of the pad, directly adjacent to the location of the leaking underground pipe elbows.
- 2) The BIOX treatment was not effective in significantly reducing the concentration of solvent constituents in the source area.
- 3) The remaining soil contamination in the source area is capable of leaching solvent constituents to site groundwater.

Figures 4 and 5 show toluene and acetone concentrations on cross sections drawn through the soil source area from east to west and north to south, respectively. These cross sections demonstrate that high concentrations of these solvent constituents are present in a soil column centered on the former location of the leaking underground pipe elbows. The contaminants apparently spread laterally as they migrated downward through the soil, then down the slope of the bedrock surface into the cutter that leads west-northwest from the source area.

3.3 Groundwater Investigations

As with the soil investigation, groundwater investigation has proceeded in phases, with reports in the following TriAD documents:

Summary of Phase I and II Groundwater Investigations, July 27, 2007 (Monitoring wells AR-1, RW-1, MW-1, MW-2, and MW-3)

Groundwater Corrective Action Plan, August 28, 2007

Report of Additional Solvent Release Investigations, March 25, 2008 (Monitoring wells MW-4 and MW-5 and February 2008 quarterly groundwater monitoring event)

Groundwater Monitoring Results – June 2008 Event, June 23, 2008 (summary of all groundwater analytical data to date)

The findings of the groundwater investigations relating to groundwater flow direction and rate have been summarized in Section 2.3 of this report, and in the Potentiometric Map (Figure 6). The extent of groundwater contamination as defined by the toluene concentration above drinking water standards (1.0 mg/L) is presented on Figure 8, Extent of Toluene in Groundwater. The map shows that the highest concentrations of solvent constituents are found in the area near the source and in the seeps along Liberty Creek and the Harpeth River. As expected from the data presented on the potentiometric map, the contaminants have migrated outward in all directions from the source area (south side of the former tank farm). It is also important to note that benzene has been detected above the drinking water standard in two perimeter monitoring wells, MW-1 and MW-5, indicating that the extent of groundwater impact may be somewhat greater to the north and east than that shown on Figure 8. TDEC has directed ELMCO to install additional groundwater monitoring wells to further define the extent of the plume to the north and east (see Section 4.2 for further details).

Table 1 presents a summary of the groundwater analytical results to date. Figure 9 contains a series of graphs showing total VOC concentration in groundwater over time at each groundwater monitoring well. From the table and graphs it can be seen that groundwater sampling data have shown significant declines in total VOC concentrations in MW-2, MW-3, AR-1, and RW-1 since the beginning of sampling. Acetone has virtually disappeared from MW-2, where it had been the dominant contaminant, with a concentration of 360 mg/L in June 2007. Toluene was the dominant contaminant in

MW-3, where it has declined from the saturation limit (free product) to 200 mg/L. Acetone and toluene are down significantly in AR-1 and RW-1 from the time these wells were installed. It is likely that additional analytical data will show some fluctuation in contaminant concentrations over time, as variables such as contaminant plume variations and water-level fluctuations interact to produce higher or lower concentrations at any given point.

Groundwater sampling data show increases in contaminant concentrations in wells MW-1 and MW-5. At MW-1, sampling data from 2007 showed no detectable concentrations of VOCs, while data from 2008 show low concentrations of several VOCs, including benzene and toluene. At MW-5, the two sampling events show a very slight increase in contaminant concentrations, with too few data to confirm the trend.

Two monitoring events at well MW-4, on the BGA property, have shown only toluene detected, both times at concentrations well below the drinking water standard. The analytical data from MW-4 demonstrate that the surface water in the lower reach of Liberty Creek is acting to block any significant contaminant flow further to the west.

3.4 Seep Monitoring

After initial sampling and analysis of samples from Liberty Creek in February 2007 by ELMCO and TDEC a routine seep monitoring program was established beginning in May 2007. Reports are submitted to TDEC on a monthly basis, the most recent being *Seep Monitoring Results – May 2008 Event*, May 23, 2008. This program includes the monthly sampling and analysis of the following locations, which are shown on Figure 1:

LC-PC (Liberty Creek Personnel Crossing)

LC-MS (Liberty Creek Main Seep)

HR-2 (Harpeth River Seep 2)

HR-3 (Harpeth River Seep 3)

In addition, a surface water sampling point was added in November 2007 at the watergate that spans Liberty Creek upstream of the main seep. Table 2 presents a summary of seep sampling results through May 2008. The seep sampling has shown significant reductions in contaminant concentrations since the beginning of monitoring, particularly at locations LC-MS and HR-2, the most contaminated of the seep monitoring locations. (Location LC-PC is in the main channel of Liberty Creek well downstream of the contaminant seep and samples from this point are therefore more affected by precipitation and creek water levels, making it a less reliable indicator of groundwater conditions.) At HR-2, where acetone is the dominant constituent, concentrations of acetone have been reduced from an average of 2,033 mg/L during May through August of 2007 to an average of 553 mg/L since that time. At LC-MS, where toluene is the dominant constituent, concentrations of toluene have been reduced from an average of 377 mg/L during May through August of 2007 to an average of 77 mg/L since that time. Further, free-product solvent has been dramatically reduced at LC-MS since construction of the interception trench in August 2007, being observed only sporadically and in small quantities through the fall and winter, and not at all since early spring 2008.

Although significant reductions in contaminant concentrations have been observed in the seep samples since late summer 2007, variation in seep sample results has been observed and is expected. There are many variables that contribute to these variations, including variations in contaminant concentrations throughout the plume (e.g., presence or absence of pockets of free product), precipitation amounts, creek and river water levels, and pumping of the interception trench.

3.5 Air Monitoring

Several phases and types of air monitoring have been performed at the site since early 2007. EnSafe has performed most of the air monitoring under direction of Mr. Bry Roberson, CIH, with one study performed inside BGA school by Mr. Greg Boothe of EHS Services. There was also some initial work performed by EnSafe as a contractor for TDEC, including real-time air monitoring of crawl spaces and basements of homes

along Daniels Drive in February 2007 using an OVM. In addition, TriAD performed daily, real-time monitoring of the area around Liberty Creek and along the Harpeth River using an OVM from March 5 to September 7, 2007. Each phase of air monitoring was performed in accordance with work plans and/or with coordination from TDEC. The following reports have been submitted to TDEC:

Results from Air Monitoring at Residences Near Liberty Creek in Franklin, Tennessee, EnSafe, April 30, 2007.

Updated Data from TriAD's Daily Air Monitoring Around Solvent Seeps into Liberty Creek, TriAD, May 4, 2007

Report on Air Monitoring Near Liberty Creek in Franklin, Tennessee, EnSafe, August 24, 2007.

Updated Table of TriAD Air Monitoring Results for Liberty Creek, email from Dwight Hinch of TriAD to Ashley Holt of TDEC, October 23, 2007.

Report on Supplemental Air Monitoring Near Liberty Creek in Franklin, Tennessee, EnSafe, December 19, 2007

Interim Report on Air Monitoring Near Liberty Creek in Franklin, Tennessee, EnSafe, June 23, 2008.

In the April 2007 monitoring event, air samples were collected and analyzed from the crawl space of 116 Daniels Drive, the basement of 127 Daniels Drive, and the basement of 131 Daniels Drive. The results indicated no vapor intrusion hazard from toluene, acetone, or isopropyl alcohol.

In a July and August 2007 monitoring event, time-integrated monitoring was performed at four locations surrounding Liberty Creek. During the August portion of this event, during which the interceptor trench was being excavated, toluene was detected at concentrations exceeding chronic and, at one sampling location, acute exposure concentrations. Because these results were thought to be skewed by the excavation work near the sampling points, the sampling event was repeated in December 2007, during which no measurable concentrations of acetone or toluene were detected.

Another time-integrated air study was performed, after delays caused by property access issues, over the period April 21 to May 19, 2008, at locations surrounding Liberty Creek and one location near the residence at 131 Daniels Drive. This study found no detectable concentrations of benzene, and concentrations of acetone and toluene were below chronic exposure concentrations at all but one point – the location southwest of the main seep – where the concentration over the four-week monitoring period averaged close to the chronic exposure level.

Time-integrated air monitoring is planned to continue at the locations surrounding Liberty Creek and near 131 Daniels Drive at regular intervals over the next year. A monitoring event is under way as of the date of this report.

Additional details regarding air monitoring results and their implications for human health are provided in Section 6.1 of this report.

4.0 DATA GAPS AND PENDING INVESTIGATIONS

As noted in Section 1.0, there are important data gaps as well as pending investigations that have been planned but are yet to be performed. The major known data gaps and pending investigations are described in this section.

4.1 Status of Free-Product Solvent Flow Toward Liberty Creek

As described in Section 3.1, the interception and capture of the free-product solvent flowing with groundwater along the east-west cutter from the soil source area at the southern end of the former Tank Farm at the ELMCO facility to the seeps into Liberty Creek was a major focus of response actions throughout 2007. In the wet winter months of early 2008, however, the flow of free-product into Liberty Creek and the Interceptor Trench dwindled to nothing, and could not be stimulated by the limited (twice per week) pumping of the Middle Trench Section allowed by ELMCO's access agreement with the property owners. It was not clear whether the free-product solvent flow stopped because the free-product solvent remaining in the hydrogeologic system

was insufficient to create such flow, or because wet weather conditions had created a temporary hydraulic barrier that could not be overcome by the limited pumping. It had become clear, however, that the determination as to whether substantive free-product solvent remained in the hydrogeologic “pipeline” between the source area and seeps was a critical factor in planning groundwater corrective actions.

With the onset of the warmer and drier weather in late spring and still no appearance of free-product solvent at the Trench or Liberty Creek seeps, ELMCO began to develop a plan to try to stimulate such flow. On behalf of ELMCO and through its attorneys Stites & Harbison PLLC, TriAD developed a letter “Plan for Additional Non-Routine Work at the Liberty Creek Interceptor Trench and Soil Pile Area”, dated May 20, 2008, which was submitted to both TDEC and the property owners (through their attorney). This plan described, among other things, a plan to try to stimulate free-product solvent flow by “cleaning out” (by excavation) the bottom of the Trench’s Middle Section and then aggressively pumping the water from it into the Trench’s Northern Section. In a June 12, 2008, letter from the property owners’ attorney to ELMCO’s attorney, property access to implement this plan was denied to ELMCO. ELMCO still considers this effort to be critical to the determination as to whether or not substantial free-product solvent might still be present in the hydrogeologic system, and intends to work with TDEC and the property owners to get it implemented.

4.2 Additional Assessment of the Lateral Extent of Groundwater Impacts

In response to ELMCO’s *Report of Additional Solvent Release Investigations*, prepared by TriAD and dated March 25, 2008, TDEC personnel have verbally advised ELMCO representatives that two additional groundwater monitoring wells are needed to adequately define the lateral extent of groundwater contamination. One well would be located east of the solvent release source area in the northeast corner of the ELMCO property on Fort Granger Drive, while the other would be located north and across Liberty Creek from well MW-5 on Daniels Drive. TDEC personnel suggested a specific property for the new northern well, and TriAD personnel have on behalf of ELMCO

contacted a representative of the property owner seeking permission to install and periodically sample a monitoring well. Despite repeated contacts, no approval or disapproval of ELMCO's request has as yet been rendered by the property owner. TDEC personnel have also contacted the property owner representative urging that the permission be granted, and a response is expected soon. Once successful access arrangements have been completed with this or another property owner in the area, TriAD will on behalf of ELMCO install, develop, and initiate monitoring of both of these planned new wells.

4.3 Liberty Creek Floodplain Soils

Field monitoring of organic vapors during the August 2007 excavation of the Interceptor Trench in the Liberty Creek floodplain east of Liberty Creek, as well as the results from TriAD's June 2007 collection and analysis of soil samples from the soil pile created by the TDEC contractor's efforts in February 2007, have shown that the overburden soils in a portion of the floodplain have apparently been impacted by ELMCO's solvent release. This includes much if not most of the soils removed during excavation of the Interceptor Trench, which were placed for storage and treatment in a shallow "Biopile" located south of the Trench between the Trench and the Harpeth River. It is believed that the soil contamination – which was observed to extend well above the bedrock, has resulted from "smearing" as free-product solvent and contaminated groundwater rose and fell with water levels in the floodplain soils. The nature and extent of this contamination in both excavated and unexcavated floodplain soils has as yet not been defined.

In the May 20, 2008, letter "Plan for Additional Non-Routine Work at the Liberty Creek Interceptor Trench and Soil Pile Area", TriAD proposed a plan for screening and testing the soils in the existing Biopile, and for reconfiguring the soils into a vegetated stockpile for relatively clean soils and a second Biopile for those soils (if any) where additional treatment by that method might be effective. Property access to implement this portion of that plan was also denied in the June 12, 2008, letter from the property owners'

attorney to ELMCO's attorney. TDEC personnel also disapproved this portion of the plan in a June 16, 2008 e-mail to TriAD personnel; however, it is believed that the technical regulatory concerns that TDEC personnel had with the Plan have been resolved. ELMCO intends to somewhat modify the plan and further work with TDEC and the property owners to gain the necessary approvals to implement it to provide the needed interim characterization of contaminant levels in these treated soils.

No plans have as yet been made to assess the nature and extent of solvent contamination in the unexcavated soils of the Liberty Creek floodplain, and it seems fruitless to do so while active remediation efforts (the trench and soil pile) continue in the area and until it has been determined that further free-product solvent flow is unlikely. However, ELMCO acknowledges the need to do so at an appropriate time in the future, and commits to working with TDEC and the property owners to develop and implement an acceptable plan for such soil characterization.

5.0 SITE CONCEPTUAL MODEL

The solvent release occurred as a leak from corroded underground pipe elbows on the south side of the ELMCO tank farm. The solvents migrated downward through the silty, sandy clay of the unsaturated zone, spreading out slightly to form a column, or subsurface "mound" of VOC-impacted soil roughly 75 feet long, 45 feet wide, and 20 to 30 feet deep. Upon encountering the bedrock surface, the solvents followed along the irregular surface, resulting in a larger top-of-rock contaminant footprint, but one still confined to the area immediately south and west of the former tank farm. The majority of the solvent migrated west-northwest along a bedrock cutter that measures roughly 35 feet deep at the Site's western boundary and contains significant weathered bedrock and perched groundwater. Migration rates along the path vary dramatically from point to point, as demonstrated by hydraulic conductivity testing described in Section 2.3 of this report.

As the solvent encountered groundwater, the differing physical properties of the principal contaminants, toluene and acetone, determined their migration characteristics. Toluene, unable to dissolve in water to any significant degree, was largely limited to migration along the phreatic surface of the groundwater, within the cutter and related fractures in a narrow band toward the west-northwest, with some migration outward in to bedding plane fractures along the cutter, as observed at MW-3. It flowed to the surface in the seeps at Liberty Creek, where free-product toluene formed the principal component of the contaminant plume until early 2008. Acetone, being infinitely miscible in water, formed a larger, dissolved-phase plume that migrated with the water along bedding planes and fractures throughout the saturated thickness of the aquifer. This dissolved phase, consisting primarily of acetone with some toluene and other ancillary VOCs, has been encountered at MW-2, the seeps along the Harpeth, and as a component of the plume emerging along Liberty Creek. No free-product solvent has been identified in the Harpeth River seeps or well MW-2. Data from MW-1 and MW-5, at the edge of the dissolved-phase plume, show no detectable concentrations of acetone but have shown other solvent-related VOCs, including toluene and benzene, at different ratios than observed in the main body of the plume closer to the source. These different ratios near the edge of the plume are expected due to the effects of dilution, biological degradation, and differing solubilities of the various constituents.

The exact migration pathways of the free-product and dissolved-phase components of the plume cannot be established with certainty. Such certainty would require large-scale, disruptive investigations along the presumed pathway, including within the residential area along Daniels Drive. However, from the location of points where it has been observed, it may be concluded that the free-product component occurred as a series of pockets and stringers of solvent within a narrow band of weathered, fractured bedrock aligned roughly east-west between the former pipe elbows and the seeps at Liberty Creek, approximately as shown in Figure 8. The current status of the free product – its size or even whether it exists – cannot be determined from existing data. No free product has been observed in the trench or at the main seep for several

months, nor has free product been observed at MW-3 since a small quantity was removed in March 2008. An effort to pump water from the trench in such a way as to allow evaluation of whether free product exists near the western end of the plume has been proposed, as described in Section 4 of this report.

The dissolved-phase component of the plume exists within a broad area, from MW-1 to the east, Liberty Creek to the west, the Harpeth River to the south, and MW-5 to the north. The exact limits of the dissolved-phase plume, as defined by drinking-water standards, have not been completely defined to the east or to the north. Additional groundwater investigation is proposed as described in Section 4 of this report.

From data gathered during the Geoprobe and air-rotary drilling investigations, it is apparent that both the free-product and dissolved-phase components of the plume exist at depths exceeding 35 feet just west of the on-Site contaminated soil column. This elevation is, at the highest, approximately 627 feet above MSL. From the measured elevations of the creek and river seeps, it is therefore also apparent that no significant free product exists above this elevation between the Site and Liberty Creek. Given that the elevations of residences along Daniels Drive that are in the path of the free-product component of the plume are approximately 645 to 650 feet above MSL and thus are protected by a thick layer of clay soil overburden, it is unlikely that these residences have been or will be directly affected by the groundwater contamination. Air monitoring in homes along Daniels Drive and in the neighborhood has demonstrated that vapor phase transport from the contaminated water is not affecting the residents of this area (see Section 6 of this report).

As noted in earlier sections of this CAP, there are underground private and municipal sewer lines in the area. The elevation of the private sewer line along the east side of the railroad spur track is well above the 627-foot maximum elevation of the contaminated groundwater and cannot therefore be acting as a migration pathway. The same may be said for the municipal sewer line along Daniels Drive. It is likely, however,

that the municipal sewer lines along Liberty Creek and the Harpeth River are acting as migration pathways, if only secondarily through flooding during wet seasons. The elevation of the Main Seep at Liberty Creek was measured at approximately 611 feet above MSL. The elevation of the sewer invert 40 feet east is approximately 613 feet above MSL. It is therefore possible that contaminated groundwater could enter the backfill around the sewer line during high-water events and migrate downgradient through the backfill (i.e., toward the Harpeth River). Indeed, contaminants have been detected in water samples collected at HR-1, a seep that is apparently related to the backup of water along the sewer line that crosses under the Harpeth River at that location. A similar situation could exist in the municipal sewer line along the Harpeth River between Liberty Creek and the railroad bridge, although the invert elevations of this sewer line are unknown. In either case the contaminated water would migrate along the sewer line backfill downgradient into areas already affected by the dissolved-phase component of the plume and do not introduce additional migration risks.

Microbiological and chemical sampling and analysis performed on surface water and groundwater samples in February 2008 indicated a variety of microbiological strains and chemical conditions that are favorable to the degradation of acetone and toluene, as well as the ancillary VOCs. As documented in the Report of Additional Solvent Release Investigations (March 25, 2008) Microbe Inotech laboratories (MiL) identified a total of 19 strains (some of which were variants of single strains), many of which were rated as good or excellent degraders. A later edition of the MiL report (June 16, 2008, attached as Appendix 3), stated that in the absence of free product the dissolved toluene contaminant plume in groundwater (ranging in concentration from 525 mg/L to less than detect and consisting of 842.6 kg total mass) would be degraded to less than 10 mg/kg in 8.4 months. A later email amendment to the report stated that the drinking water standard of 1 mg/L toluene would be achieved in 9.8 months. These estimates are based on the number and type of microbial degraders, the total mass of contaminants (including acetone) present across the plume, the nutrient levels measured in February 2008, and the removal of the free product from the system. As noted above, the

present amount of free product in the system is unknown. MiL stated that augmentation of the system with nutrients was unnecessary to achieve remediation in the time frames cited.

6.0 RISK ASSESSMENT FINDINGS

Mr. Mark Bowers of Secaps Environmental, Inc., was retained to perform a screening level risk assessment for both human and ecological receptors in the vicinity of the ELMCO facility and the affected portions of the Harpeth River and Liberty Creek. The purpose of the risk assessment was to aid in directing remedial action to those areas and conditions that pose significant risk to human health or the environment, and was performed in accordance with U.S. EPA guidance. The risk assessment report is included in Appendix 2.

6.1 Human Health

Both residential and recreational receptor scenarios were assessed to determine what level of risk would result to the public if no further action were to be taken with regard to contamination at the site. (Note: The risk assessment evaluated conditions as they existed at the site on June 1, 2008.) Conservative assumptions of reasonable maximum exposure were used to ensure that the findings would be reflective of the worst-case conditions. The conclusion of the human health risk assessment was that site conditions as they currently exist pose no significant risk to local populations and that no action is required to protect human health.

6.2 Ecological

Exposure to ecological receptors in both the Harpeth River and Liberty Creek was assessed to determine what level of risk would result to the environment if no further action were to be taken with regard to contamination at the site. (Note: The risk assessment evaluated conditions as they existed at the site on June 1, 2008.)

The assessment for the Harpeth River confirmed previous TDEC findings that the contamination entering the river poses no significant risk to aquatic organisms. Low dissolved oxygen effects on the benthic organisms in isolated areas immediately adjacent to the seeps are not expected to have a quantifiable effect on the overall river ecosystem.

The assessment for Liberty Creek found that fish and benthic organisms in the lower 600-foot reach of the creek are potentially at risk due to the presence of VOCs in surface water. Chronic toxicity impacts may exist, and episodic low dissolved oxygen periods are reportedly possible where contaminants induce eutrophic conditions that could affect resident organisms. Some 90% of this toxicity is due to toluene.

7.0 ASSESSMENT OF CORRECTIVE ACTION NEEDS

In this section, each area of contaminated media is evaluated to determine what if any corrective actions need to be taken to lower contaminant concentrations and reduce risks.

7.1 Source Area Soils

The confirmation subsurface soil investigations performed in May 2008 in the BIOX-treated source area and under the former Tank Farm (see Section 3.2) have demonstrated that substantial soil contamination still exists in the source area, extending under the southern edge of the tank farm pad, and that these soils appear to be capable of continuing to release solvent constituents to the underlying groundwater. The contamination is at depth and would not appear to pose a significant risk to normal industrial or construction workers. However, the risk to the groundwater itself, and potentially to ecological receptors in Liberty Creek via the groundwater pathway, is sufficient to warrant corrective actions targeted to reducing the amount of volatile organic contaminants that are available to migrate into the groundwater pathway.

7.2 Surface Water in Lower Liberty Creek

As described in Section 6.2 and Appendix 2, the presence of volatile solvent constituents in surface water in the lower reaches of Liberty Creek (at least at and downstream of the point – the “watergate” – where the east-west cross-fence installed by ELMCO crosses the stream) pose a potential risk to fish and benthic organisms because of their potential chronic toxicity and because of their potential to induce eutrophic conditions that could result in episodic low dissolved oxygen periods. Such episodes are more likely to occur at low flow conditions. The risk is sufficient to warrant consideration of corrective actions that either reduce the groundwater discharge of solvent constituents to the stream or increase dissolved oxygen concentrations at low flow conditions.

7.3 Groundwater

Because it is not used and resides relatively deeply in the bedrock except at the lower elevations where it discharges into Liberty Creek and the Harpeth River, the groundwater that has been contaminated by ELMCO’s solvent release does not pose a risk to human health. Layers of clay soil and generally tight limestone bedrock provide effective barriers against the potential upward migration of organic vapors. The contaminated shallow aquifer typically has very low yield and is thus not suitable for domestic water supply use. Further, municipal water is readily available in the potentially impacted area. Therefore, there seems little likelihood that anyone in the near future would pursue development of a water well in the potentially impacted area. However, ELMCO is working with City of Franklin officials to restrict development of water production wells in the area. Should groundwater usage change in the future, the risks would have to be re-evaluated using then-current groundwater concentrations of the quite degradable solvent constituents of concern.

The contaminated groundwater that discharges into Liberty Creek, however, does cause the concentrations of volatile solvent constituents that create the risk to fish and benthic organisms described in Section 7.2 above. As described in that section,

corrective actions that would reduce the groundwater discharge of solvent constituents to the stream should be considered, especially through the “cutter” flow path that has been identified as apparently the primary discharge pathway. This would certainly include the already planned efforts to induce the flow of any remaining free-product solvent in the hydrogeologic system into the Interceptor Trench where it can be captured and removed, as well as any efforts to remediate the source area soils as described in Section 7.1 above.

7.4 Harpeth River

As described in Section 6.2 and Appendix 2, the discharges of solvent constituents into the Harpeth River via the seeps of contaminated groundwater or Liberty Creek itself are not sufficient to pose a significant risk to human health or fish and aquatic life. No corrective actions are therefore needed to protect the river. However, the discharges into the Harpeth River will ultimately be reduced by any corrective actions taken to address source area soils (see Section 7.1 above) and the unacceptable concentrations of solvent constituents in surface water in the lower reaches of Liberty Creek.

7.5 Liberty Creek Floodplain Soils

As described in Section 4.3 and in Appendix 2, there does not yet exist any data on solvent constituent concentrations in the excavated and unexcavated Liberty Creek floodplain soils, and thus the risks posed by such concentrations and the need for corrective actions cannot as yet be assessed. Once the active remediation efforts at the trench and soil pile have been completed, it is expected that soil sampling and analysis efforts will be performed to gather the necessary data, and that ELMCO will work with TDEC and the property owners to determine appropriate soil cleanup level(s) based on the risks associated with the planned and allowable uses of the property. Any necessary corrective actions would then be designed and implemented.

8.0 CORRECTIVE MEASURES STUDY FOR SOURCE AREA SOILS

As described in Section 7.1 above, corrective measures for source area soils are needed in order to reduce the potential for solvent constituents to migrate from the soils into the underlying groundwater. In this section, some potential corrective measures are evaluated and a recommended course of action is presented.

8.1 Evaluation of Potential Corrective Measures

Because of the high potential for significant migration of solvent constituents into the underlying groundwater and the limited mechanisms available for natural degradation of soil contamination at such depths, natural attenuation is not a feasible alternative. In addition, the very limited success demonstrated by the 2007 BIOX treatment efforts demonstrates that it is very difficult to distribute in the subsurface the reagents needed to enhance natural attenuation mechanisms.

BioManagement Services, Inc. ("BMS"), the vendor of the BIOX technology, has offered to re-treat a portion of the source area for free, but would not be able to do so for several weeks. They have also acknowledged that acetone contamination can be hard to treat by chemical oxidation processes. ELMCO continues to evaluate this offer, but has decided to focus primarily on other alternatives. The offer for free re-treatment does not seem to extend to the full area where it appears that corrective action is needed, and the lack of success of the initial treatment seems to argue against further attempts. In fact, that lack of success seems to argue against any technology which involves pressure injection of reagents into the clay soil subsurface.

One generally sure way of removing a soil source area is via excavation followed by either on-site treatment of the removed soils or off-site shipment of the soils to a suitable commercial facility for treatment and/or disposal. In this case, however, the excavation option is fraught with difficulties. Although the soil source area is fairly well defined by the investigations that have been performed, its shape will require the removal and handling of an even larger amount of "clean" soil to get at the large amount

of “dirty” soil that needs to be remediated. It is also not clear to what soil concentrations of the solvent constituents of concern that soil would have to be removed. The SPLP data from the May 2008 soil investigations indicate that the solvent constituents are surprisingly mobile in water, although the SPLP method would be expected to be much more aggressive at such mobilization than would be expected to occur in the in-place environment. TriAD has roughly estimated that there are 1,000 cubic yards of “dirty” soil that need to be removed for treatment or off-site disposal, and that getting at this soil will require “benching” and the removal and handling of 2,000 cubic yards of “clean” soil and the replacement of most if not all of the removed “dirty” soil with imported “clean” soil.. Such excavation would almost certainly require that the equipment operators and other personnel be supplied with at least Level C breathing protection and probably Level B supplied air for improved work efficiency. TriAD and OCS have estimated the costs of simply excavating and handling this amount of soil to be in excess of \$70,000. That total does not include implementation of methods to effectively control VOC emissions from the open excavation – assuming such effective methods exist. The contaminated soils contain high concentrations of highly volatile organic solvent constituents, and organic vapor emissions would be difficult and costly to control. There is always also the potential for a rain event during the excavation effort that might cause a huge release of the contaminants into the underlying groundwater.

When the contaminated soils are removed, then something will have to be done with them. Such soils will be a listed hazardous waste that would have to be extensively treated before they could be placed back into the on-site excavation, and the manpower, equipment, and materials to perform that treatment on-site at the ELMCO facility would likely be quite expensive. Unless the excavation and soil treatment are performed gradually in smaller, more manageable quantities (which would likely increase the time and costs), simply finding adequate space at the ELMCO facility for the excavation and treatment activities might also be a limiting factor. There would also be the continuing problem of controlling organic vapor emissions.

TriAD has contacted Waste Management for potential prices for off-site treatment and disposal of the excavated “dirty” soils. WM personnel suggest that incineration of the soils may be necessary in order to achieve the RCRA LDR treatment standards necessary for the soils to be ultimately disposed by landfill. Costs for transportation and commercial incineration of the excavated soils would be expected to easily exceed \$1,000,000.

One option that has been briefly explored is *in situ* soil mixing by which specialized heavy equipment would be mobilized to the site to provide for the physical mixing of the “dirty” soils in place with a suitable reagent material. While this option would seemingly provide for much more effective control of organic vapor emissions, the costs of mobilizing the heavy equipment needed (likely \$50,000 or more), and its limited availability, would argue against such an option. TriAD was unable to obtain a serious proposal from such vendors.

Another corrective measures option for the source area soils is *in situ* multi-phase vacuum extraction, potentially enhanced with chemical oxidant injection. Under this option, a number of wells would be installed and screened only within the contaminated subsurface zones, and then a strong vacuum would be applied to the wells in a designed pattern to remove liquids and vapors. This option effectively utilizes the high volatility of the solvent constituents of concern, and by its very nature provides for effective control of organic vapor emissions. While TriAD personnel have some concerns about the permeability of the tight clay subsurface soils to even air or vapor movement, the vendor personnel contacted from EcoVac Services seemed confident in its potential effectiveness in even this environment. Considering that there is some heterogeneity in the subsurface stratigraphy, and that water/solvent movement is likely to be along the same pathways available to vapor movement, this technology seems particularly capable of relatively rapidly removing from the subsurface soils the contamination that is most likely to migrate into the underlying groundwater. This

technology is proven and reliable, and the vendor has been successfully implementing it for several years. Costs for this *in situ* option also appear to be much more reasonable.

8.2 Proposed Remedy

ELMCO intends to promptly pursue a pilot test of the EcoVac Services Enhanced Fluid Recovery (EFR®) process in the soil source area. A copy of the proposal from EcoVac Services is included as Appendix 3. A minimum of 4 wells will be installed by TriAD within the soil overburden and screened across the appropriate depths, and then EcoVac Systems will perform the pilot testing described in Appendix 3. The pilot testing results will then be evaluated by EcoVac Services, TriAD, and ELMCO for potential additional application of EcoVac technologies as described.

9.0 CORRECTIVE MEASURES FOR LIBERTY CREEK

As described in Section 7.2 above, corrective measures are needed to address the unacceptably high concentrations of solvent constituents – principally toluene – in the lower reaches of Liberty Creek. In this section, some potential corrective measures are identified and evaluated, and a course of action is recommended. It must also be remembered that any action that reduces contaminant concentrations in groundwater, including the recommended remedy for the source area soils described above, will also act to reduce solvent concentrations in Liberty Creek.

One obvious and necessary component of corrective measures for Liberty Creek is the capture and removal of free-product solvent discharges. To that end, implementation of the trench cleaning and aggressive pumping described in TriAD's May 20, 2008, letter "Plan for Additional Non-Routine Work at the Liberty Creek Interceptor Trench and Soil Pile Area", which is designed to induce free-product flow into the trench where it can be captured and removed, is vital to determining if a free-product discharge hazard to Liberty Creek still exists. If a free-product solvent discharge can be induced by the planned efforts, then some form of continued trench operations will be necessary.

These operations have proven successful in the past, and no other more-effective means of managing the migrating free-product solvent has been identified.

If the planned trench efforts are not successful at inducing free-product flow into the trench, then it can probably be concluded that insufficient free-product solvent exists in the cutter “flow-path” to pose a significant threat of discharge into Liberty Creek. In such case, ELMCO proposes to create a permeable reactive barrier across the cutter flow path by backfilling the bottom portion of the trench with a mixture of sand and reagent material such as the “BOS 2000” material described in Appendix 4. This material would provide a long-term, passive means of treating the contaminated groundwater – including the chance globules of free-product solvent – that migrate toward the creek through this cutter flow path.

In addition to these efforts at removing contamination from the groundwater that flows into Liberty Creek, ELMCO intends to explore with TDEC, the property owners, City officials, and other stakeholders the potential for reforming the channel of lower Liberty Creek to provide for increased aeration at low-flow conditions. Aeration would readily strip the toluene – which causes 90% of the aquatic toxicity – from the creek water, and would add oxygen. ELMCO acknowledges that such an effort would require various approvals and permits from TDEC, the property owners, and other agencies. However, if TDEC and the property owners consider such a feasible remedial measure, ELMCO intends to promptly pursue a topographic survey of the Liberty Creek stream channel from the Harpeth River to the watergate at the cross-fence so as to provide the necessary data for design of the channel improvements.

10.0 CONTINGENCY PROVISIONS

Implementation of each of the proposed corrective measures described in Sections 8.0 and 9.0 above will involve periodic inspections and monitoring to determine their effectiveness. Should they prove ineffective over time, then the changed conditions will be re-evaluated through a similar process of risk assessment and identification and

evaluation of potential corrective measures. New corrective measures will then be attempted as deemed appropriate.

12.0 CONTINUED MONITORING

As part of ongoing corrective action, both groundwater and seep locations will be monitored as described in the following sections. All samples collected will be analyzed for the standard list of VOCs by U.S. EPA SW846 Method 8260B by a qualified commercial laboratory. All samples will be collected into individually labeled, laboratory-supplied containers, preserved as required, and transported to the laboratory under chain-of-custody procedures. Trip blanks will be included in each cooler containing samples to be analyzed for VOCs.

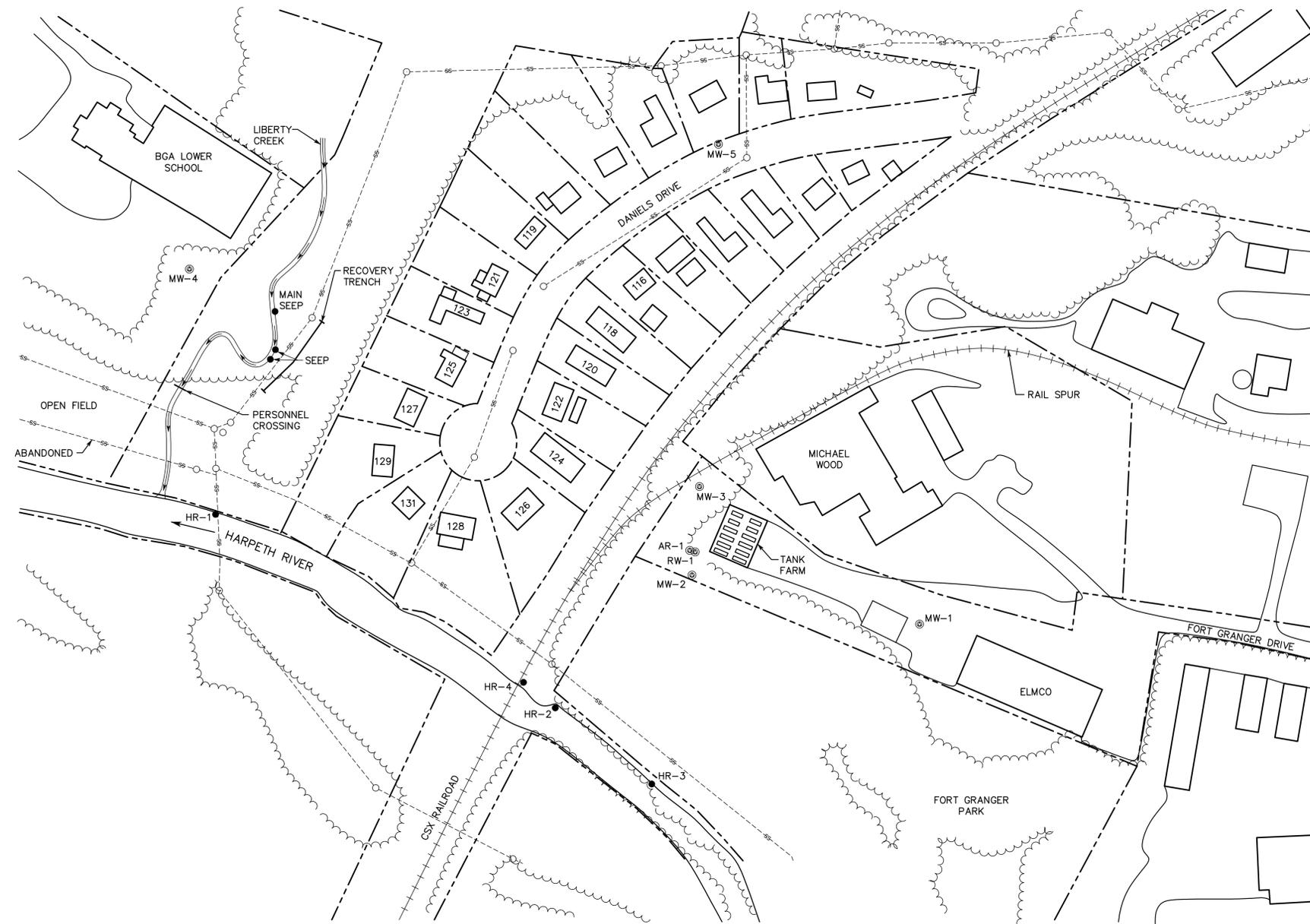
12.1 Groundwater

All groundwater monitoring wells will be monitored on a quarterly basis until approval is granted by TDEC to reduce either the number of wells sampled or the sampling frequency. Reports will be submitted quarterly, within 30 days of receipt of laboratory reports. Sampling will be performed using low-flow purge techniques, with purging via a bladder pump discharging through a flow-through cell until readings of pH, conductivity, and, if possible, temperature are stable (10 percent for conductivity and temperature and 0.1 standard pH units for pH). Temperature readings may not be stable within 10 percent due to heating or cooling effects of the purged water in the flow-through cell; the low yield of some of the wells increases residence times in the tubing and flow-through cell. The bladder in the pump will be a new, disposable bladder that will not be reused. The tubing will be dedicated to the well. The pump will be disassembled and decontaminated between sampling locations. Samples will be collected by directing the pump discharge directly to the laboratory-supplied containers.

12.2 Seeps and Surface Water

Seeps and surface water will continue to be sampled monthly in accordance with the TDEC-approved *Revised Plan for Collection and Analysis of Water Samples Related to*

Selected Seeps in to Liberty Creek and the Harpeth River, dated May 25, 2007.
Reports will be submitted monthly, within 30 days of receipt of the laboratory report.
Sampling locations and frequency will be adjusted as approved by TDEC.



NOTE
 BASE MAP ADAPTED FROM AERIAL PHOTOGRAPH
 NOT VERIFIED BY SURVEY.

- LEGEND**
- ⊙ MONITORING WELL
 - SEEP
 - MANHOLE
 - STRUCTURE
 - ~~~~~ VEGETATION
 - - - - - SANITARY SEWER
 - -- PROPERTY LINE

FIGURE 1
SITE MAP

SOLVENT RELEASE INVESTIGATION
 EGYPTIAN LACQUER MANUFACTURING CO.
 FRANKLIN, TENNESSEE

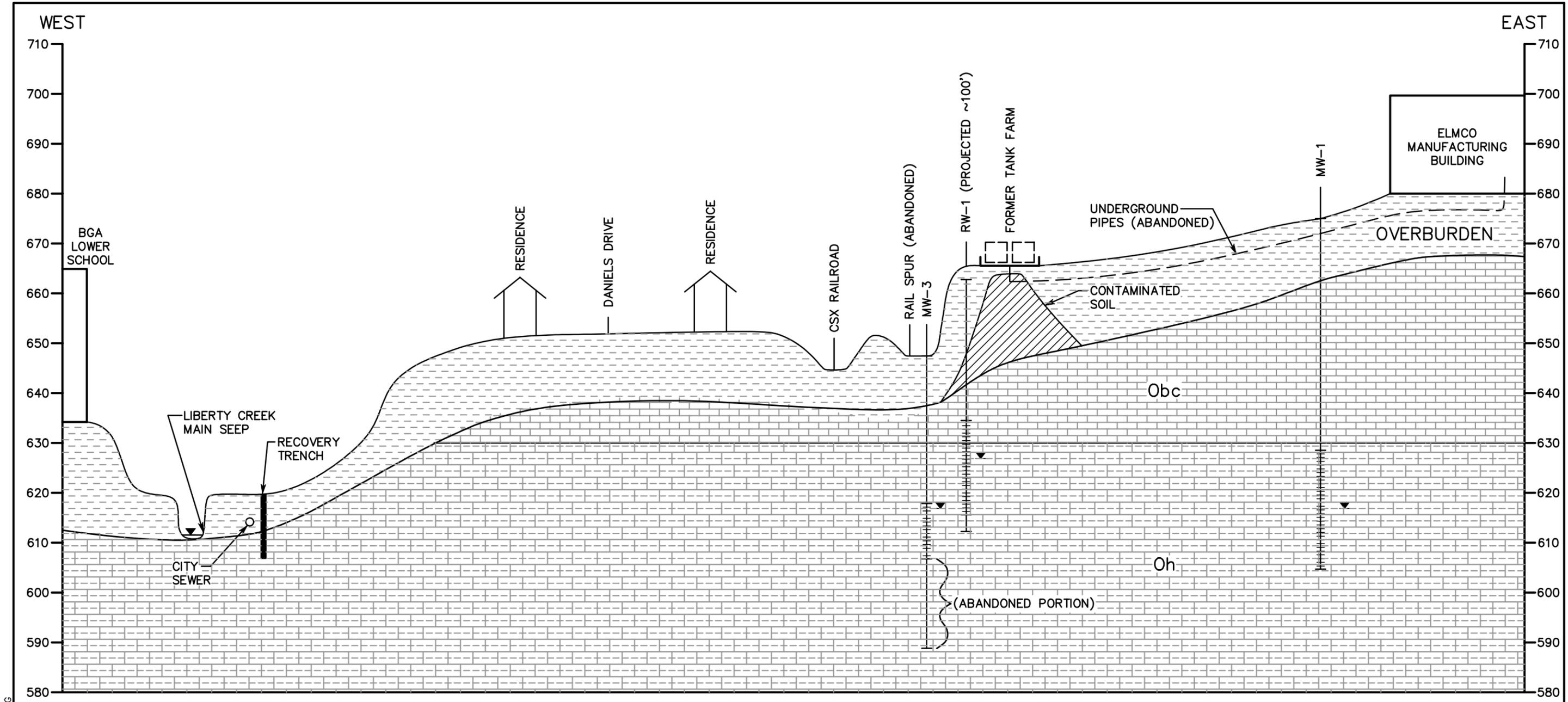
SCALE: AS SHOWN DR ALW CR CMS REV TDH

PREPARED BY:



Triad ENVIRONMENTAL CONSULTANTS, INC.
 Suite 200, 207 Donelson Pike, Nashville, TN 37214
 615-889-6888 fax 615-889-4004

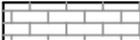
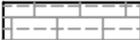
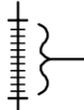
PROJ: 07-ELM01-01 DATE: 03/25/08 SHEET 1 OF 1



NOTES

1. Obc/Oh CONTACT BASED ON GEOLOGIC MAP OF THE FRANKLIN QUADRANGLE, TENNESSEE DIVISION OF GEOLOGY, 1963
2. TOP OF ROCK BASED ON DRILLING DATA, INFERRED BETWEEN DATA POINTS.

LEGEND

-  OVERBURDEN
-  Obc (BIGBY CANNON LIMESTONE)
-  Oh (HERMITAGE LIMESTONE)
-  MONITORING WELL SCREEN
-  WATER LEVEL ON 06/03/08

SCALE

HORIZ. 1" = 100'
VERT. 1" = 20'

FIGURE 2
WEST TO EAST CROSS SECTION
ELMCO TO LIBERTY CREEK

EGYPTIAN LACQUER MANUFACTURING CO.
FRANKLIN, TENNESSEE

SCALE: AS SHOWN DR ALW CHK CMS REV TDH

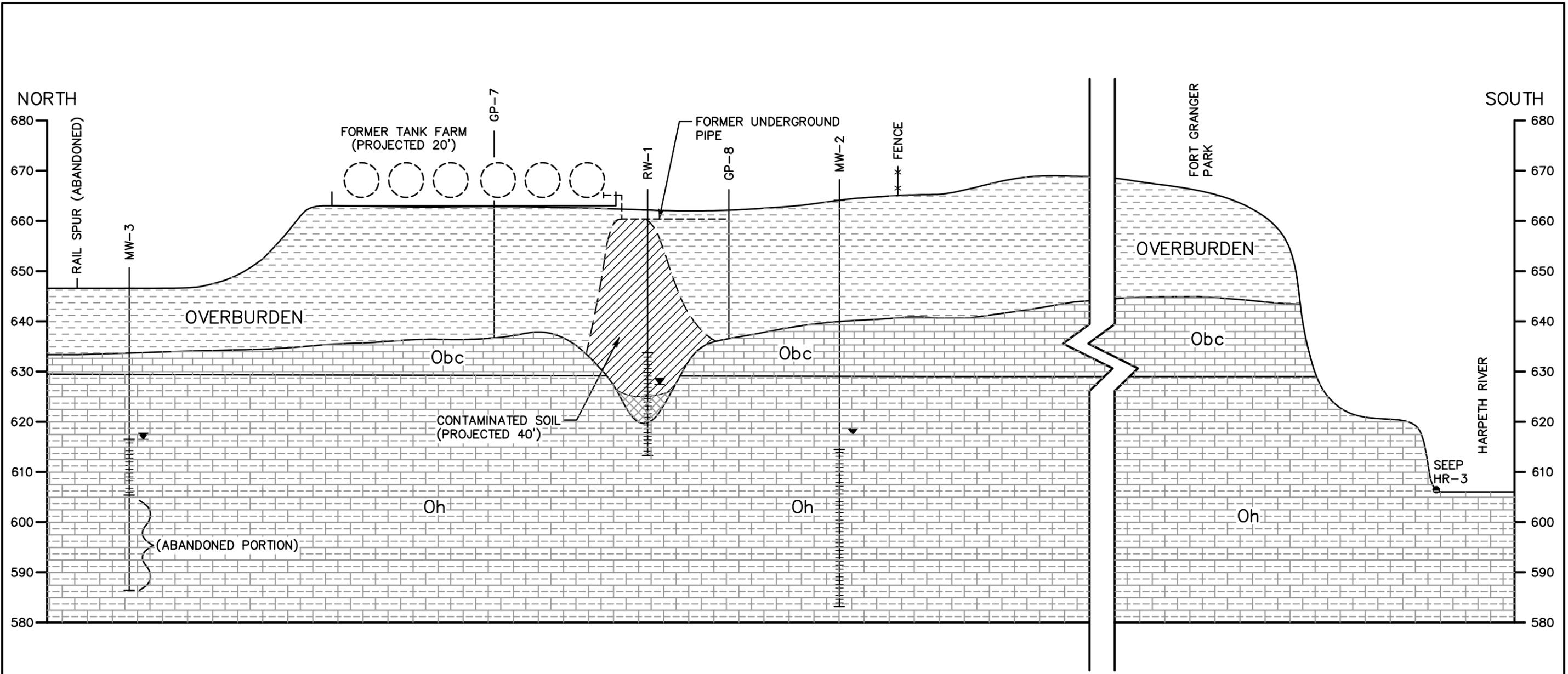
PREPARED BY:

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PROJ: 07-ELM01-01 DATE: 06/19/08 SHEET 1 OF 1

07-ELM01-01-EAST-WEST-CROSS-SECTION-06-03-08.DWG

07-ELM01-01\0101-NORTH-SOUTH-CROSS-SECTION-06-03-08.DWG



NOTES

1. Obc/Oh CONTACT BASED ON GEOLOGIC MAP OF THE FRANKLIN QUADRANGLE, TENNESSEE DIVISION OF GEOLOGY, 1963
2. TOP OF ROCK BASED ON DRILLING DATA, INFERRED BETWEEN DATA POINTS.

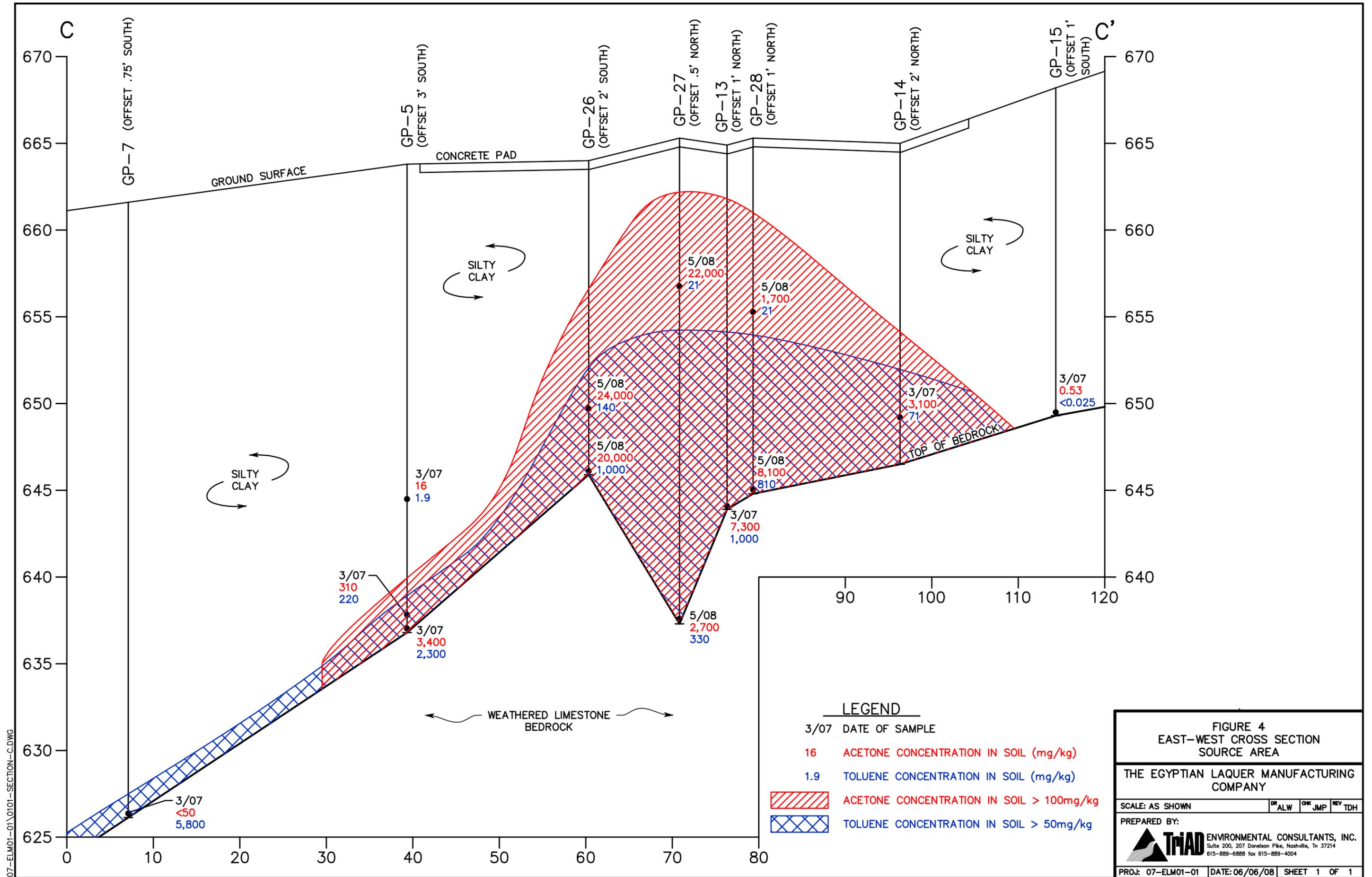
LEGEND

- OVERBURDEN
- Obc (BIGBY CANNON LIMESTONE)
- Oh (HERMITAGE LIMESTONE)
- WEATHERED BEDROCK
- MONITORING WELL SCREEN
- WATER LEVEL ON 06/03/08

SCALE

HORIZ. 1" = 20'
VERT. 1" = 20'

FIGURE 3			
NORTH TO SOUTH CROSS SECTION ELMCO TO HARPETH RIVER			
EGYPTIAN LACQUER MANUFACTURING CO. FRANKLIN, TENNESSEE			
SCALE: AS SHOWN	DR ALW	CHK CMS	REV TDH
PREPARED BY:			
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PROJ: 07-ELM01-01	DATE: 06/19/08	SHEET 1 OF 1	



07-ELM01-01\0101-SECTION-C.DWG

LEGEND

3/07 DATE OF SAMPLE

16 ACETONE CONCENTRATION IN SOIL (mg/kg)

1.9 TOLUENE CONCENTRATION IN SOIL (mg/kg)

ACETONE CONCENTRATION IN SOIL > 100mg/kg

TOLUENE CONCENTRATION IN SOIL > 50mg/kg

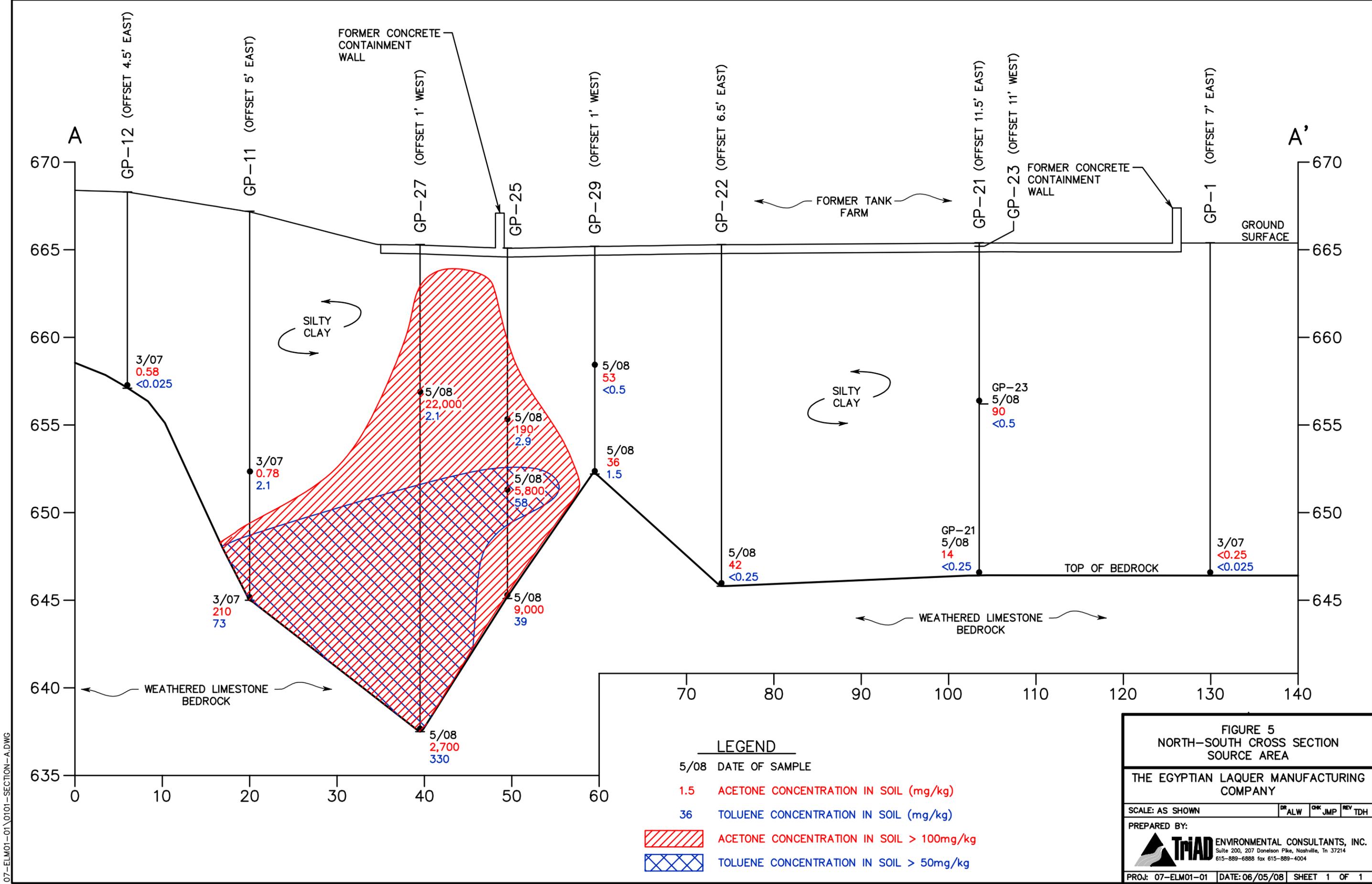
FIGURE 4
EAST-WEST CROSS SECTION
SOURCE AREA

THE EGYPTIAN LAQUER MANUFACTURING
COMPANY

SCALE: AS SHOWN DR ALW CHK JMP REV TDH

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07-ELM01-01\0101-SECTION-A.DWG

FIGURE 5
NORTH-SOUTH CROSS SECTION
SOURCE AREA

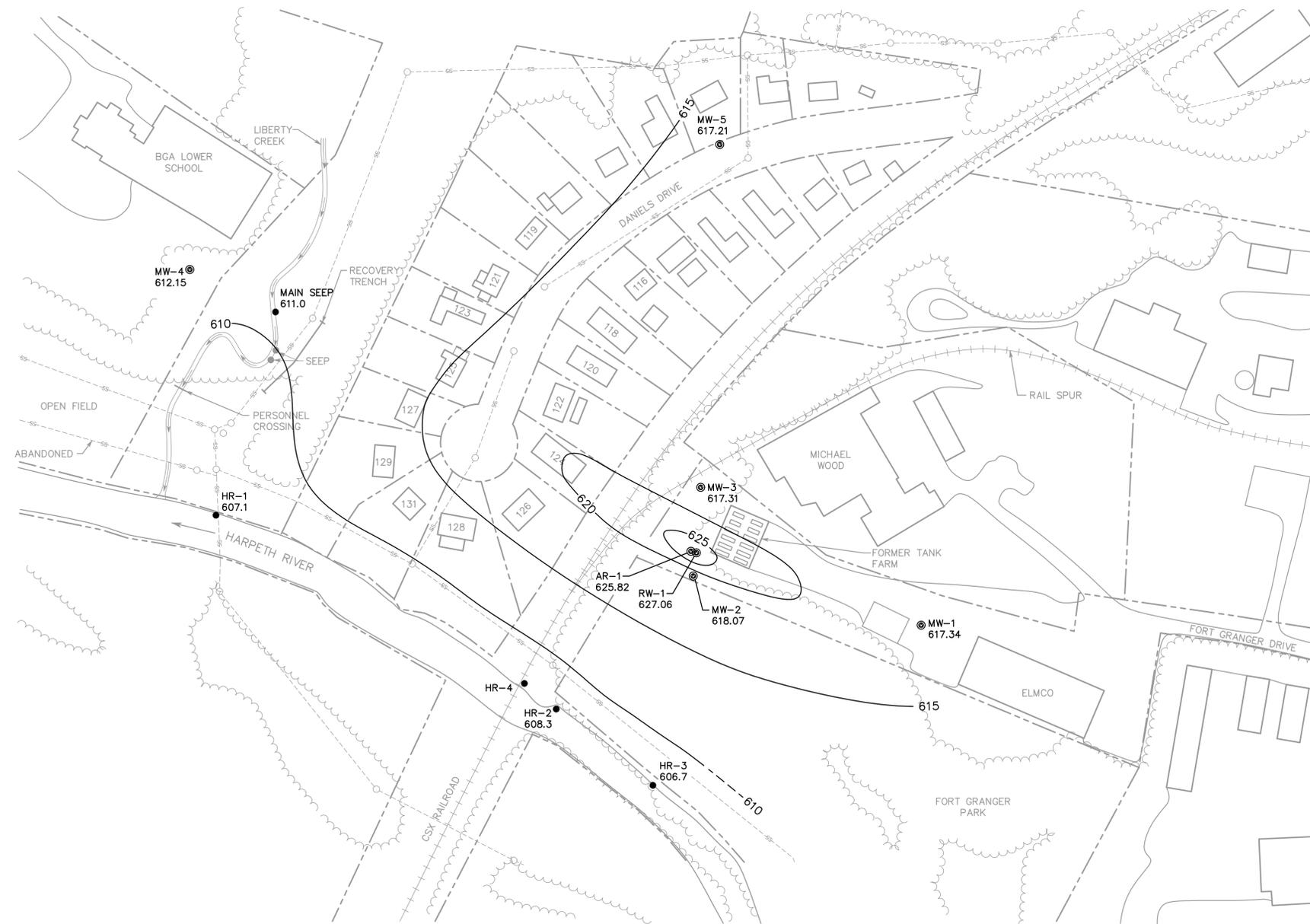
THE EGYPTIAN LAQUER MANUFACTURING COMPANY

SCALE: AS SHOWN DR ALW CRK JMP REV TDH

PREPARED BY:

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Suite 200, 207 Donelson Pike, Nashville, TN 37214
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PROJ: 07-ELM01-01 DATE: 06/05/08 SHEET 1 OF 1

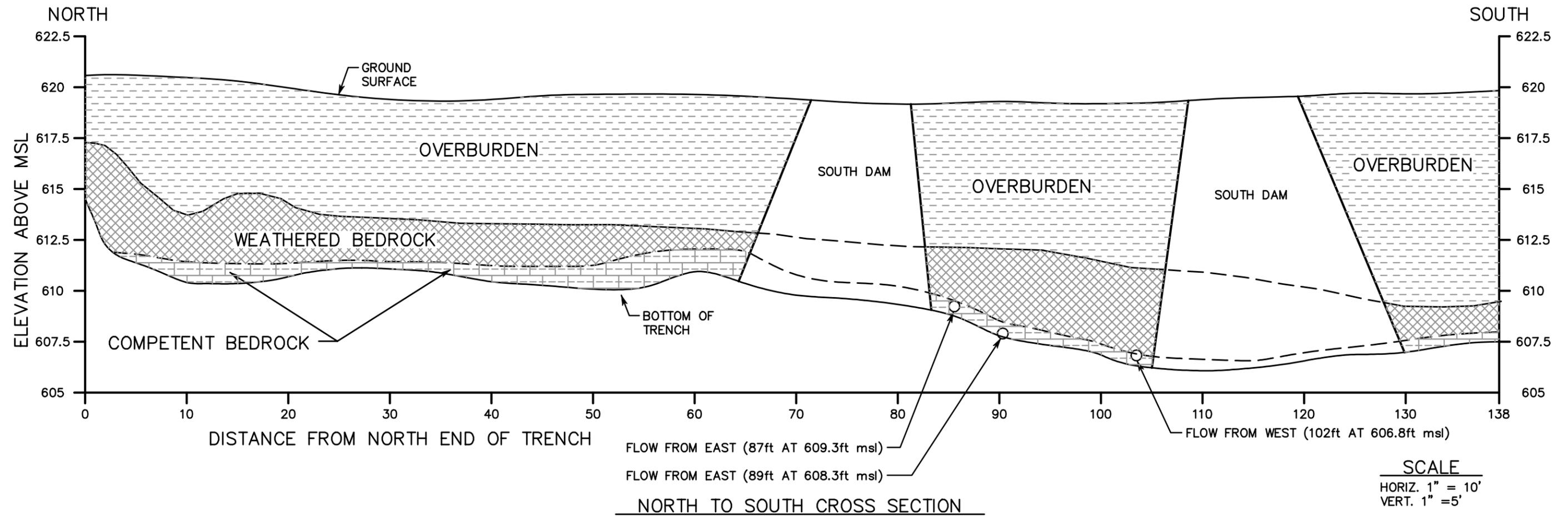
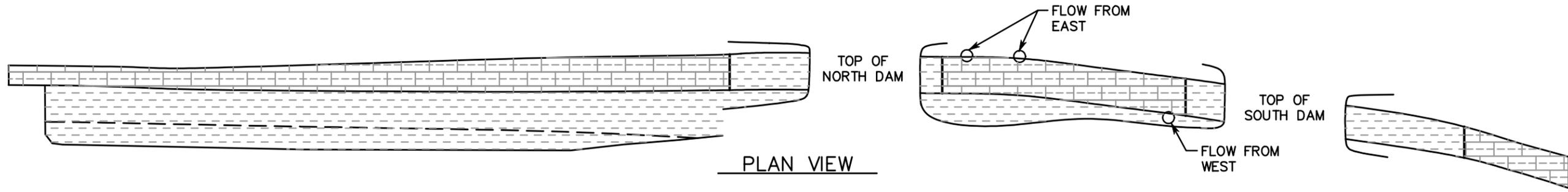


NOTE
 BASE MAP ADAPTED FROM AERIAL PHOTOGRAPH
 NOT VERIFIED BY SURVEY.

- LEGEND**
- ⊙ MONITORING WELL
 - SEEP
 - MANHOLE
 - ▭ STRUCTURE
 - ~~~~~ VEGETATION
 - - - - - SANITARY SEWER
 - - - - - PROPERTY LINE
 - 615 — POTENTIOMETRIC SURFACE CONTOUR

FIGURE 6 POTENTIOMETRIC MAP JUNE 3, 2008			
SOLVENT RELEASE INVESTIGATION EGYPTIAN LACQUER MANUFACTURING CO. FRANKLIN, TENNESSEE			
SCALE: AS SHOWN	DR ALW	CHK CMS	REV TDH
PREPARED BY: TRIAD ENVIRONMENTAL CONSULTANTS, INC. <small>Suite 200, 207 Donelson Pike, Nashville, TN 37214 615-889-6888 fax 615-889-4004</small>			
PROJ: 07-ELM01-01	DATE: 06/19/08	SHEET 1 OF 1	

07-ELM01-01(01)-2-POI-MAP-06-03-08.DWG



SCALE
 HORIZ. 1" = 10'
 VERT. 1" = 5'

NOTES

1. ALL ELEVATIONS BY TRIAD FOR REFERENCE, THE LIBERTY CREEK MAIN SEEP ELEVATION IS 611.23 (msl).
2. VERTICAL EXAGGERATION 2X.

LEGEND

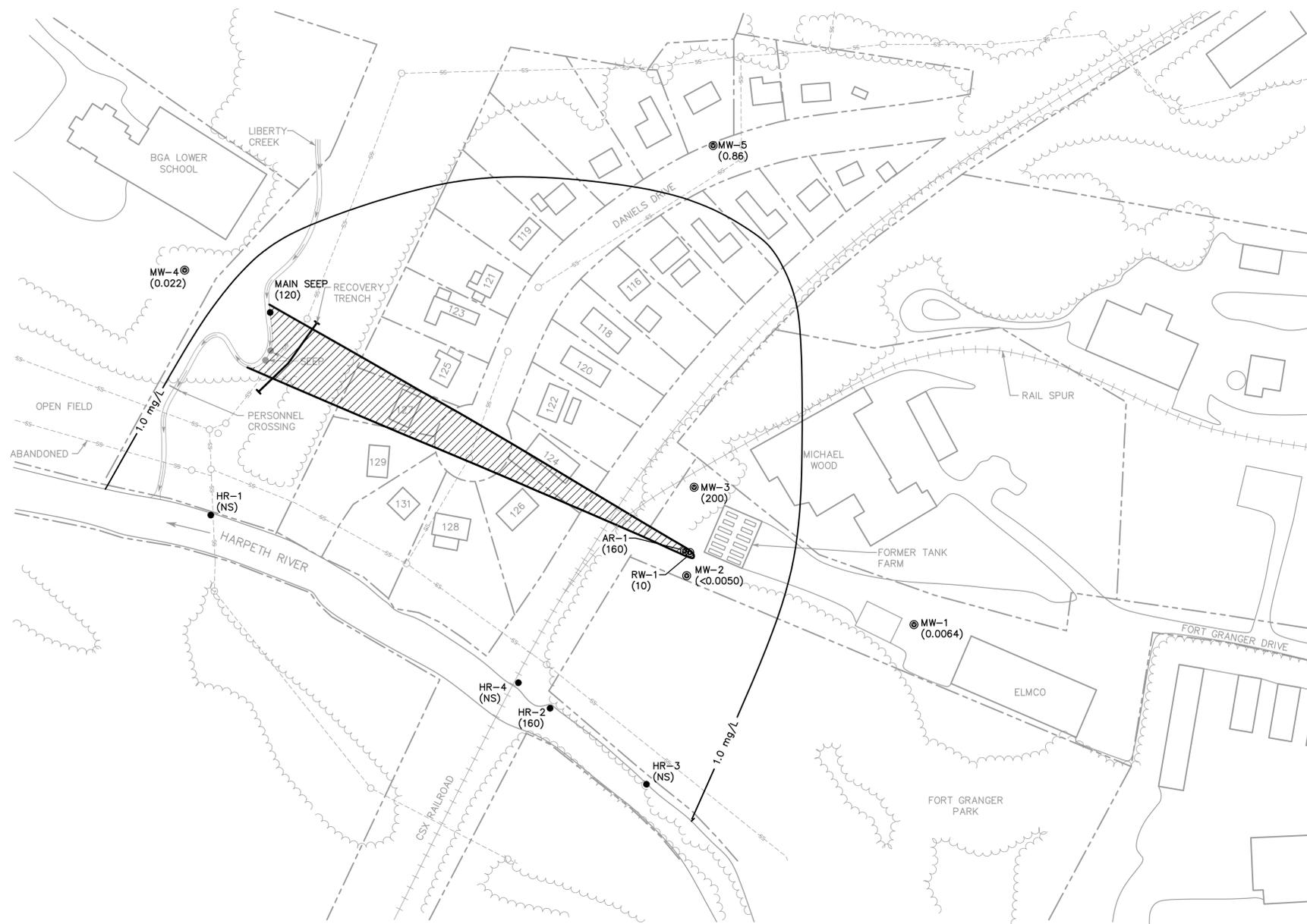
- WATER/PRODUCT FLOW
- [Dashed pattern] OVERBURDEN
- [Cross-hatched pattern] WEATHERED BEDROCK
- [Brick pattern] COMPETENT BEDROCK

FIGURE 7
 LIBERTY CREEK INTERCEPTOR TRENCH

EGYPTIAN LACQUER MANUFACTURING CO.
 FRANKLIN, TENNESSEE

SCALE: AS SHOWN	DR ALW	CHK MSP	REV CMS
PREPARED BY:			
TRIAD ENVIRONMENTAL CONSULTANTS, INC. <small>Suite 200, 207 Donelson Pike, Nashville, TN 37214 615-889-6888 fax 615-889-4004</small>			
PROJ: 07-ELM01-01	DATE: 08/13/07	SHEET 1 OF 1	

07-ELM01-01-RECOVERY-TRENCH-CROSS-SECTION.DWG



NOTES

1. THIS MAP IS PART OF A LARGER REPORT AND SHOULD BE USED ONLY IN CONJUNCTION WITH THE TEXT OF THE REPORT. OTHER CHEMICAL CONSTITUENTS HAVE BEEN IDENTIFIED IN GROUNDWATER.
2. BASE MAP ADAPTED FROM AERIAL PHOTOGRAPH NOT VERIFIED BY SURVEY.

LEGEND

- ⊙ MONITORING WELL
- SEEP
- MANHOLE
- ▭ STRUCTURE
- ~ VEGETATION
- - - SANITARY SEWER
- - - PROPERTY LINE
- (170) TOLUENE CONCENTRATION IN mg/L (JUNE 2008)
- (NS) NOT SAMPLED
- 1.0 mg/L — LIMIT OF TOLUENE PLUME DEFINED TO DRINKING WATER STANDARD
- ▨ AREA OF PRINCIPAL CONTAMINANT PLUME

**FIGURE 8
EXTENT OF TOLUENE
IN GROUNDWATER**

SOLVENT RELEASE INVESTIGATION
EGYPTIAN LACQUER MANUFACTURING CO.
FRANKLIN, TENNESSEE

SCALE: AS SHOWN DR ALW DR CMS REV TDH

PREPARED BY:
TRIAD ENVIRONMENTAL CONSULTANTS, INC.
Suite 200, 207 Donelson Pike, Nashville, TN 37214
615-889-6888 fax 615-889-4004

PROJ: 07-ELM01-01 | DATE: 06/19/08 | SHEET 1 OF 1

07-ELM01-01-01-3-TOLUENE-CONC-MAP-06-03-08.DWG

FIGURE 9
TOTAL VOCs IN GROUNDWATER

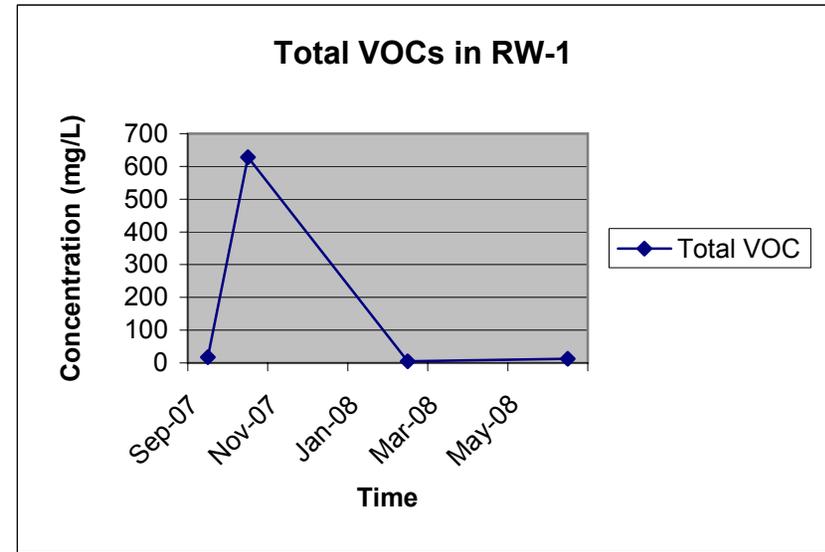
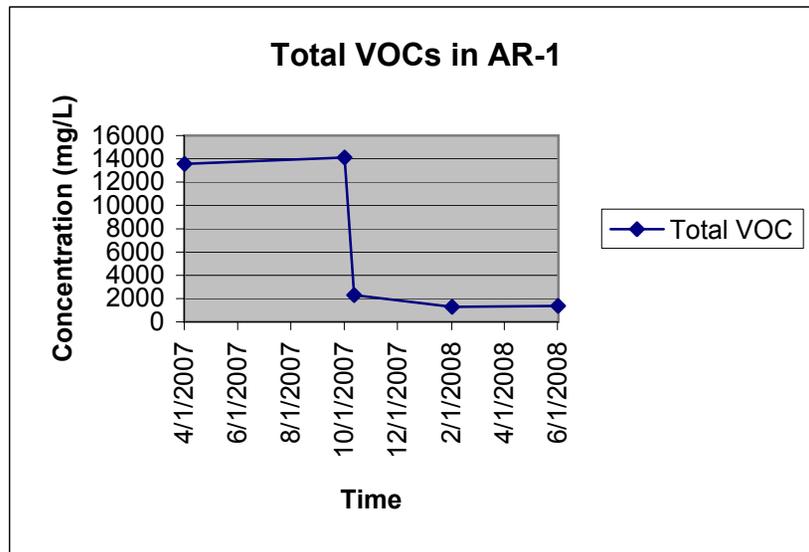
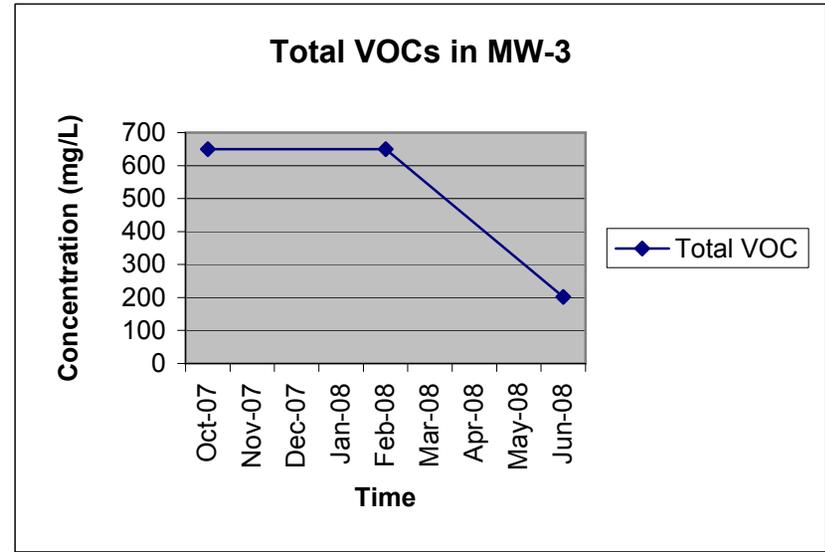
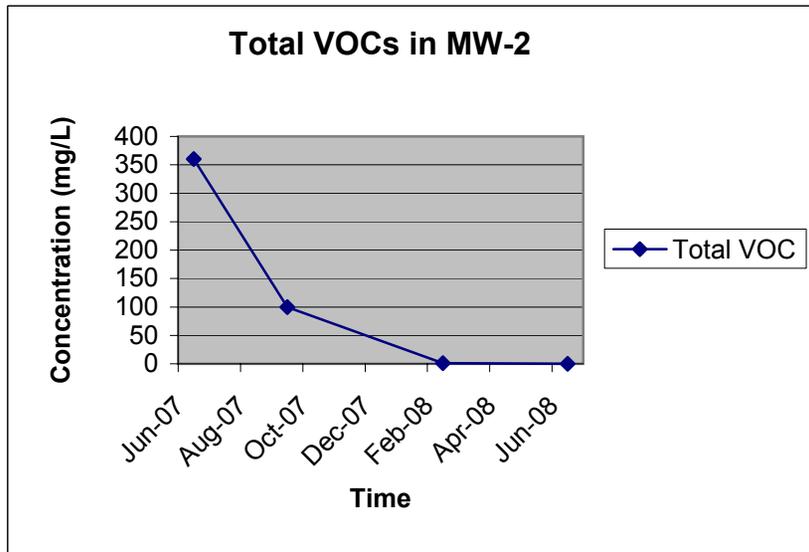


TABLE 1
GROUNDWATER ANALYTICAL SUMMARY
EGYPTIAN LAQUER MANUFACTURING COMPANY
All concentrations in mg/L

Constituent	Regulatory Level of Concern	MW-1 ³				
		4/18/2007	9/19/2007	2/21/2008	3/12/2008	6/3/2008
Volatiles						
Acetone	22 ²	<0.050	<0.050	<0.050	<0.050	<0.050
Benzene	0.005 ¹	<0.0010	<0.0010	0.0086	0.0040	0.011
Di-isopropyl ether	NP	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethylbenzene	0.7 ¹	<0.0010	<0.0010	0.0038	0.0030	0.010
Isopropylbenzene(cumene)	0.68 ²	<0.0010	<0.0010	0.0047	<0.0010	0.0025
Methyl Ethyl Ketone (MEK)	7.1 ²	<0.010	<0.010	<0.010	<0.010	<0.010
n-propylbenzene	NP	<0.0010	<0.0010	0.0038	<0.0010	0.0013
Toluene	1 ¹	<0.0050	<0.0050	<0.0050	<0.0050	0.0064
Xylenes	10 ¹	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
1,2,3-Trimethylbenzene	NP	<0.0010	<0.0010	0.0012	<0.0010	0.0024
1,2,4-Trimethylbenzene	0.015 ²	<0.0010	<0.0010	0.0050	<0.0010	0.0033
1,3,5-Trimethylbenzene	NP	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Semi-volatiles						
1-Methylnaphthalene	NP	NA	0.00018	NA	NA	NA
2-Methylnaphthalene	NP	NA	0.00019	NA	NA	NA

Notes:

NP - Not Promulgated

NA - Not Analyzed

NS - Not Sampled

Bold - Detected at concentration above laboratory detection limit

Shade - Detected at concentration above regulatory level of concern

¹ Tennessee General Use Groundwater Criteria, June 2008

² USEPA Regional Screening Levels for Chemical Contaminants at Superfund Sites, May 2008

³ April and September 2007 samples collected via bailer. Other samples collected via low-flow methods.

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⁶ October 12, 2007, sample collected using low-flow methods after purging well dry and allowing to recover.

⁷ September 2007 sample collected using low-flow methods, October 2007 sample collected using low-flow methods after purging well dry and allowing to recover. Other samples collected using low-flow purge method.

TABLE 1 (CONTINUED)
GROUNDWATER ANALYTICAL SUMMARY
EGYPTIAN LAQUER MANUFACTURING COMPANY
All concentrations in mg/L

Constituent	Regulatory Level of Concern	MW-2 ⁴			
		6/20/2007	9/19/2007	2/21/2008	6/3/2008
Volatiles					
Acetone	22 ²	360	100	0.059	<0.050
Benzene	0.005 ¹	<0.25	<0.10	0.046	0.052
Di-isopropyl ether	NP	<0.25	<0.10	<0.10	<0.10
Ethylbenzene	0.7 ¹	<0.25	<0.10	0.026	0.022
Isopropylbenzene(cumene)	0.68 ²	<0.25	<0.10	0.0064	0.0039
Methyl Ethyl Ketone (MEK)	7.1 ²	<2.5	<1.0	< 0.010	< 0.010
n-propylbenzene	NP	<0.25	<0.10	0.0045	0.0015
Toluene	1 ¹	<1.2	<0.50	0.78	<0.0050
Xylenes	10 ¹	<0.75	<0.30	0.022	0.013
1,2,3-Trimethylbenzene	NP	<0.25	<0.10	0.0081	0.0057
1,2,4-Trimethylbenzene	0.015 ²	<0.25	<0.10	0.0071	0.0052
1,3,5-Trimethylbenzene	NP	<0.25	<0.10	0.0058	<0.0010
Semi-volatiles					
1-Methylnaphthalene	NP	NA	0.00012	NA	NA
2-Methylnaphthalene	NP	NA	0.00012	NA	NA

Notes:

NP - Not Promulgated NA - Not Analyzed NS - Not Sampled

Shade - Detected at concentration above regulatory level of concern

¹ Tennessee General Use Groundwater Criteria, June 2008

² USEPA Regional Screening Levels for Chemical Contaminants at Superfund Sites, May 2008

³ April and September 2007 samples collected via bailer. Other samples collected via low-flow methods.

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TABLE 1 (CONTINUED)
GROUNDWATER ANALYTICAL SUMMARY
EGYPTIAN LAQUER MANUFACTURING COMPANY
All concentrations in mg/L

Constituent	Regulatory Level of Concern	MW-3		
		10/1/2007	2/21/2008	6/3/2008
Volatiles				
Acetone	22 ²	<25	Free Product	<2.5
Benzene	0.005 ¹	<0.50		<0.050
Di-isopropyl ether	NP	<0.50		<0.050
Ethylbenzene	0.7 ¹	<0.50		0.13
Isopropylbenzene(cumene)	0.68 ²	<0.50		<0.050
Methyl Ethyl Ketone (MEK)	7.1 ²	<5.0		0.87
n-propylbenzene	NP	<0.50		<0.050
Toluene	1 ¹	650		200
Xylenes	10 ¹	<1.5		0.52
1,2,3-Trimethylbenzene	NP	<0.50		<0.050
1,2,4-Trimethylbenzene	0.015 ²	<0.50		<0.050
1,3,5-Trimethylbenzene	NP	<0.50		<0.050
Semi-volatiles				
1-Methylnaphthalene	NP	<0.00010		NA
2-Methylnaphthalene	NP	0.00016	NA	

Notes:

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NA - Not Analyzed

NS - Not Sampled

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¹ Tennessee General Use Groundwater Criteria, June 2008

² USEPA Regional Screening Levels for Chemical Contaminants at Superfund Sites, May 2008

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TABLE 1 (CONTINUED)
GROUNDWATER ANALYTICAL SUMMARY
EGYPTIAN LAQUER MANUFACTURING COMPANY
All concentrations in mg/L

Constituent	Regulatory Level of Concern	MW-4	
		2/21/2008	6/3/2008
Volatiles			
Acetone	22 ²	<0.050	<0.050
Benzene	0.005 ¹	<0.0010	<0.0010
Di-isopropyl ether	NP	<0.0010	<0.0010
Ethylbenzene	0.7 ¹	<0.0010	<0.0010
Isopropylbenzene(cumene)	0.68 ²	<0.0010	<0.0010
Methyl Ethyl Ketone (MEK)	7.1 ²	<0.010	<0.010
n-propylbenzene	NP	<0.0010	<0.0010
Toluene	1 ¹	0.17	0.022
Xylenes	10 ¹	<0.0030	<0.0030
1,2,3-Trimethylbenzene	NP	<0.0010	<0.0010
1,2,4-Trimethylbenzene	0.015 ²	<0.0010	<0.0010
1,3,5-Trimethylbenzene	NP	<0.0010	<0.0010
Semi-volatiles			
1-Methylnaphthalene	NP	NA	NA
2-Methylnaphthalene	NP	NA	NA

Notes:

NP - Not Promulgated

NA - Not Analyzed

NS - Not Sampled

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³ April and September 2007 samples collected via bailer. Other samples collected via low-flow methods.

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TABLE 1 (CONTINUED)
GROUNDWATER ANALYTICAL SUMMARY
EGYPTIAN LAQUER MANUFACTURING COMPANY
All concentrations in mg/L

Constituent	Regulatory Level of Concern	MW-5	
		2/22/2008	6/3/2008
Volatiles			
Acetone	22 ²	<0.050	<0.50
Benzene	0.005 ¹	0.009	0.013
Di-isopropyl ether	NP	<0.0010	<0.010
Ethylbenzene	0.7 ¹	0.0060	<0.010
Isopropylbenzene(cumene)	0.68 ²	0.0012	<0.010
Methyl Ethyl Ketone (MEK)	7.1 ²	<0.0010	<0.10
n-propylbenzene	NP	<0.0010	<0.010
Toluene	1 ¹	0.79	0.86
Xylenes	10 ¹	0.014	<0.030
1,2,3-Trimethylbenzene	NP	0.0018	<0.010
1,2,4-Trimethylbenzene	0.015 ²	0.0011	<0.010
1,3,5-Trimethylbenzene	NP	<0.0010	<0.010
Semi-volatiles			
1-Methylnaphthalene	NP	NA	NA
2-Methylnaphthalene	NP	NA	NA

Notes:

NP - Not Promulgated

NA - Not Analyzed

NS - Not Sampled

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TABLE 1 (CONTINUED)						
GROUNDWATER ANALYTICAL SUMMARY						
EGYPTIAN LAQUER MANUFACTURING COMPANY						
All concentrations in mg/L						
Constituent	Regulatory Level of Concern	AR-1 ⁵				
		4/18/2007	10/1/2007	10/12/2007 ⁶	2/21/2008	6/3/2008
Volatiles						
Acetone	22 ²	13,000	14,000 (15,000)	1,900	960	1,200
Benzene	0.005 ¹	<1.0	<5.0	<5.0	<0.10	<1.0
Di-isopropyl ether	NP	<1.0	<5.0	<5.0	<0.10	<1.0
Ethylbenzene	0.7 ¹	<1.0	<5.0	<5.0	0.42	<1.0
Isopropylbenzene(cumene)	0.68 ²	<1.0	<5.0	<5.0	<0.10	<1.0
Methyl Ethyl Ketone (MEK)	7.1 ²	11	<50	<50	<1.0	<10
n-propylbenzene	NP	<1.0	<5.0	<5.0	<0.10	<1.0
Toluene	1 ¹	560	120 (540)	390	330	160
Xylenes	10 ¹	<3.0	<15	<15	2.0	<3.0
1,2,3-Trimethylbenzene	NP	<1.0	<5.0	<5.0	<0.10	<1.0
1,2,4-Trimethylbenzene	0.015 ²	<1.0	<5.0	<5.0	<0.10	<1.0
1,3,5-Trimethylbenzene	NP	<1.0	<5.0	<5.0	<0.10	<1.0
Semi-volatiles						
1-Methylnaphthalene	NP	NA	<0.00010	NA	NA	NA
2-Methylnaphthalene	NP	NA	<0.00010	NA	NA	NA

Notes:

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TABLE 1 (CONTINUED)
GROUNDWATER ANALYTICAL SUMMARY
EGYPTIAN LAQUER MANUFACTURING COMPANY
All concentrations in mg/L

Constituent	Regulatory Level of Concern	RW-1 ⁷			
		9/19/2007	10/12/2007	2/21/2008	6/3/2008
Volatiles					
Acetone	22 ²	3.8	430	< 0.050	<2.5
Benzene	0.005 ¹	<0.050	<5.0	0.0016	<0.050
Di-isopropyl ether	NP	<0.050	<5.0	0.0019	<0.050
Ethylbenzene	0.7 ¹	0.91	2.9	0.20	0.45
Isopropylbenzene(cumene)	0.68 ²	<0.050	<5.0	0.0036	<0.050
Methyl Ethyl Ketone (MEK)	7.1 ²	<0.050	<5.0	<0.010	<0.50
n-propylbenzene	NP	<0.050	<5.0	<0.010	<0.050
Toluene	1 ¹	9.1	180	4.4	10
Xylenes	10 ¹	3.6	15	0.65	1.8
1,2,3-Trimethylbenzene	NP	<0.050	<5.0	<0.010	<0.050
1,2,4-Trimethylbenzene	0.015 ²	<0.050	<5.0	<0.010	<0.050
1,3,5-Trimethylbenzene	NP	<0.050	<5.0	<0.010	<0.050
Semi-volatiles					
1-Methylnaphthalene	NP	0.00017	NA	NA	NA
2-Methylnaphthalene	NP	0.00017	NA	NA	NA

Notes:

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**Table 2: Summary of Analytical Results
Liberty Creek and Harpeth River Seeps
Results in mg/L**

Sampling Location	LC-PC		LC-MS ^a		HR-2		HR-3		Watergate	
	Acetone	Toluene	Acetone	Toluene	Acetone	Toluene	Acetone	Toluene	Acetone	Toluene
05/18/07	5.1	18	<12	54^E	1,700^E	360^E	150	82^E	NS	NS
05/24/07	18	12^E	<12	140	1,800	400	20	24	NS	NS
06/1/07 ^b	5.1	0.72^E	51	760^E	3,700	450^E	<0.050 ^R	<0.0050 ^R	NS	NS
06/08/07	20	35^J	<50	330	1,900	470	92	55	NS	NS
07/09/07	18^E	35^E	< 250	340	1,500	180^V	NS	NS	NS	NS
08/8/07 ^c	NS	NS	< 25	640	1,600	150	NS	NS	NS	NS
09/19/07	24	33	<10	32	780	130	NS	NS	NS	NS
10/15/07 ^d	NS	NS	<120	260	890	250	NS	NS	NS	NS
11/09/07 ^e	<12	24	<12	16	400	180	NS	NS	<0.50	11
12/10/07	3.0	7.8	<1.2	4.1	620^{J6}	160^{J6}	NS	NS	<1.2	4.2
01/28/08	1.4	5	19	74^E	330^E	84	NS	NS	0.52	2.6
02/15/08 ^f	5.3	8.1	14	38	460	170	NS	NS	<1.0	4.3^E
04/2/08 ^g	6.1^E	4.4	120^E	93	NS	NS	NS	NS	3.0^E	7.0
05/07/08	8.8	6.9^E	<25	100^E	390	140	NS	NS	<0.5	3.0^E

Bold text indicates a detected parameter

Notes:

- ^a LC-MS samples on 5/18 and 5/24/07 were collected from downstream end of boom area; later samples from point of seep
- ^b LC-PC sample collected 6/1/07 also contained 0.032 mg/L MEK
- ^c LC-MS sample collected 8/8/07 also contained 0.57 mg/L benzene
- ^d LC-MS sample collected 10/15/07 also contained 3.2 mg/L n-propylbenzene, 17 mg/L 1,2,4-trimethylbenzene, 3.1 mg/L 1,2,3-trimethylbenzene, and 2.9 mg/L 1,3,5-trimethylbenzene
- ^e LC-MS sample collected 11/9/07 also contained 0.27 mg/L cis-1,2-dichloroethene
Watergate sample also contained 0.053 mg/L tetrachloroethene
- ^f HR-2 sample collected 2/21/08
- ^g LC-PC sample also contained 0.0019 mg/L ethylbenzene, 0.016 mg/L MEK, and 0.010 mg/L xylenes
Watergate sample also contained 0.0016 mg/L ethylbenzene and 0.0069 mg/L xylenes

NS - Location not sampled, dry or below river level

Laboratory qualifiers:

- ^E Estimated result. Sample concentration exceeds the calibration range.
- ^J Matrix interference, spike value is high
- ^R Results rejected by Laboratory -- not valid
- ^V The sample concentration is too high to evaluate accurate spike recoveries.
- ^{J6} Matrix Interference, spike value too low

Microbe Inotech Laboratories, Inc.
Summary Report of Analysis
[MILB – 5289A Final w. Addendum]

Chris Scott, P.G.
Triad Environmental Consultants
207 Donelson Pike, Suite 200
Nashville, TN 37214
Phone: 615-889-6888
Fax: 615-889-4004

June 16th, 2008

cscott@triadenv.com

Description and Chain of Custody Record Information:

- Tuesday, January 29, 2008 – 1:22 PM: Received by client courier, five (5) liquid samples; four (4) for Bioremediation Biofeasibility Studies with nutrient chemistry and strain identification and one (1) for total plate counts with strain identification. One (1) vial of toluene and one (1) vial of acetone were received for use as the substrate in the biofeasibility study.
- MiL, Inc. REPORT & Invoice No.: MILB-5289A Report Date: Feb. 11th, 2008
- Project Name: Bioremediation/Natural Attenuation Study – Franklin, TN

Total Heterotrophic Plate Counts Processing:

[Standard Bacterial Plate Count 9215- standard spread plate method] Within 20 minutes of reception an aliquot from each sample is checked for weight or volume and serially diluted. The dilutions are aseptically transferred in a laminar flow biological cabinet and plated onto previously prepared and dried Trypticase Soy Agar (TSA medium) in Petri plates. Observations for Colony Forming Units per 1 gram of soil (CFU/g) or per 1 milliliter of liquid sample (CFU/mL) are made after 24 and 48 hours of incubation at 30°C for Aerobic counts.

Total Heterotrophic Plate Count Results:

Sample #	Sample Name	24 hrs incubation	48 hrs incubation
1	Driskill	1.60×10^2	5.00×10^2
2	LL-MS	3.80×10^2	1.57×10^3
3	LL-PC	2.06×10^3	3.76×10^4
4	HR-2	1.3×10^2	6.4×10^2
5	Bacterial Sheen	3.65×10^4	1.74×10^5

* $<1.0 \times 10^0$ CFU/mL=None Detected

Samples 1-4 will be included in the bioremediation study.

Sample # ⇒ Strain ↓	5289A-1 Driskill	5289A -2 LL-MS	5289A -3 LL-PC	5289A -4 HR-2
1	10%	--	5%	--
2	15%	--	--	--
3	25%	15%	15%	--
4	20%	20%	30%	--
5	30%	40%	45%	75%
6	--	25%	--	--
7	--	--	5%	10%
8	--	--	--	15%
Total Strains: 8				
Total Strain Types per Sample →	5	4	5	3

Sample # ⇒ Strain ↓	5289A-5 Bacterial Sheen
1	10%
2	10%
3	5%
4	5%
5	70%
Total Strains: 5	
Total Strain Types per Sample →	5

Processing---VITEK® Identification:

The isolated strain is Gram stained for classification (i.e. Gram-positive or Gram-negative). A sterile swab is used to aliquot sample from original agar plate. The aliquot is diluted in a saline solution to an OD absorbance between 0.53-0.69. The diluted sample is then transferred to a VITEK® plate and incubated in the instrument until a positive identification is obtained.

Bacterial Strain Identification:

VITEK® Identification Database			
MiL, Inc. ID + Strain Number	Closest Match	Percent Probability	Confidence Level
5289A-1/4-1	<i>Granulicatella elegans</i>	89%	Species
5289A-2-2	<i>Pseudomonas fluorescens</i>	99%	Species
5289A-1/2/3-3	<i>Pseudomonas aeruginosa</i>	98%	Species
5289A-1/2/3-4	<i>Aeromonas sobria</i>	89%	Species
5289A-1/2/3/4-5	<i>Brevundimonas diminuta/vesicularis</i>	Slashline	Genus
5289A-2-6	<i>Staphylococcus intermedius</i>	91%	Species
5289A-3/4-7	<i>Pseudomonas putida</i>	99%	Species
5289A-4-8	<i>Staphylococcus lentus</i>	88%	Species

VITEK® Identification Database			
MiL, Inc. ID + Strain Number	Closest Match	Percent Probability	Confidence Level
5289A-5-1	<i>Pseudomonas fluorescens</i>	--	Species
5289A-5-2	<i>Aeromonas hydrophila/caviae</i>	Slashline	Genus
5289A-5-3	<i>Staphylococcus intermedius</i>	98%	Species
5289A-5-4	Unidentified Organism	--	--
5289A-5-5	Unidentified Organism [see Biolog ID below]	--	--

Nomenclature Key:

- Project Number assigned by the MiL, inc.
- Sample Number
- Strain Number

Interpretation Summary:

In order to create the database that we use to identify your organisms, thousands of species of bacteria, yeast, mold, and fungi had to be tested. In fact each species itself had to be tested hundreds of times to determine a set of characteristics unique to each species. The species characteristics that are in our database are an "average" of the characteristics of hundreds of tested bacteria of the same species. The Similarity Coefficient of your organism refers to the similarity and distance to the hypothetical 'mean' organism in the database. The database organism has a similarity coefficient of one and

the MiL, Inc. 7259 LANSDOWNE AVENUE, SUITE 200 ST. LOUIS MO 63119-3421

PHONE: (800) 688-9144 FAX: (314) 645-2544

a distance of zero. So the closer your strain is to one and zero the more closely it matches the mean organism in the database.

For VITEK Data:

- A good match is one with a probability approaching 100% and a confidence level of species.

Processing---BIOLOG®:

Using standard methods for colony isolation, a pure colony from the original Trypticase Soy Agar (TSA) Petri plate containing the sample was selected for further isolation and growth onto a new Petri plate containing TSA dried media. Following a three day incubation period at 30°C, a colony is selected from the Petri plate and inoculated into sterile water, vigorously mixed, and aliquoted into a BIOLOG® 96-well plate specific for the growth of bacteria. At the conclusion of a 4-24 hour incubation at 30°C, the plate is read using BIOLOG® software for strain identification. In this work, one of the thirteen isolated strains was selected for identification by the Biolog method.

Sample Identification using BIOLOG®:

MiL, Inc. ID	Closest Match ID by BiOLOG® Aerobic Method	Percent Probability	Sim. Coef.
5289A-5-5	<i>Pseudomonas fuscovaginae</i>	100%	0.59

Nomenclature Key:

- Project Number assigned by the MiL, inc.
- Sample Number
- Strain Number

Similarity and Distance Coefficient Interpretation:

The Similarity and Distance Coefficient of your organism refers to the similarity and distance to the hypothetical 'mean' organism in the database. The database organism has a similarity coefficient of one and a distance of zero. So the closer your strain is to one and zero the more closely it matches the mean organism in the database. A good match is one with a similarity coefficient greater than 0.5

Endpoint Assay Processing:

The tested bacterial strains were grown overnight on Trypticase Soy (Broth) Agar (TSA) at 30°C and then suspended in sterile saline to a turbidity of 40%-50%T. The strains are then aliquotted into a 96-well microtiter plate that contains an undisclosed growth medium of mineral salts, vitamins and buffer without a major carbon source. The wells also contain a tetrazolium dye redox indicator system. Bacterial growth (metabolic respiration/oxidation of carbon sources) is monitored by tetrazolium reduction as measured at 590nm in a microplate reader. Acetone or Toluene(@10 µL) was added to selected wells to serve as the major carbon source. Trypticase Soy Broth (TSB) serves as the positive control for bacterial growth and water serves as the negative control for bacterial growth in this assay. Total volume of each well is 150µL.

Total growth is measured after 24 hours of incubation at 30°C. The data is processed and given with background blank values subtracted. Bar-chart interpretation of the data is provided on the pages following the executive summary report of analysis. The design template of the experiment is located in the raw data section of this report. The template shows the arrangement and position of strains in the matrix. Individual strain feasibility for biodegradation potential is reported as one of the following classifications:

- Excellent Degradar
- Good Degradar
- Fair Degradar
- Minimal Degradar
- No Effect
- Growth Inhibited

Aerobic Endpoint Assay Results:

(Please also see graphical results at end of Summary Report)

Contaminant ⇒ Strain ↓	<u>Acetone</u>	<u>Toluene</u>
5289A-1/4-1	Good	Good
5289A-2-2	Excellent	Growth Inhibited
5289A-1/2/3-3	Excellent	Excellent
5289A-1/2/3-4	Growth Inhibited	Fair
5289A-1/2/3/4-5	Growth Inhibited	Growth Inhibited
5289A-2-6	Good	Excellent
5289A-3/4-7	Excellent	Excellent
5289A-4-8	Excellent	Excellent

Figure 1. Graphical interpretation of Aerobic Endpoint Assay

5289A TriAD Environmental Consultants, Inc Aerobic Endpoint Assay, 8 Strains with Toulene

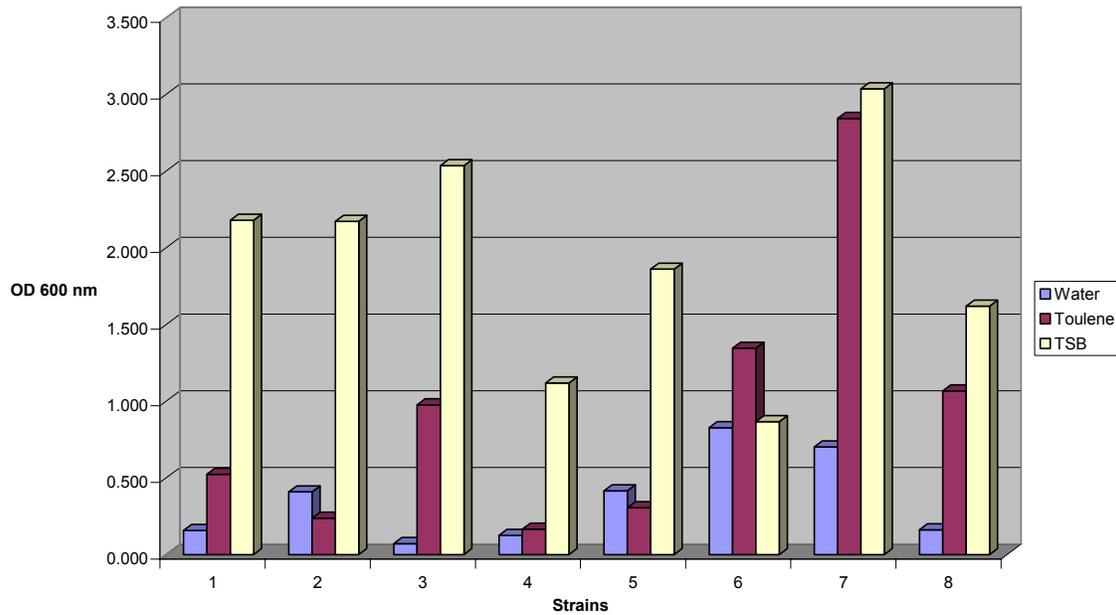
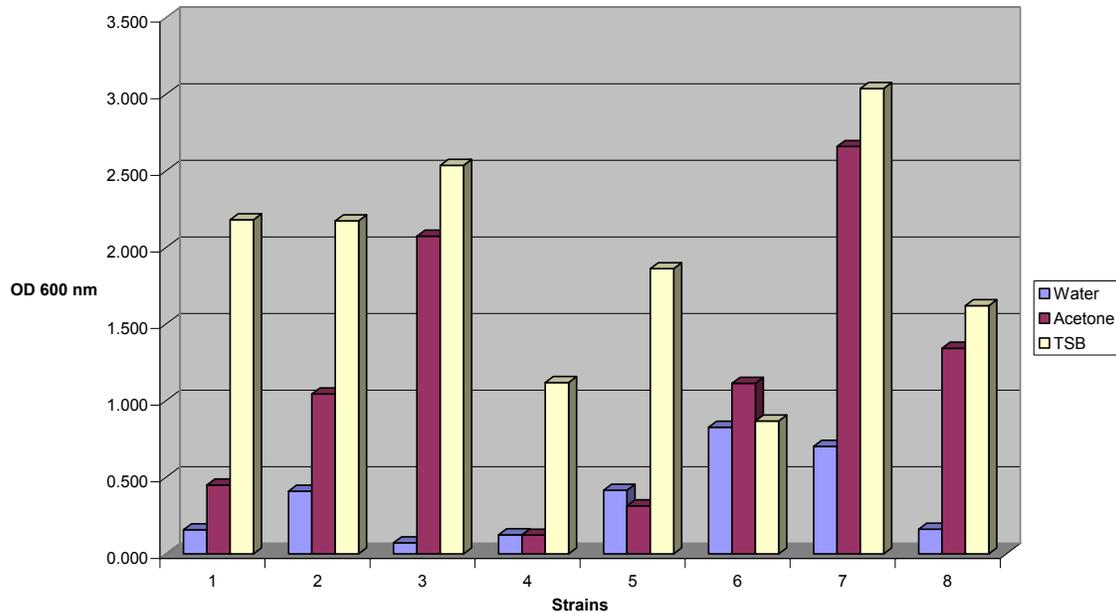


Figure 2. Graphical interpretation of Aerobic Endpoint Assay

5289A TriAD Environmental Consultants, Inc Aerobic Endpoint Assay, 8 Strains with Acetone



Liquid Nutrient Chemistry Results – mg/L-liquid (pH is a unit-less quantity):

<u>Sample</u> ⇒ <u>Analyte</u> ↓	<u>Driskill</u>	<u>LC-MS</u>	<u>LC-PC</u>	<u>HR-2</u>	<u>Method</u>
pH	8.25	7.06	7.65	7.15	*4500-H B
Iron	<0.020	5.23	0.424	2.69	*3030F, 3120B Total
Nitrogen, Ammonia (as N)	<0.10	1.39	<0.10	0.28	*4500-NH ₃ F Total
Nitrogen, Nitrite (as N)	<0.10	<0.01	0.33	<0.01	*4500-NO ₂ B
Nitrogen, Nitrate (as N)	5.51	0.26	2.90	0.24	*4500-NO ₃ D
Phosphorus, Orthophosphate (as P)	0.219	0.902	0.284	0.788	*4500-P BE
Sulfate, Turbidimetric	95	64	86	3	*4500-SO ₄ E
Total Organic Carbon (TOC)	1.3	13.4	2.6	194	*5310C, Organic Carbon

*Units given in mg/L

Nutrient Chemistry Which Should Be Maintained for Optimum Activity:

pH of Sample:	6.5 – 8.0 are considered good conditions
Iron:	Satisfactory (>10 mg/L)
Total Organic Carbon:	
Nitrogen as N:	C:N:P ratio is typically poor at contaminated sites and usually low on available nitrogen
Ammonia:	
Nitrite:	
Nitrate	Optimum C:N:P ratio to be maintained (120 – 100):10:1
o-Phosphate	

Discussion:

To support implementation of bioremediation, the property owner must scientifically demonstrate that degradation of site contaminants can occur at rates sufficient to be protective of human health as well as the environment. This document provides data that supports a technical course of action, which, if followed, should support bioremediation at sites where this type of process is protective of the environmental quality of ground water and soils. Bioremediation results from the integration of several attenuation mechanisms, which may be classified as either destructive or nondestructive. Destructive processes include biodegradation, abiotic oxidation, and hydrolysis. Nondestructive attenuation mechanisms include sorption, dilution (caused by dispersion and infiltration), and volatilization. The chemical parameters for soil and groundwater can significantly affect bacterial populations; therefore monitoring of bioremediation projects may include these parameters, although less frequently than comparative population counts and degradative studies as completed in this study.

Dissolved Oxygen and BTEX data:

An inverse relationship between dissolved oxygen and BTEX concentrations is an important indication of aerobic biodegradation and may be used as evidence that biodegradation of fuel hydrocarbons is occurring. Low dissolved oxygen levels in an area with fuel hydrocarbon contamination, generally indicates that an active zone of aerobic hydrocarbon biodegradation is present. Dissolved oxygen is the most thermodynamically favored electron acceptor used in the biodegradation of fuel hydrocarbons. Measurements of dissolved oxygen concentrations are used to estimate the mass of contaminant, which can be biodegraded by aerobic processes. Each 1.0 mg /L of dissolved oxygen consumed by microbes will destroy approximately 0.29 mg/L of BTEX compounds. During aerobic biodegradation, dissolved oxygen levels are reduced to below background levels as aerobic respiration occurs. Anaerobic bacteria (obligate anaerobes) generally cannot function at dissolved oxygen levels greater than about 0.5 mg/L.

Nitrate:

After dissolved oxygen has been depleted in the microbiological treatment zone, nitrate may be used as an electron acceptor for anaerobic biodegradation. Measurements of nitrate concentrations can be used to estimate the mass of contaminant, which can be biodegraded by de-nitrification processes. Each 1.0 mg/L of nitrate-nitrogen consumed by microbes results in the destruction of approximately 0.9 mg/L of BTEX compounds. Each 1.0 mg/L of nitrate consumed by microbes, results in the destruction of approximately 0.21 mg/L of BTEX compounds.

Sulfate:

After dissolved oxygen and nitrate have been depleted in the microbiological treatment zone, sulfate may be used as an electron acceptor for anaerobic biodegradation. Sulfate concentrations are used as an indicator of anaerobic degradation of fuel compounds. Each 1.0 mg/L of sulfate consumed by microbes results in the destruction of approximately 0.22 mg/L of BTEX compounds.

Ferrous Iron (Fe II):

In some cases ferric iron is used as an electron acceptor during anaerobic biodegradation of petroleum hydrocarbons. During this process, ferric iron is reduced to the ferrous form, which may be soluble in water. Ferrous iron concentrations are used as an indicator of anaerobic degradation of fuel compounds. Each 1.0 mg/L of ferrous iron produced during microbial iron oxidation results in the degradation of 0.047 mg/L of BTEX. Bacteria are capable of producing "siderophores," iron-specific chelating or binding agents to scavenge for iron. [For more information see the following reference, *Iron Chelation in Plants and Soil Microorganisms*, L.L. Barton and B.C. Hemming (editors), Academic Press, Inc., New York, 1993, 490pp. ISBN 0-12-079870-0.].

Temperature:

Ground water temperature directly affects the solubility of oxygen and other geochemical species. The solubility of dissolved oxygen is temperature dependent, being more soluble in cold water than in warm water. Ground water temperature also affects the metabolic acidity of bacteria. Rates of hydrocarbon biodegradation roughly double for every 10 – degree Celsius (10°C) increase in temperature ("Q" 10 rule) over the temperature range between 5 and 25°C. Ground water temperatures less than about 5°C tend to inhibit biodegradation, and slow rates of biodegradation are generally observed in such waters.

pH:

The pH of ground water has an effect on the presence and activity of microbial populations in ground water. This is especially true for methanogens. Microbes capable of degrading petroleum hydrocarbon compounds generally prefer pH values varying from 6.5 to 8 standard units.

Minimum Estimated Project Length Projection

The minimum estimated time for completion of the remedial action is based upon several functions among the most important of which are the 1) bacterial population density and diversity, 2) the nature of the hydrocarbon substrate and its concentration, 3) the calculation of number of half-lives to reach the desired clean-up or regulatory level, 4) the presence and specific degrading activity of the degrading organisms and the nature of the matrix. Analytical measurements for nutrient status are useful in providing information to increase or otherwise optimize bacterial density, diversity and activity levels. We stress the empirical nature of the estimate and note its dysfunction for periods greater than 10 months. Periods greater than 10 months, we would report as non-remedial given the current conditions. If such a condition exists, optimization of conditions will be mandatory for bioremediation to proceed at an appreciable rate. This may be attempted by increases in population levels and degradative activity levels by effecting changes in the nutrient status, oxygenation, and in some cases the introduction of a significant degrader population.

- [I] **Four of eight strains examined ranked "Excellent" aerobic growth on Toluene with only 2 strains ranking lower at "Good" and "Fair" and two strains were inhibited by Toluene.**
- [II] **Remediation goals for Site groundwater's:**

- Toluene 10 mg /L

[III] Reportedly Measured Analytical Chemistry for Site Soil Groundwater:

- Toluene 525mg/L Highest conc. (saturation)
842.6 Kg Total Mass 0.88g/L average for mix w. acetone
- Acetone 2,162 Kg Total Volume: 3,399,198 L

Brief Site description: See Toluene Map



[IV] Determined population count info at 48 hrs [CFU/mL]:

Sample #	Sample Name	48 hrs incubation
1	Driskill	5.00 x 10 ²
2	LL-MS	1.57 x 10 ³
3	LL-PC	3.76 x 10 ⁴
4	HR-2	6.4 x 10 ²

.....Quick Rule of Thumb Estimate [MiL, inc - empirical relationships based on experience of 17years with these assays and over 10,000 national and international projects]

Estimated Project Length – Conditions at sampling continuously prevailing –

Project Length = f ([strain activity rank][number of ½ life to projected level][population rank][contaminate/substrate])
Scale of 10-1 (10 being the lowest activity level) based on endpoint assay
Scale of 1-10 (1 being the best) calculated for different hydrocarbons (3.5 for Toluene)

Toluene - 525 mg/L to 10 mg/L

2 x 6 x 6 x 3.5 = 252 days or 8.4 months [see note above]

Note also: Presuming removal of Free Phase First

Total Petroleum Hydrocarbons and Aromatic Hydrocarbons:

These analytes are used to determine the type and distribution of fuel hydrocarbon in the aquifer. The combined concentrations of BTEX and the trimethylbenzenes (TMB) should not be greater than 50 percent of the TPH concentration. If these compounds are found in concentrations greater than 50 percent of the TPH concentration, sampling errors such as emulsification of product in the ground water sample should be investigated.

'Rule of Thumb' Quick Nutrient Estimation:

"How Much Nitrogen and Phosphate are needed to Add to Site for Remediation Based Upon Total Petroleum Hydrocarbon?"

Estimation Method for Determining Material Amounts:

The estimated contaminant mass for source area plume is:

Client provided data: Total approximate dissolved masses are: Toluene 842.6 Kg
Acetone 2,162 Kg therefore the total hydrocarbon estimate is ca. 3,005 Kg. with an aquifer volume of approx. 3,399,198 L.

"How much biological oxygen demand is needed in a closed system to degrade a Kilogram of total petroleum hydrocarbon or carbon?" Our rule is two times the amount of Carbon to be degraded.

Therefore for 3,005Kg of Toluene/Acetone, we can assume 6,010 Kg to be the Total Carbon Number for our ratio. Using the Typical Ratio: 100-10-1, we obtain:

6,010 Kg Carbon (present-see above explanation)

601Kg of Nitrogen (optimally to be added homogeneously to the source area plume)

60.1 Kg of Phosphate (to be added homogeneously to the source area plume)

The Nitrogen and Phosphate may be added simultaneously as monoammonium phosphate with the balance of nitrogen added as a slow release urea. With this information an engineer should be in a position to determine the amount of material needed and the engineering implementation design for the project; however, this may be an

underestimate depending upon the chemical composition of the contaminants [see below].

Best Method of Calculating Process Nutrient Requirements:

Estimating the material needs for bioremediation is based on the same principles used for all chemical reactions. The ratio of reactants is dictated by the stoichiometric equation. For bioremediation this requires a balanced redox equation. Although design estimates as above are frequently used, there are advantages to writing a balance reaction for generating these ratios. First, estimates can be made on supplement needs for which rule-of-thumb ratios are unavailable. Second, it may be desirable to estimate the amount of a by-product, such as CO₂. Third, the reactant ratios vary with the metabolic mode selected and the nature of the nutrients. Finally, the ability to develop the stoichiometric equation provides insight on discrepancies between treatability studies and field response. Discrepancies may result from significant natural oxygen demand, an underestimation of the original organic load, or lower utilization rates that can result from poor distribution of nutrient supplements. The total quantity of reactants can be calculated from a balanced reaction, given the amount of contaminant per mass of soil or volume of groundwater.

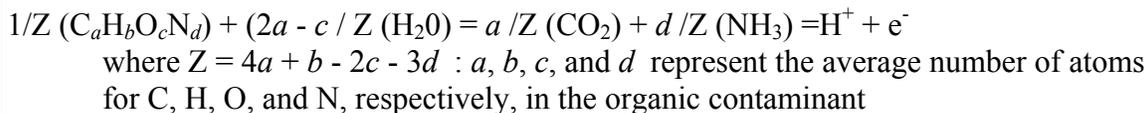
The steps in the process are as follows: First, field data provide the type and concentration of contaminants and nutrients available. The second step is to convert field data to a mass loading of contaminants. This is typically done by using concentration contours. Any contaminant plume varies significantly in concentration. As a result, a plume may be subdivided into zones for which mean concentrations are estimated to calculate mass contaminant loads per zone. The extensiveness of this calculation is related to the accuracy desired and limited by the adequacy of the field data.

The delivery of chemicals for *in situ* bioremediation is not uniform throughout a site but is based on the localized mass load within selected zones. For example, nutrient addition may not be necessary for a significant portion of a plume but may be vital for the heart of the contamination area. The technique for coupling and balancing two halves of a redox reaction is a subject covered in college chemistry 101; however, although the development of stoichiometric equations for the breakdown of organic compounds uses the same principles, they are not as straight forward. The total reaction must include the organic species being oxidized, the electron donor being reduced, and the major nutrients for cell growth. There are four common electron acceptors and two common forms of nitrogen for nutrients. To make the writing of the stoichiometric equation easier, fortunately for those having forgotten alot of chemistry, a generalized approach for organic biodegradation with each potential electron acceptor and two nutrient sources has been developed by P.L. McCarty [“Bioengineering Issues Related to *In-Situ* Remediation of Contaminated Soils and Groundwater,” *Environmental Biotechnology*, Omenn, S.S. (Ed.), Plenum Press, New York, pp. 143-162, 1987.]

The overall stoichiometric equation is a result of the summation of half reactions for the organic substrate, the selected electron acceptor, and the biomass synthesis reaction. Table 1 provides the half reactions for several electron acceptors and two cell synthesis equations.

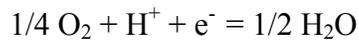
Table 1. Generalized Half Reactions for Organic Redox Reactions

Half Reaction of Electron Donor $\approx H_D$

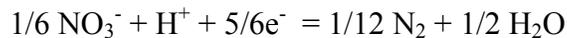


Half Reaction of the Electron Acceptor $\approx H_A$

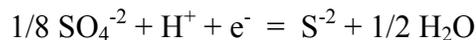
Aerobic: When oxygen is the electron acceptor:



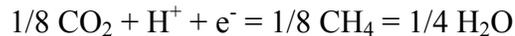
Anaerobic: When nitrate is the electron acceptor:



When sulfate is the electron acceptor:

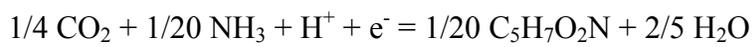


When carbon dioxide is the electron acceptor:

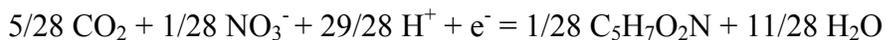


Cell Synthesis Equation $\approx \text{C}_s$

When ammonia is the nitrogen source:



When nitrate is the nitrogen source:



Note: An approximate composition of cellular structure is $\text{C}_5 \text{H}_7 \text{O}_2 \text{N}$. The phosphorus need for microbial growth is approximately 1/6 to 1/10 that for nitrogen.

Ammonia is the nitrogen source for one cell synthesis equation and nitrate is the source for the second. The overall reaction can be given in general terms by



where H_D = half reaction for the organic compound oxidation, electron donor

H_A = half reaction for the electron acceptor

C_s = reaction that provides nutrient requirements for biomass synthesis

The cell synthesis reaction equates the nutrient demand to the amount of biomass that will be produced. During the degradation of the organic compound, a portion of that energy yields cellular growth. A factor is included in the reaction for distribution of this energy between biomass synthesis and other needs. These factors are represented by

f_e = fraction of organic oxidized for energy

f_s = fraction associated with conversion to microbial cells where $f_e + f_c = 1$

For aerobic systems, the f_s factor for energy distribution is found to range between 0.12 and 0.6 (see Table 2 below). The slower the reaction (the harder the compound is to degrade) the smaller the value of f_s . The energy fraction going to cell synthesis for anaerobic systems is much lower than for aerobic systems. Thus the amount of biomass produced is significantly less.

Table 2. Factors for Energy Distribution for Biomass Synthesis in Redox Reactions

Electron Acceptor	f_s values for Equation (I).
O ₂	0.12—0.60 (mean 0.5)
NO ₃	0.1—0.5
SO ₄	0.04—0.2
CO ₂	0.04—0.2

SOURCE: McCarty, 1987.

Problem:

Estimate the electron acceptor and nutrient needs for bioremediation of groundwater contaminated with 23005 Kg of hydrocarbons (Toluene/Acetone) in 3,399,198L (0.88g/L) having concentrations given below.

Toluene	C ₇ H ₈	.025 g/L (28%)
Acetone	C ₃ H ₆ O	<u>0.63 g/L (72%)</u>
		0.88 g/L

Table 4. Example Estimating the Average Chemical Structure of BTEX

Contaminants.

Name	Empirical Formula	Mass Proportion by Atomic Wt.*			Fraction of Total Mass as based on Concentration [†]	Total Molecular Atomic Wt. Contribution [‡]		
		C	H	O		C	H	O
column #		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Toluene	C ₇ H ₈	84	8	0	0.25/0.88	23.9	2.3	0
Acetone	C ₃ H ₆ O	36	6	16	0.63/0.88	<u>25.9</u>	<u>4.3</u>	<u>11.5</u>
Total atomic mass contribution						49.8	6.6	11.5
Average No. of Atoms (mass/atomic wt.)						4.2	6.6	0.7

* Atomic wt. x no. of atoms of each

† Ave. concentration of the compound divided by the total concentration of all contaminants

‡ Columns (1) X (4), (2) X (4), (3) X (4) respectively

Answer: C_{4.2}H_{6.6}O_{0.7}; use C₄H₇O as the mean overall structure of the mixture of contaminants.

Step 1. Since most contaminated sites are a result of a mixture of organic compounds, it is easier to write one redox reaction for the mean chemical structure rather than a reaction for each compound present. The above mixture is represented by a single chemical structure for writing a stoichiometric equation. **The average chemical structure is**

estimated as C₄H₇O. Using the overall chemical structure, the balance stoichiometric equation is obtained by substituting according to the equations of Table 1.

Step 2. Determine the most appropriate electron acceptor and metabolism mode for destruction of the above hydrocarbon mixture.

Answer: Oxygen, aerobic

Step 3. Select an appropriate source for the nutrient nitrogen.

Answer: Either ammonia or nitrate can be used. For most organisms and for this example ammonia nitrogen is selected. Ammonia is readily available to microorganisms, but it does create an additional oxygen demand. For aerobic systems, some ammonia will be oxidized to nitrite and nitrate by indigenous bacteria. Oxygen demands will be greater than estimated from the reaction for the sole oxidation of the contaminants. Nitrate, however, can serve as an electron acceptor which may not be desired for some organisms or bioremediation systems.

Step 4. Select an appropriate energy factor for the conversion of hydrocarbon to cellular mass.

Answer: Hydrocarbons oxidize relatively fast, so a value for f_s of 0.5 is selected.

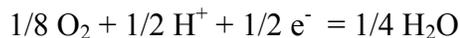
Step 5. Write the appropriate half reactions and the equation for cell growth using the yield fractions f_e and f_s (see Table 1):

Answer: $Z = 4a + b - 2c - 3d$
for C₄ H₇ O₁ N₀: $a = 4$, $b = 7$, $c = 1$, $d = 0$.
Answer: $Z = 4(4) + 7 - 2 = 9$

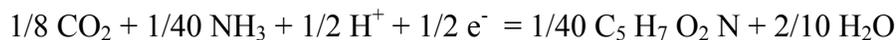
For H_D one obtains by substitution:



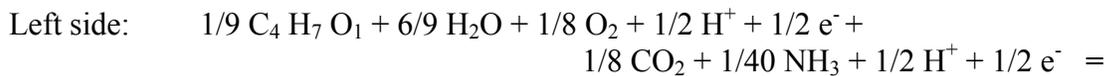
For $f_e\text{HA}$ one obtains by substitution. [$f_e + f_s = 1$ with $f_s = 0.5$ then $f_e = 0.5$]



For $f_s\text{C}_s$ one obtains by substitution:



Step 6. Write the overall reaction by summation of half reactions and cell growth equation (sum H_D, $f_e\text{HA}$, and $f_s\text{C}_s$). Sum all quantities on the left side of the equal sign and then all quantities on the right side:



Answer. The stoichiometric equation is, for NH₃ as the nutrient nitrogen source:



in final form:



Step 7. Calculate molecular weights to establish mass ratios.

Answer: Molecular weights

$$\text{C}_4\text{H}_7\text{O} = 71$$

$$\text{O}_2 = 32$$

$$\text{NH}_3 \text{ as N}^* = 14$$

$$\text{CO}_2 = 44$$

* note: Nutrients are sold in terms of nitrogen (N).

Step 8. Determine mass ratios:



$$1 : 1.13(32/71) : 0.23 (14/71) : 1/6(0.23)(14/71) : 2.88(44/71)$$

or **1: 0.51 : 0.05 : 0.01 : 1.78**

For every kilogram of contaminant degraded 0.51 Kg of oxygen, 0.05 Kg of nitrogen, 0.01 Kg of phosphorus are required, and 1.78 Kg of CO₂ are produced.

Step 9. Calculate the pounds of oxygen, ammonia, and phosphorus necessary to bioremediate 3,399,198 L of groundwater contaminated with 0.884 g/L of Toluene/Acetone [mean empirical formula C₄H₇O]. The chemical supply needs are:

Answer:

0.884 g/L x 3,399,198 L = 3005 Kg of Toluene/Acetone mixture --

Oxygen required: (3005 Kg) (0.51) = 1,533 Kg as O₂

Nitrogen required: (3005 Kg) (0.05) = 150.3 Kg as N

Phosphorus required: (3005 Kg) (0.01) = 50 Kg as P

CO₂ produced: (3005 Kg) (1.78) = 5,349 Kg as CO₂

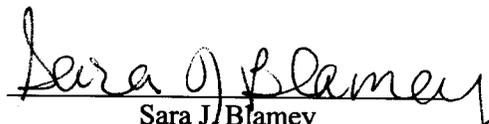
The amount of nitrogen and phosphorus available (current measurements) must be established and subtracted from the above so the net balance can be delivered to the system.

Rate of Delivery Comments:

Assuming mixing techniques that achieve at least 90 percent contact between soils and additives, single-dose applications should be limited to 3 lb of nutrients per cubic yard of soil to prevent undesirable osmotic effects. Higher nutrient requirements should use time-release nutrients or repeated applications. A common rate on a, per square foot basis, [below the aforementioned limit] is 75lbs/5000 sq. ft.

Thank you from the staff on project:


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Attorney-Client Communication or Attorney Work Product

**Egyptian Lacquer Manufacturing Company, Inc.
("ELMCO")**

**Risk Assessment in Support of Correction Action
Plans**

Prepared for:

Stites & Harbison, PLLC
Nashville, Tennessee

Prepared by:

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June 2008

Attorney-Client Communication or Attorney Work Product

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1.0 INTRODUCTION

The purpose of the Egyptian Lacquer Manufacturing Company (ELMCO) human health and ecological risk assessments is to assess the potential effects on human health and the environment associated with a historical release from the facility's solvent transfer piping system. The assessments assumed that no action would be taken to control or eliminate releases beyond those measures implemented prior to June 2008.

Results of the risk assessments will be used to support alternatives selection as part of the revised Corrective Action Plan (CAP) for the ELMCO facility. The CAP is being prepared on behalf of ELMCO through its attorneys at Stites & Harbison, PLLC by TriAD Environmental Consultants, Inc. (TriAD).

Site History and Background

In late 2006 and early 2007, investigations into objectionable odors found that free product and/or dissolved aromatic and ketone solvents were seeping from the eastern bank of Liberty Creek and the northern bank of the Harpeth River west and south, respectively, of the ELMCO manufacturing facility. Investigations in early 2007 at the ELMCO facility found that the likely source of these solvents were leaks in underground pipes which conveyed solvents from ELMCO's aboveground tank farm to its manufacturing building. Subsequent investigations identified a relatively confined column of solvent-impacted soil beneath the leak location as well as free product and dissolved phase aromatic and ketone compounds in groundwater. Monitoring of ambient air, air within residences and air within Battle Ground Academy Lower School (BGA) has also been performed. The two primary contaminants (acetone and toluene) have been detected in some air samples. The piping system has since been decommissioned and a number of actions have been taken to eliminate or control the residual source. Additional details regarding the site and investigation history are provided in the CAP.

Previous Risk Evaluations

Various screening level analyses have been performed in conjunction with previous actions at the site. Human health screening has been used to gauge the significance of surface water, air and groundwater results. The Tennessee Department of Health has also reportedly conducted a risk assessment to evaluate potential impacts on recreational users of the Harpeth River (TDEC 2007).

TDEC evaluated surface water results to determine whether current surface water impacts pose a threat to aquatic receptors. In addition, limited toxicity testing of waters from Liberty Creek was performed. This risk assessment represents the first attempt to fully characterize the threat posed to human health and the environment due to the historical leaks in the ELMCO solvent piping system. Human health and ecological risks are addressed separately in the following sections.

2.0 HUMAN HEALTH RISK ASSESSMENT

The human health risk assessment (HHRA) was performed in general accordance with USEPA risk assessment guidance. Specific guidance documents used in preparing the HHRA are listed in the References. Consistent with USEPA guidance (USEPA 1989), the HHRA process was divided into five elements:

- Data Collection and Evaluation
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Uncertainty Analysis

Each of these five elements is described in detail in succeeding sections of the HHRA. The last section of the HHRA discusses results in the context of potential risk management decisions and provides remedial goal options for environmental media based upon the exposure scenarios and assumptions.

2.1 DATA COLLECTION AND EVALUATION

Data Compilation and Evaluation

The following data evaluation steps were performed:

- Gather and sort data
- Evaluate analytical methods
- Evaluate quality of data with respect to sample quantitation limits
- Evaluate quality of data with respect to qualifiers and codes
- Evaluate quality of data with respect to blanks
- Compare potential site-related contaminant levels to background
- Identify chemicals of potential concern (COPCs) based on risk-based screening

The process was used to ensure data used were of acceptable quality and to identify chemicals associated with the source that warranted formal assessment in the HHRA. Only samples for those media associated with exposure pathways expected to be completed were considered. Based upon current and anticipated future land uses in the area and other factors, no soil sample results were compiled for this effort. The original pipe leak occurred at depth and as a consequence, surface soils were not affected. This was confirmed in TriAD's 'Final Report of Confirmation Soil Investigations under Former Tank Farm and in BIOX Treatment Area at ELMCO Facility, June 10, 2008'. Industrial workers are not expected to come into contact with contaminated soils at depth. Potential risks associated with subsurface soil during remedial activities (ex., excavation) will be addressed under OSHA HAZWOPER regulation.

It has been acknowledged that groundwater does not meet drinking water standards due in large part to the presence of volatile organic compounds suspected to have originated from the ELMCO piping system. Site investigations have revealed that the water bearing

zones in local geologic formations provide low to extremely low yield. As such, the potential for these formations to supply water for domestic purposes is questionable. There are currently no documented groundwater uses on or in the potentially affected vicinity of the ELMCO facility. In early 2007, contractors for the Tennessee Department of Environment and Conservation identified the few water supply wells (all domestic) in the larger site vicinity and found, through sampling and analysis, that none had been impacted by the release. Municipal water is available to local residents and a review found that it was the exclusive source of potable supply in the subject area. As a consequence, no completed groundwater exposure pathways were identified and no quantitative assessment of groundwater risks was performed. In the event of any proposed changes in local groundwater use, additional evaluation may be warranted.

Gather and Sort Data

Numerous sampling investigations have been conducted on and around the ELMCO facility since the fourth quarter 2006. Details regarding these investigations are provided in the CAP and under separate cover. Data produced by previous field efforts were entered into a project database. Data were subjected to a measurement quality objectives review and lab qualifiers were considered as part of the data quality assessment. It was presumed that data were of sufficient quality to support risk assessment end uses although formal data verification/validation was not performed.

Sampling locations, location descriptions, sampling dates and associated media considered for use in the HHRA are summarized in Table 1 and represent the culmination of the initial data gathering (and exclusion) effort. Data from some efforts were not included due to lack of supporting documentation.

Evaluation of Analytical Methods

Analytical methods were evaluated during the DQA process. The methods for specific chemical/compound groups were largely comparable between efforts. The analytical suite differed between ELMCO and TDEC studies as well as between media. Based on the approach, chemicals were assumed to be absent from samples in which they were not analyzed. The variable analytical suite (among other factors) led to differing numbers of analyses for individual parameters in a medium.

Evaluation of Sample Quantitation Limits

Quantitation limits (QLs) for samples collected from multiple field efforts were generally adequate for the primary contaminants (acetone and toluene). For air samples, exceptions were frequently noted for benzene and less regularly for acetone. Due to the high concentrations of acetone and toluene in some aqueous samples, the detection (or reporting) limits (DL/RL) for other compounds were elevated. These issues appear to have masked secondary contaminants which have more recently been detected as primary contaminant levels have decreased.

Evaluation of Qualified and Coded Data

Any data coded 'R' (rejected) by the laboratory or data validator/quality assessor were excluded from risk assessment use. Data with 'U' (non-detect) or 'UJ' (non-detect; estimated detection limit) qualifiers were handled as follows for statistical purposes.

Where an adequate DL was obtained:

- result set equal to one-half DL

Where inadequate DLs were reported, the associated results were not used to quantify exposure. Estimated values qualified as 'J' (estimated) or 'JE' (estimated, exceeded calibration range) were used at face value.

Comparison to Blanks

Blank (including field, rinsate, filter and laboratory blanks) comparisons were routinely performed as part of the data quality process for samples collected by TriAD. Use of field-related blanks in associated with TDEC sampling efforts was uncertain in some cases. Data qualifiers were assigned to results as necessary to reflect the blank influences on quantitation limits and confidence.

Comparison to Background

Background data were not collected for seeps. Limited background surface water sampling by TriAD (Liberty Creek) and TDEC (Harpeth River) found no ELMCO-related constituents. Therefore, no comparisons to reference conditions were necessary. For ambient air, background samples were collected at residences outside potential site influences. Due to results for ambient air background samples, no formal screening was incorporated into the overall COPC selection process.

Selection of COPCs

Data considered for use in the HHRA process are presented in Attachment A. In order to reduce the number of chemicals requiring formal risk analysis, risk-based screening steps were performed.

Frequency of Detection

Chemicals that were not detected in any sample for a particular medium were not considered as COPCs. Benzene was considered a special case and further discussion is provided below. Determinations were made based upon exposure units applicable to specific scenarios. No minimum frequency cutoff criteria were applied in the COPC identification process.

Comparison to Risk-Based Concentrations

Maximum detected concentrations in exposure media were compared to conservative risk-based screening concentrations. The purpose was to reduce the number of parameters carried forward for formal assessment. Exposure media were further segregated by exposure unit for screening, where applicable. Where multiple scenarios applied to an exposure unit, RBCs based upon the most conservative of the scenarios were used. This was done to avoid formal assessment of chemicals for exposure

unit/scenario combinations where they obviously would not pose an unacceptable risk or hazard.

All screening values were based on a target risk of 1E-6 and/or a target hazard quotient of 0.1. The following paragraphs provide a detailed discussion of the screening values as well as their application. Discussions are organized by exposure medium. The intent of the screening process was to identify COPCs under current conditions.

Surface Water

Surface water (WS) screening values are presented in Table 2. The current recreational user/trespasser scenario was identified as the most conservative of those that may involve exposure to surface water bodies in the vicinity of the ELMCO facility. Screening values for surface water were computed using assumptions and equations shown in Table 3 along with toxicological values and chemical-specific factors provided in Tables 4 and 5. The exposure assumptions were based on recreational use by a 0 to 6 year old child for non-carcinogenic endpoints or an integrated child/adult (30 year exposure duration; 6 years as child, 24 years as adult) for carcinogenic endpoints.

The screening process addressed Liberty Creek and the Harpeth River separately. The former is not a navigable stream, is characterized by variable (although generally low) flow and is most likely to be frequented by children and adults residing in the vicinity. The latter is a sizeable water body reportedly used regularly for canoeing and recreational angling. Available data also indicates they have been differentially impacted by the ELMCO site.

Data derived from five 2008 (monthly – January through May) sampling events in Liberty Creek were used. For the Harpeth River, data from the last four sampling events (October, November and December 2007; March 2008) were used. These data collected by TriAD and TDEC were considered most representative of current conditions. Plans and findings for these investigations are detailed under separate cover. The results of the surface water screening analyses are presented in Tables 6 and 7. Toluene was identified as the sole COPC in Liberty Creek surface water. No COPCs were indicated for the Harpeth River.

Air

Air screening values are presented in Table 2. The current residential scenario was identified as the most conservative of those that may involve exposure via air pathways in the vicinity of the ELMCO facility. Screening values for air were computed using assumptions and equations shown in Table 8 along with toxicological values provided in Table 4. The exposure assumptions were based on a 0 to 6 year old child for non-carcinogenic endpoints or an integrated child/adult (30 year exposure duration; 6 years as child, 24 years as adult) for carcinogenic endpoints.

The screening process addressed air exposure based on three datasets. In March 2007, two-day time-integrated average air sampling was performed in the BGA with school air (AS) samples from six unspecified locations. No work plan or formal report was

received regarding the BGA air monitoring. These data collected by EHS Services, LLC were considered representative of current ambient conditions. Residential air (AR) samples (24 hour time-integrated average) were collected from one crawlspace and two basements in Daniels Drive homes in April 2007. In accordance with a TDEC-approved work plan, intensive ambient air (AA) sampling was performed along the Liberty Creek corridor and between Daniels Drive and the Harpeth River in the spring of 2008. Weekly 7-day time-integrated average samples were collected from April 21 and May 19, 2008. These data collected by EnSafe were considered representative of current ambient conditions. Plans and findings for these investigations are detailed under separate cover.

The results of the air screening analyses are presented in Tables 9, 10 and 11. Toluene was identified as the sole COPC in ambient air only. No COPCs were indicated for school or residential air. It should be noted that the detection limits for benzene and acetone exceeded the screening values in some instances. Further discussions regarding this observation are provided in the Uncertainty section.

2.2 EXPOSURE ASSESSMENT

The purpose of the exposure assessment was to identify receptors and to estimate potential exposures under plausible current and future exposure scenarios. Consistent with RAGS Part A, exposure assessment was conducted in three steps: 1) characterization of exposure setting; 2) identification of exposure pathways; and 3) quantification of exposure.

Characterization of Exposure Setting

Local Land Use and Description

Details regarding the location, demographics and physical characteristics of the site are provided in the CAP. The following summarizes those aspects of the site that are most critical for assessing potential current and future exposures.

The site consists of the ELMCO facility, the residential properties along Daniels Drive and the Liberty Creek and Harpeth River corridors within the area of documented environmental impact. The BGA school was considered to be within the Liberty Creek corridor.

Exposure Areas and Potential Receptors

Based on the outcome of the screening analyses, the relevant exposure areas (or units – EU) include Liberty Creek (WS) and outside areas along the Liberty Creek and Harpeth River corridors (AA).

Potential surface water receptors are local children and adult residents who may also use Liberty Creek for recreational purposes. Those same local residents along with school children at BGA represent the primary receptors via air pathways.

Sensitive Subpopulations

Infants and small children are more susceptible to the toxic effects of some chemicals in the environment. Current residential and recreational scenarios recognize that residences exist on or in close proximity to areas where COPCs were identified in affected media. As a result, risks to children under the age of 7 were evaluated. However, because of access restrictions, distance to existing residences/schools and topography, children under 5 are unlikely to regularly contact surface waters.

Identification of Exposure Pathways

Exposure pathways link a source or contaminated medium to an exposed individual or receptor. This is done based on the location and nature of the contaminated media and the types and patterns of human activity. In order to complete a pathway, a source, affected medium, point of contact and effective exposure route must exist. The sources of contamination associated with the ELMCO site are discussed in the CAP. For purposes of the HHRA, it was assumed that current conditions are (and will be) representative of exposure media for all future exposure scenarios. As a consequence, no formal fate and transport or source dissipation modeling was used to predict exposures. It should be noted, however, that decreasing concentration trends have been observed in seeps along Liberty Creek and the Harpeth River. Because these features represent the primary sources of contaminants to both surface water and ambient air, continued declines would be expected to result in reduced levels in exposure media.

Affected Media

Each environmental medium investigated as part of the ELMCO studies was found to be affected to some extent by volatile organic compounds. Based on the results of the screening analyses, the media addressed in the HHRA were as follows:

- **Surface Water** samples collected in Liberty Creek were found to have elevated concentrations of toluene, some above conservative risk-based concentrations.
- **Ambient Air** samples collected from along Liberty Creek, just southeast of the BGA building, and west and south of Daniels Drive residences were found to have detectable concentrations of toluene, some above conservative risk-based concentrations.

Exposure Points and Routes

The exposure points for each medium were established as the contaminated areas or media in the respective EUs. Exposure routes evaluated in the HHRA included the following:

- Incidental ingestion of COPCs in Liberty Creek surface water
- Dermal contact with COPCs in Liberty Creek surface water
- Inhalation of COPCs in ambient air in the Liberty Creek and Harpeth River corridors

Individual exposure to contaminated media varied between receptor populations, exposure scenarios and EUs.

Detailed Exposure Scenarios

Exposure scenarios were constructed based upon the conceptual site model; considering specific receptors, activities, exposure units and timeframes. A single conservative scenario was evaluated.

- **Current Resident:** This scenario assumed that individuals residing along Daniels Drive would be the primary receptors. The receptor populations will be children and adults. Primary exposures will be to ambient air under standard residential conditions. In addition, the receptors will occasionally enter Liberty Creek for recreational purposes. During these excursions, individuals will be exposed to surface water via incidental ingestion and dermal contact.

No additional (less conservative) scenarios were addressed based on findings for the current residential receptor.

Quantification of Exposure

Chemical exposures were quantified as chronic daily intakes (CDI) for each applicable exposure scenario, pathway and route consistent with USEPA guidance (USEPA 1989). The primary calculations were based on 'reasonable maximum exposure' (RME) in each case. Where associated RME risk and/or hazard were subsequently found to exceed project targets, results are discussed in the Risk Characterization and Uncertainty Analysis sections.

The CDI were computed for non-cancer health endpoints, as no carcinogenic COPCs were identified. Exposures to non-carcinogen exposures are averaged over the exposure duration only. Where receptors in two different age groups were potentially applicable to a scenario, exposures to non-carcinogens were quantified based upon the younger group (ex. children for current residential/recreational use scenarios). This approach is conservative in that the younger age groups have higher exposure rates (gross or in relation to body weight).

Tables 3 and 8 provide the exposure assumptions and formulae used to quantify RME exposure via surface water ingestion and dermal contact, and ambient air inhalation routes. Chemical-specific exposure inputs are provided in Table 5.

Exposure Point Concentrations

The concentration term in each exposure CDI equation is intended to represent the average that may be contacted over the exposure duration. Due to the uncertainties associated with these estimates, the 95% upper confidence limit (UCL) of the mean is most commonly used as the exposure point concentration (EPC) for RME exposure estimates (USEPA 2002). For the HHRA, ProUCL Version 3.0 (ProUCL) (USEPA 2004a) was used to compute UCL values for each parameter and scenario. ProUCL uses the 'W test' ($n \leq 50$) or Lilliefors test ($n > 50$) statistics to test for normal and lognormal data distributions. If the data do not fit the conventional distributions, it also tests for the gamma distribution which is often better suited to positively skewed environmental data

using the Anderson-Darling or Kolmogorov-Smirnov test. UCL mean concentrations are computed using various parametric and non-parametric methods. Depending upon the results of the normality testing, the program recommends a particular UCL estimate as most appropriate given the data distribution for a parameter.

It was assumed that all datasets tested represented a single population and were derived from a random sample of each medium. Uniform exposure throughout the applicable EU(s) was assumed when applying EPCs for CDI estimation. The recommended UCL estimate was used to quantify RME exposure for each scenario and medium either directly or indirectly where time-weighted average (TWA) exposures were addressed.

For surface water, toluene results for each of the 2008 Liberty Creek sampling events were used to compute the EPC. To add further conservatism, only data for sampling stations downstream of the main seep were considered. For ambient air, toluene results for the four sampling events conducted between April 28 and May 19, 2008 were used. The EPC was computed as the UCL of the mean for all locations over time. This approach is expected to overpredict chronic residential exposure as the highest concentrations were consistently reported at location TI-2A; along Liberty Creek outside the area likely to be frequented by residents or school children.

Tables 12 and 13 summarize general statistics, and RME EPC values for surface water and ambient air, respectively along with the specific statistics and rationale used to compute them.

Chronic Daily Intakes

The formulae and EPC values were combined to compute CDI for each relevant scenario, exposure unit, medium and route. The outputs of this step for RME assumptions are presented in Tables 14 and 15 for surface water and ambient air, respectively. Additional discussion is provided in the Risk Characterization and Uncertainty Analysis sections.

2.3 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to evaluate available information regarding the potential for COPCs to cause adverse health effects and provide an estimate of the relationship between the magnitude of exposure and the probability (or severity) of the effect. In accordance with guidance (USEPA 1989), this assessment was performed in two steps.

The first step, hazard assessment, involves determination of whether an exposure can cause an increase in an adverse health effect and if the effect will manifest in humans. This amounts to a general causation analysis with consideration given to the nature and strength of evidence. The second step, dose-response evaluation, is a quantitative evaluation of toxicity data aimed at determining the relationship between dose and the degree of adverse effect in the exposed population. From this analysis, reference doses (RfD) for non-carcinogens and slope factors (SF) for carcinogens are derived. These values allow for estimation of non-carcinogenic hazard or carcinogenic risk as a function

of exposure. Cancer and non-cancer effects are assessed separately, although some chemicals may cause both types of effect.

Chemical toxicity information used in the HHRA is presented in Table 4. These values were used to compute conservative screening values as well as to perform the quantitative risk assessment. SF and RfD values are provided along with other chemical-specific factors that support route-specific analysis. The primary source of toxicity values was USEPA's Integrated Risk Information System (IRIS). Other sources were used when information was not available in IRIS. The derivation of these values is provided in referenced documents.

Non-Carcinogenic Effects

Non-cancer effects include all health effects that are not cancer. For most non-carcinogens, the human body is capable of detoxifying or otherwise protecting itself against the potential harmful effect. A threshold level typically exists above which these mechanisms are no longer able to protect the exposed individual. Common effects are organ toxicity (kidney, liver, heart), blood disorders, central nervous system disorders (permanent damage or transient impairment), reproductive toxicity and developmental effects (retarded growth, defects). The threshold concept has been rejected in some instances citing the difficulty of empirically distinguishing a true threshold from a dose-response curve that is nonlinear at low doses (USEPA 1996, 1998).

Reference doses are derived based on experimental no observed or lowest observed adverse effect levels (NOAEL and LOAEL). Ideally, experiments would be based on human subjects under chronic exposure conditions with a well-defined lower limit of toxic response (NOAEL) identified. However, very few such studies of adequate quality have been performed. As a result, most toxicological data used to derive RfDs have been obtained from chronic (or acute) animal studies.

In order to account for uncertainties related to sub-chronic experimental exposure, failure to identify an NOAEL/use of an LOAEL, extrapolation from animal species to humans and sensitive human populations, RfDs typically reflect a series of uncertainty (or safety) factors ranging from 1 to 10. A modifying factor may also be applied to reflect the weaknesses or strengths of the associated toxicological database. The RfD is computed as the NOAEL (or LOAEL) divided by the product of all applicable uncertainty and modifying factors.

Although sub-chronic (2 weeks to 7 years) and acute (less than 2 weeks) RfDs have been developed for some chemicals, only chronic RfDs (in units of mg/kg-day) were used for the HHRA based upon the proposed risk characterization approach. Oral and inhalation RfDs were used in the evaluation. They are provided in Table 4 along with uncertainty/modifying factors, target organs/effects and references.

Carcinogenic Effects

A slope factor and the accompanying weight-of-evidence determination are the toxicity data most commonly used to evaluate potential human carcinogenic risks. The basic

methods EPA uses to derive these values are outlined below. Additional detail is provided in USEPA's *Guidelines for Carcinogen Risk Assessment* (EPA 1986 and 2005).

In general, estimates of carcinogenicity are not based on a threshold assumption. Exposure at any magnitude is thought to present some potential for carcinogenesis. A weight-of-evidence classification has historically been assigned based upon the strength of supporting human and/or animal data available for a chemical. The following classifications were defined by USEPA 1986:

- Group A: Known human carcinogen
- Group B: Probable human carcinogen
 - Group B1: Limited evidence/data regarding carcinogenicity in humans
 - Group B2: Sufficient evidence in animals and inadequate or no evidence in humans
- Group C: Possible human carcinogen
- Group D: No classifiable as to human carcinogenicity
- Group E: Evidence of noncarcinogenicity for humans

For chemicals falling in Groups A, B and sometimes C, slope factors are derived using mathematical models to extrapolate from responses in high dose animal studies to responses anticipated at relatively low dose human environmental exposures. Slope factors represent the 95% upper confidence limit of the slope of the dose-response curve for a specific exposure route (oral or inhalation). USEPA has traditionally used the linearized multistage model for this application which has been shown to be conservative (i.e., predicts higher cancer potency) than other available models.

In 2005, USEPA issued updated guidelines on carcinogen risk assessment (USEPA 2005). The highlights of the changes are:

- Consideration of all potentially relevant biological information. In addition to tumor data, data indicating other responses are to be used and modeled if they may be a measure of carcinogenic risk
- Mode of action is emphasized in order to ensure the mechanisms and uncertainties associated with a chemical's likelihood to cause harm are considered in the dose-response approach

The alphanumeric weight-of-evidence classification has been replaced by a weight-of-evidence narrative. Five standardized hazard descriptors are recommended: Carcinogenic to Humans, Likely to Be Carcinogenic to Humans, Suggestive Evidence of Carcinogenic Potential, Inadequate Information to Assess Carcinogenic Potential and Not Likely to Be Carcinogenic to Humans.

- The narrative also summarizes hazard assessment results and provides a conclusion regarding the human carcinogenic potential on a route-specific basis. The types of evidence considered and how it was used to draw conclusions are discussed. The

significant issues/strengths/limitations of data and conclusions and the mode of action information are summarized to support the dose-response approach.

- Various dose-response assessment options are provided. Extrapolation is based on extension of a biologically based model if supported by substantial data. Otherwise, default approaches can be applied that are consistent with current understanding of mode(s) of action of the agent, including approaches that assume linearity or nonlinearity of the dose-response relationship, or both.

Oral slope factors for COPCs (in units of (mg/kg-day)⁻¹) are provided in Table 4 along with references. Alphanumeric weight-of-evidence classifications are also presented. As of yet, the revised weight-of-evidence guidelines are not reflected in the primary toxicological information sources for many chemicals.

Dermal Toxicity Values

Dermal exposures are calculated based on absorbed dose. As a result, oral toxicity values must be modified to reflect absorbed rather than administered dose. Oral RfDs were converted to their absorbed equivalent as (USEPA 1992, 2004b):

$$\text{Oral RfD} \times \text{Gastrointestinal Absorption Factor} = \text{Dermal RfD (mg/kg-day)}$$

Similarly, oral SFs were adjusted to represent absorbed dose as:

$$\text{Oral SF/Gastrointestinal Absorption Factor} = \text{Dermal SF (mg/kg-day)}^{-1}$$

Absorption factors and dermal toxicity values used in the HHRA are presented in Table 4 along with related source references.

Toxicological Profiles

Basic toxicological profiles were obtained from ORNL on-line database service June 2008. Each was reviewed and supplemented to reflect project-specific assumptions and/or updated toxicological or chemical characteristic data prior to use. The general characteristics and toxicological effects of the COPCs are summarized in Attachment B.

2.4 RISK CHARACTERIZATION

Risk characterization combines the outputs of the exposure and toxicity assessments to estimate the potential for adverse effects in the exposed populations. The output of risk characterization provides the key elements for risk management and supports remedial decision-making. Non-carcinogenic and carcinogenic risks are predicted and evaluated separately. No carcinogenic COPCs were identified through the screening process.

Non-Cancer Effects

Non-cancer health effects were evaluated through comparison of estimated intake with the reference dose. The ratio (CDI/RfD) is called the hazard quotient (HQ). The HQ is a simple numerical index used to determine whether exposure presents a potential health

risk. It does not, however, represent the probability or severity of the effect. When the HQ exceeds 1, the potential exists for non-cancer health risks.

When non-cancer effects associated with exposure to multiple chemicals are possible, they are estimated by a hazard index (HI). The HI is a summation of the individual HQs associated with exposure to all chemicals through all related and relevant exposure pathways. This assumption of additive effect does not consider synergistic or antagonistic mechanisms.

An HI above 1 indicates that a potential health risk may be posed. HI greater than 1 must be interpreted with caution, however, because the dose-response curves and the target organ/primary effects for the individual chemicals may differ. Additionally, uncertainty and modifying factors often differ by orders of magnitude (as a function of experimental conditions and overall database quality) between chemicals indicating the RfDs vary in terms of the level of confidence that can be placed in them. When an HI exceeds 1, USEPA guidance recommends that the non-cancer hazard assessment further segregate based on common target organ or effect. This was not an issue for the ELMCO HHRA as only a single COPC was identified.

Cancer Risks

For carcinogens, USEPA has established a target risk range of 10^{-4} to 10^{-6} (1 in 10000 to 1 in 1000000 chance of developing cancer). Generally, risks below 10^{-6} warrant no further action while those above 10^{-4} indicate some form of action will be needed. Cancer risks within the range may not warrant remedial action. For the ELMCO HHRA, a cancer risk target of 10^{-5} (1 in 100000) was established. Because no carcinogenic COPCs were identified, however, no discussion of cancer risk is provided.

Risk Characterization Results

Hazard (along with CDI) calculations for surface water and ambient air routes are presented in Tables 14 and 15, respectively. Total non-cancer hazard estimates were rounded to the nearest single digit. Discussions focus on risk and hazard associated with 'reasonable maximum exposure' (RME) unless otherwise specified. Risk and hazard summaries are discussed below.

Current Resident: Non-cancer hazard associated with exposure to surface water and ambient air may be summarized as follows:

- *Non-cancer HI*
 - 0.5: Associated primarily with exposure to toluene in surface water (HQ = 0.4).
- *Chemicals of Concern:* None
- *Discussion:* Non-cancer findings are not actionable as the hazard index was less than 1. Conservative EPC assumptions for both surface water and ambient air increase the confidence in this conclusion. Only data from surface water locations expected to be

maximally impacted were considered. Ambient air results from areas proximal to residences were consistently below risk-based screening values. Only one of four recent samples collected near the BGA school exceeded the toluene screening value.

Table 16 provides a summary of cancer risk, non-carcinogenic hazard and chemicals of concern (COC) for the current resident scenario under RME assumptions.

2.5 UNCERTAINTY ANALYSIS

Inherent in any risk evaluation are uncertainties related to the data used, exposure assessment assumptions made, toxicological values applied and the general characterization framework. The following discusses some of the primary sources of uncertainty related to the HHRA.

Uncertainties Associated with Data Used

Data Quality Issues

Censored data were handled in a consistent manner. One-half the detection (or reporting) was substituted for non-detect results. Where limits were inadequate to allow for definitive risk-based screening (human health and/or ecological), non-detect data were excluded from the final statistical dataset.

Analytical suites differed between studies and media. Aqueous media were generally analyzed for all compounds included in the USEPA 8260B method. For air samples, focus was placed on the primary contaminants (acetone and toluene) and benzene. Where a particular group of contaminants (ex. semi-volatiles) was not analyzed, it was assumed that the associated compounds were not present. This is a reasonable assumption as analytical suites were ostensibly determined based upon the suspected contaminant sources.

All data used to perform the HHRA were subjected to some degree of data quality assessment. However, no formal data validation or quality assessment reports were provided.

For ELMCO (and related) studies, quantification targets were generally adequate to provide for definitive screening assessment. An exception was consistently noted for benzene in air samples. The benzene detection limits were as follows for the various air sampling studies that produced data used in the HHRA.

Air Locations	Dates	Detection Limits	Units
BGA School	3/7/2007	0.094 – 0.26	mg/m3
Residences	4/12/2007	0.04	mg/m3
Ambient	4/28-5/19/2008	0.006	mg/m3

Based on these limits, definitive screening against a conservative risk-based concentration (0.00031 mg/m3) was not possible. In order to evaluate the subject further,

a simplifying assumption was made that the ratio of toluene to benzene in air samples would be comparable to that in the source term (Henry’s law constants are similar).

The source of airborne toluene and benzene would be expected to be seeps or impacted surface water in the area. Toluene/benzene (T/B) ratios were computed for associated sources during periods around each of the air sampling events. Results were also spatially segregated with Liberty Creek results compared with nearby air monitoring locations (BGA, Residences and TI-1, -2A, 3 and 4) and Harpeth River seep results associated with monitoring location TI-5. Reported airborne toluene results were then divided by the respective ratios to estimate the maximum potential benzene concentration in air.

As shown below, the predicted maximum benzene concentration for each sampling event and area was below the conservative screening value. It is important to note that benzene was not detected in any of the 41 air samples collected to date in the vicinity of the ELMCO facility. Although some uncertainty remains due to the theoretical basis of the estimates, the results of this analysis provide some confidence that airborne benzene concentrations were below health protective levels during previous air monitoring events.

Area	Assumed Source Medium	Dates	Mean T/B Ratio	Average Air Toluene		Estimated Benzene Level	Units
Liberty Creek	Seep	5/18-24/2007	776	0.0613	a,b	0.000079	mg/m3
	Surface water	5/18-24/2007	420	0.0613	a,b	0.00014	mg/m3
Liberty Creek	Seep	5/18-24/2007	776	0.073	c	0.000094	mg/m3
	Surface water	5/18-24/2007	420	0.073	c	0.00017	mg/m3
Liberty Creek	Seep	1/28-5/7/2008	510	0.1033	d	0.0002	mg/m3
	Surface water	1/28-5/7/2008	471	0.1033	d	0.00022	mg/m3
Harpeth River	Seep	1/28-5/7/2008	420	0.015	e	0.000049	mg/m3

Notes:

- a – applies to BGA school (AS) results (3/7/2007)
- b - 5 of 6 non-detect for toluene
- c – applies to samples collected from residences (AR) (4/12/2007)
- d – applies to ambient air samples from locations TI-1, TI-2A, TI-3 and TI-4 (4/28-5/19/2008)
- e – applies to ambient air samples from location TI-5 (4/28-5/19/2008)

Sampling Design Issues

Current site conditions were established as those that existed during most recent sampling events for each medium. In some instances (residential and school air), substantial source reductions have occurred since the sampling events relied upon for the HHRA. As a result, higher confidence can be placed in the screening level conclusions for those media.

Contaminated soils also exist in the Liberty Creek floodplain, including at the seep locations and a soil pile from excavation of an interceptor trench. However, the soils in this area – which is being actively used to remediate the subsurface flow of free-product solvent – have not yet been adequately characterized, and are not addressed in this assessment. The area is fenced to prevent access as cleanup actions continue. Based on the characteristics of the primary contaminants, significant volatilization from surface

materials would be expected and EPCs may be relatively low. Lack of data for these areas does, however, add uncertainty to the overall assessment.

The surface water and air sampling efforts employed a biased approach; using a judgment or search based sampling design rather than random allocation of samples. For surface water and ambient air, additional randomly allocated sample locations would have been expected to produce lower results. As a result, the sampling approach employed is considered conservative.

Three households were monitored for residential air quality. The residences and sampling points were preferentially selected to represent 'worst-case' conditions. Homes directly over or adjacent the limestone 'cutter' believed to have conveyed free product from the ELMCO pipe leak area to seeps along Liberty Creek were chosen. Within each home, areas expected to provide reasonable maximum concentration estimates, including basements or crawlspaces, were monitored. In some instances, alternate household sources (paint thinners, gas cans) of detected compounds were present but this information was not used to qualify findings. Although there is some potential for preferential migration paths that may not have been captured in the investigative scope, the biased approach to sampling, observed dissipation in the strength of sources that might affect vapor intrusion potential, and detected concentrations consistently below actionable levels lend confidence to associated conclusions.

Exposure Assessment

The exposure assessment defined the conditions under which individuals could come into contact with affected media. The definition of these conditions had a significant bearing on exposure estimates. The following paragraphs discuss specific aspects of the exposure assessment that introduce uncertainty in the screening evaluation.

Exposure Routes/Pathways

Soil pathways were discounted due to the subsurface nature of the original release. As a result, no formal analysis was performed. It is possible that soils immediately surrounding seeps could be affected. These materials would represent a small fraction of the total soil area to which an individual may be exposed. Furthermore, the volatile nature of the primary contaminants would likely lead to rapid loss. As a result, omission of soil pathways is not expected to result in significant underestimation of overall risk. Groundwater is not currently used for any purpose as discussed earlier.

Exposure Assumptions

No site-specific information was available upon which to base exposure assessment assumptions. Default exposure assumptions were used where applicable to the exposure scenarios developed. In the absence of default values or where they lacked site-specific applicability, best professional judgment was used. Primary exposure assumptions were selected to reflect reasonable maximum exposure.

For direct ambient air-related routes, standard conservative default assumptions were generally used to quantify exposure. Due to the characteristics of Liberty Creek, surface

water exposure assumptions were chosen to reflect infrequent wading. Use of default body weight and ingestion/inhalation rates could overestimate or underestimate average exposure. These assumptions are expected to provide a reasonably conservative outcome on average although exposure frequencies may be the least certain of the primary assumptions.

Scenario- and Receptor-Specific Assumptions

Residential

Adverse weather conditions, modern activity patterns and time spent away from the home would all suggest that a residential exposure frequency of 350 days/year is extremely conservative. Children (and adults) are unlikely to spend much time outdoors on rainy, snowy or cold days. Furthermore, recent studies have shown that children spend far less time outside in general than was the case in previous generations. The ambient air inhalation rates assumed are expected to overestimate exposure. Household air quality results were lower than those for ambient air. All these factors combined would suggest overestimation of air-related exposure based on default assumptions.

Recreational

Due to the lack of specific information regarding trespasser access to the site, conservative exposure frequency assumptions were made for children and adults (50 days/year). Topography and the lack of a fishery in Liberty Creek would tend to limit its attractiveness for frequent recreational activity. As a consequence, assumptions and remedial decisions based upon them are expected to remain conservative. The chance that future recreational use-related hazard and/or risk are overestimated based on these assumptions is moderate. Recreational exposure frequency will be dependent upon access controls and the key features that might draw individuals to the site.

For recreational users, it was assumed that all exposure, during these activities, would be in the most heavily contaminated portions of Liberty Creek. It is more likely that these individuals would spend only a fraction of their time downstream of the seeps with the remainder spent in other reaches without significant contamination. As a result, exposure to site-related contaminants would be less than estimated and the BRA would overestimate average daily exposure to COPCs.

Exposure Point Concentrations

For each area/medium, it was assumed that most recent results were representative of the range and distribution that would be observed in a random sample. Random exposure throughout the respective exposure units was assumed for all scenarios. In the case of future residential uses, the decision scale may be smaller than the EU defined by the air sampling network. As stated earlier, ambient air results from areas immediately adjacent Daniels Drive homes were consistently lower than observed at other locations. As a result, the air EPC is expected to overstate long-term residential exposure.

With respect to recreational activities, certain surface water features may lead individuals to return to particular locations more often rather than being uniformly exposed to materials throughout the Liberty Creek corridor. Conversely, some locations may

seldom, if ever, be visited. The biased sampling design which excluded upstream (background) locations and use of data only from the most heavily impact stream reaches likely resulted in a positively biased estimate of surface water concentrations that may be contacted on a long-term basis.

Ambient air and surface water concentrations are expected to decline as the strength of principal sources (stream bank seeps) continue to dissipate. Over the long-term, this should result in reduced exposure to local receptors.

Uncertainties Associated with Toxicity Assessment

Considerable uncertainty can be attributed to the toxicological values used in risk evaluation. Their derivation often relies on extrapolation of acute responses to chronic responses, between species or populations (general to sensitive or vice versa) and from dosing sequences or rates not representative of exposure in the context of environmental contamination. The following discussions provide details relevant to the ELMCO HHRA.

Derivation of reference doses (RfD) usually involves animal study results. Uncertainty factors (UF) are applied to provide additional margins of safety when extrapolating results to the human population. UF are assigned based on the study subjects (animal/human) and duration (acute/chronic). Modifying factors (MF) may also be assigned to reflect deficiencies in the studies or general toxicological database related to potential adverse effects. The higher the combined UF/MF, the less confidence that can be placed in the applicability to humans under chronic exposure conditions. Factors for constituents detected in the Isabella FFS area ranged from 300 (benzene) to 3,000 (toluene).

Uncertainties Associated with the Risk Evaluation

The HHRA was structured to provide conclusions under the conservative assumption of reasonable maximum exposure. The use of biased sampling results with an investigative focus on more impacted areas adds further to the conservatism of the evaluation.

2.6 HHRA CONCLUSIONS

Based on screening analysis, toluene was the only COPC identified for ambient air and surface water-related pathways, and it poses only non-cancer risks. Non-cancer risks were quantified with a cumulative hazard index of less than 1; indicating no action was required to protect human health. Some uncertainty exists due to various factors including less than optimal benzene quantitation limits in air and the absence of soil data adjacent seeps. There are currently no documented groundwater uses on or in the vicinity of the ELMCO facility. Municipal water is available to local residents and a review found that it was the exclusive source of potable supply in the area. As a consequence, no completed groundwater exposure pathways were identified and no quantitative assessment of groundwater risks was performed. In the event of any proposed changes in local groundwater use, additional evaluation may be warranted.

3.0 ECOLOGICAL RISK ASSESSMENT

The purpose of the streamlined ecological risk assessment (ERA) is to provide risk-based interpretations of site data and conservative estimates of risk posed by chemicals present in site media. The assessment was performed in general accordance with guidance available from USEPA (USEPA 1997, 1998, 1999).

3.1 PROBLEM FORMULATION

Site Background

The site background and physical setting are discussed in the introductory text and the CAP.

Management Goal, Assessment Endpoints and Measures of Effect

The ERA was designed to support the remedial action objective for the ELMCO facility CAP. Due to the nature of the release from the former transfer pipe leak at the facility as well as chemical characteristics, the sole focus of the ERA was surface water-related resources. The objective addressed in this ERA is:

- Protect aquatic receptors in Liberty Creek and the Harpeth River from volatile organic compounds entering the respective water bodies through bank seeps.

The remedial decision associated with this objective is:

- What actions (if any) are necessary to control introduction of volatile organic compounds to streams surrounding the ELMCO facility and/or to remove said contaminants once they enter?

The assessment endpoints relevant to supporting these decisions are:

- Diversity and productivity of benthic macroinvertebrate communities,
- Survival and reproduction of fish.

The benthic macroinvertebrate and fish communities are to be protected or restored so that they are comparable to those which would be reasonably anticipated in each of the subject streams.

Concentrations of chemicals in surface water are the measurement endpoints for each assessment endpoint. Based on the streamlined nature of the ERA, no species-specific dose-response evaluations were performed. Previous TDEC findings and statements, as documented in responses to comments on the original CAP submittal, were also incorporated to reach conclusions regarding the current risks posed to aquatic ecosystems.

Identification of Chemicals of Potential Ecological Concern (COPECs)

The same datasets assembled to support the human health risk assessment were used for the ERA. Data considered for inclusion in the ERA are presented in Attachment A. Background screening was not incorporated into the COPEC selection process as no reference locations have been sampled to date. Additional screening was performed to reduce the number of chemicals addressed in the ERA; these steps are discussed below.

Frequency of Detection

Chemicals that were not detected in any sample were not considered; no formal minimum frequency cutoff criteria were applied in the COPEC identification process. Frequency of detection was, however, considered as a supplemental criterion for eliminating some chemicals from formal assessment.

Comparison to Risk-Based Concentrations

Maximum detected concentrations in exposure media were compared to conservative risk-based screening concentrations. All screening values were based on NOAEL levels where available. A detailed discussion of the screening values as well as their application is provided below.

Surface-water data were screened by comparing maximum detected concentrations to conservative ecological benchmarks. TDEC (2006) and USEPA (2006) water quality criteria (WQC) were reviewed as the primary sources for screening values. None of the chemicals present in surface water was found to have a numeric WQC relevant to protection of fish and aquatic life. Other sources were used in order to provide values for as many detected chemicals as possible. Screening values used in this assessment are presented in Table 17.

The screening process addressed Liberty Creek and the Harpeth River separately. The former is a small suburban tributary stream characterized by variable (although generally low) flow which has been impacted by seeps emanating from its left (east) bank. According to TDEC, the stream has not and currently does not support a resident sport fishery. The latter is a sizeable water body reportedly capable of sustaining a sport fishery. Available data also indicates they have been differentially impacted by the ELMCO site.

The results of the surface water screening analyses are presented in Tables 18 and 19. Acetone and toluene were identified as COPECs in Liberty Creek surface water. Toluene was the sole COPEC indicated for the Harpeth River.

3.2 ANALYSIS

The analysis step involved characterizing the habitat types present in the watershed, quantifying potential exposure, and evaluating the potential effects of the exposures on representative types of exposed organisms.

Ecosystem Characterization

The only habitat type considered for either watershed was riverine. The streams addressed in the ERA are described below.

Liberty Creek is a characteristic small suburban stream with flashy flow in response to storm events and subject to numerous insults. The stream is generally shallow (< 1 foot) with an incised channel. Riffles are relatively infrequent spaced between sluggish runs and/or stagnant pools; particularly during low flow periods. Limited observation indicates riparian vegetative cover is generally good although the canopy is limited in some areas. Stream hydrodynamics lead to frequent reshaping of gravel (and finer) substrates in response to storms and there is visual evidence of past channelization. Insults may include fertilizers and lawn care chemicals, road wash and general sedimentation along with elevated temperatures exacerbated by its shallow depth and incomplete canopy. In low velocity reaches, substrates have been observed to be covered by a mix of inorganic sediments and organic detrital matter; the latter potentially responsible for a sewage odor. These factors may also create low dissolved oxygen conditions in some reaches. Based on qualitative observations, Liberty Creek conditions are generally fair to poor throughout its watershed. As a consequence, the reference watershed aquatic ecosystem would be expected to be less than optimal.

The Harpeth River is prominent regional feature with an 870 square mile watershed and a total length of 125 miles. It winds through the City of Franklin passing just south of the ELMCO facility. In the vicinity of the site, it has a narrow riparian corridor regularly infringed upon by development including lawns, roadways, buildings and parking areas. Due to its size, canopy cover is incomplete for the entire subject reach. During the 2007 drought, flow near the site was measured at less than 5 cubic feet per second (cfs) although the norm is likely in excess of 100 cfs. The Harpeth is subject to the same insults as Liberty Creek over a broader area. Low dissolved oxygen episodes have been documented during warm weather periods in areas unaffected by the ELMCO facility. No specific reconnaissance has been performed to assess in-stream conditions. The preceding factors suggest that the reference Harpeth River aquatic ecosystem would be less than ideal.

Exposure Characterization

Potential exposures to surface water receptors were quantified based on individual sample results rather than on area-wide or site-wide averages. For Liberty Creek, results from five 2008 sampling events were used. Data from four Harpeth River sampling events (10/21/2007 – 3/18/2008) were considered. Aquatic organisms were assumed to be exposed to water present at the sampled locations throughout their lifetimes.

Effects Characterization

Surface water-related effects were characterized based upon multiple lines of evidence. The first was comparison to chronic water quality criteria or, if no criterion was available, screening benchmarks obtained from EPA Region IV or other sources. These values were identical to those used for COPEC screening. Other lines of evidence included

toxicity tests performed by TDEC as well as technical conclusions rendered by TDEC in response to comments on the previous CAP submittal.

3.3 RISK CHARACTERIZATION

The risk characterizations for Liberty Creek and the Harpeth River are presented separately. The preceding problem formulation and ecosystem, exposure and effects characterizations were combined to quantify ecological risk associated with contaminated surface water in each stream.

A hazard quotient/hazard index (HQ/HI) approach was used to estimate potential surface water toxicity/risk. HQ values were calculated for individual COPECs as follows:

$$\text{HQ} = (\text{detected concentration} / \text{chronic ecological screening value})$$

HI values are the sum of risks from all COPECs and were calculated as follows:

$$\text{HI} = \Sigma \text{HQ}$$

Toxic effects were assumed to be additive for all COPECs regardless of the toxic endpoint or exposure route.

Hazard quotients and hazard indices were computed on a sample-specific basis to facilitate temporal and spatial analysis (Table 20). An HI (or HQ) greater than 1 was considered to demonstrate possible risk to aquatic receptors. An HI above 10 was interpreted to indicate probable effects. Other lines of evidence are also discussed.

Liberty Creek

Surface water hazard indices exceeded 15 during each sampling round at all locations (Table 20). Toluene was the primary (>90%) contributor in each instance. The average HI at the 'Watergate' location (upstream of the main seep) was 25 while that at the Personnel Crossing (LC-PC) was 35. Although the average HI at 'Watergate' was lower, the computed value for this location was occasionally higher than that downstream of the main seep on the same date.

TDEC conducted acute toxicity testing using water from an unspecified location in Liberty Creek in February 2007. Slight toxicity was indicated for the water flea (*Ceriodaphnia dubia*) while the waters were not acutely toxic to fathead minnows (*Pimephales promelas*). These findings were consistent with expectations based on LC₅₀ thresholds for fish and benthic organisms provided in USEPA's AQUIRE database. It should be noted that water quality was worse at the time these tests were performed. In particular, toluene concentrations were substantially higher on average than observed in 2008.

The computed chronic HIs suggest that survival, growth and/or reproduction of aquatic life in the affected reach could be negatively impacted by long-term exposure under prevailing conditions. TDEC has previously stated that the impacts on aquatic organisms are likely to be severe downstream of source areas due to low dissolved oxygen levels

caused by proliferation (and subsequent death) of aquatic flora purportedly induced by site-related contaminants. It is not known whether low dissolved oxygen levels were confirmed.

Harpeth River

Surface water hazard indices did not exceed one (1) for any sampling event at either Harpeth River sampling location (Table 20). Toluene was the only COPEC. The maximum HIs were computed based on samples collected during low flow conditions in October/November 2007. As flow returned to more typical levels in December 2007/early 2008, instream COPEC concentrations dropped significantly. As a result, no adverse chronic (or acute) effects are predicted.

TDEC previously concluded with confidence that the COPEC concentrations observed in the Harpeth River posed no toxicity threat to aquatic life. The ERA findings were consistent with those assertions. TDEC did indicate negative effects on benthic organisms were likely in isolated areas due to low dissolved oxygen episodes associated with the proliferation (and subsequent death) of aquatic flora adjacent source seeps. No fish kills have been documented in response to these occurrences.

3.4 ERA CONCLUSIONS AND PRELIMINARY REMEDIATION GOALS

Under current conditions, fish and benthic organisms are potentially at risk in Liberty Creek due to the presence of volatile contaminants in surface water. Episodic low dissolved oxygen periods are reportedly possible where contaminants induce eutrophic conditions which could affect resident faunal populations.

In the Harpeth River, recent data does not indicate that significant risks are posed to aquatic organisms in direct association with volatile contaminants emanating from bank seeps. Low dissolved oxygen effects on benthic organisms in isolated areas immediately adjacent seeps are not expected to have a quantifiable effect on the overall river ecosystem.

In the absence of information showing that concentrations higher than the available screening levels would be protective, the water-quality screening values used in the ERA for acetone and toluene are suggested as Liberty Creek preliminary remediation goals. Toxicological data from multiple on-line sources as well as reference stream conditions suggests that the chronic screening values may be unnecessarily conservative as quantitative remedial goals. Chronic toxicity tests may be used to estimate tolerable acetone and toluene concentrations under site-specific conditions. Maintenance of dissolved oxygen at levels comparable to upstream reference areas is also recommended.

REFERENCES

- Michigan Department of Environmental Quality. 2008. Rule 57 Water Quality Values (on-line)
- National Library of Medicine Specialized Information Services (on-line database)
- Oak Ridge National Laboratory (ORNL). 2008. Regional Screening Levels for Chemical Contaminants at Superfund Sites. DOE/ORNL (on-line)
- TDEC. 2007. Notice of Deficiency and Response to Public Comments – ELMCO Groundwater Corrective Action Plan. November 20, 2007.
- TDEC. 2008. Rules of the Tennessee Department of Environment and Conservation, Tennessee Water Quality Control Board, Division of Water Pollution Control – Chapter 1200-4-3: General Water Quality Criteria. Revised June 2008.
- USEPA. 1986. Guidelines for Carcinogen Risk Assessment. Risk Assessment Forum, USEPA. FR 51(185):33992-34003, September 24, 1986
- USEPA. 1989. Risk Assessment Guidance for Superfund Volume I – Human Health Evaluation Manual (Part A) Interim Final, EPA/540/1-89/002, December 1989.
- USEPA. 1991. Standard Default Exposure Factors-Supplemental Guidance to RAGS
- USEPA. 1992. Dermal Exposure Assessment: Principles and Applications, EPA/600/8-91/011B, January 1992.
- USEPA. 1996a Guidelines for reproductive toxicity risk assessment. Federal Register 61(212):56274-56322.
- USEPA. 1997. Exposure Factors Handbook, Volumes I – III, EPA/600/P-95/002fa, August 1997.
- USEPA 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. EPA-540-R—97-006, June 1997
- USEPA. 1998. Guidelines for neurotoxicity risk assessment. Federal Register 63(93):26926-26954.
- USEPA 1998. Guidelines for Ecological Risk Assessment. EPA-630-R-95-002F, April 1998.
- USEPA. 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities – Peer Review Draft. OSWER, EPA 530-D-99-001A.
- USEPA. 2001. Risk Assessment Guidance for Superfund Volume I – Human Health Evaluation Manual (Part D – Standardized Planning, Reporting and Review of Superfund Risk Assessments) Final, December 2001
- USEPA. 2002. Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites, December 2002.
- USEPA Region V. 2003. Ecological Screening Levels – RCRA. August 2003 (on-line)

- USEPA. 2004a ProUCL 3.0 -. *A Statistical Software*. USEPA, National Exposure Research Lab, EPA, Las Vegas Nevada, October 2004.
- USEPA. 2004b. Risk Assessment Guidance for Superfund Volume I – Human Health Evaluation Manual (Part E – Supplemental Guidance for Dermal Risk Assessment) Final, EPA/540/R/99/005, July 2004.
- USEPA. 2005. Guidelines for Carcinogen Risk Assessment. EPA/630/P -03/001B, March 2005
- USEPA Region IX 2005 Preliminary Remediation Goals Tables (on-line database)
- USEPA. 2006. National Recommended Water Quality Criteria. Office of Water
- USEPA Region VI. Human Health Medium-Specific Screening Levels – March 2008 (on-line database)
- USEPA. Various. Supplemental Guidance to RAGS: Region IV Bulletins, Human Health Risk Assessment and Ecological Risk Assessment Bulletins (on-line).
- USEPA. Integrated Risk Information System (on-line database)
- USEPA, National Center for Exposure Assessment database provisional values

Table 1 - Location Descriptions, Sampling Dates and Sample Matrices
ELMCO Facility, Franklin, TN

Location Name	Location Description	Sampling Dates	Sample Matrix
AR-1	At release point	4/18/2007, 10/1/2007, 10/12/2007, 2/21/2008, 6/3/2008	WG
BGA-1	BGA interior	3/7/2007	AS
BGA-2	BGA interior	3/7/2007	AS
BGA-3	BGA interior	3/7/2007	AS
BGA-4	BGA interior	3/7/2007	AS
BGA-5	BGA interior	3/7/2007	AS
BGA-6	BGA interior	3/7/2007	AS
HR-2	Harpeth River seep, just u.s. of RR bridge	5/18/2007, 5/24/2007, 6/1/2007, 6/8/2007, 7/9/2007, 8/8/2007, 9/19/2007, 10/12/2007, 11/9/2007, 12/10/2007, 1/28/2008, 2/21/2008, 5/7/2008, 5/18/2008	SEEP
HR-3	Harpeth River seep, 175 ft. u.s. of RR bridge	5/18/2007, 5/24/2007, 6/1/2007, 6/8/2007	SEEP
LC-MS	Liberty Creek main seep	6/1/2007, 6/8/2007, 7/9/2007, 8/8/2007, 9/19/2007, 10/12/2007, 11/9/2007, 12/10/2007, 1/28/2008, 2/15/2008, 4/2/2008, 5/7/2008	SEEP
LC-MS	Liberty Creek main seep	5/18/2007, 5/24/2007	WS
LC-PC	Liberty Creek at Personnel Crossing	5/18/2007, 5/24/2007, 6/1/2007, 6/8/2007, 7/9/2007, 8/8/2007, 9/19/2007, 10/12/2007, 11/9/2007, 12/10/2007, 1/28/2008, 2/21/2008, 5/7/2008	WS
MW-1	400 ft ESE of release site (background?)	4/18/2007, 9/18/2007, 2/21/2008, 3/12/2008, 6/3/2008	WG
MW-2	50 ft S of release site	6/20/2007, 9/19/2007, 2/21/2008, 6/3/2008	WG
MW-3	150 ft N of release site	10/1/2007, 2/21/2008, 6/3/2008	WG
MW-4	Old BGA property, 900 ft NW of release site	2/21/2008, 6/3/2008	WG
MW-5	Daniels Dr., 675 ft N of release site	2/21/2008, 6/3/2008	WG
RES116	116 Daniels Dr., crawlspace	4/12/2007	AR
RES127	127 Daniels Dr., basement	4/12/2007	AR
RES131	131 Daniels Dr., basement	4/12/2007	AR
RW-1	Recovery well at release point	9/18/2007, 10/12/2007, 2/21/2008, 6/3/2008	WG
TDEC HR-A	Harpeth River, u.s. Franklin STP Outfall	10/31/2007, 11/19/2007, 12/19/2007, 3/18/2008	WS
TDEC HR-B	Harpeth River, RB seepage u.s. of Liberty Crk	3/18/2008	SEEP
TDEC HR-C	Harpeth River, u.s. Liberty Creek	10/31/2007, 11/19/2007, 12/19/2007, 3/18/2008	WS
TDEC LC-A	Liberty Creek, behind Old BGA	10/31/2007, 11/19/2007, 12/19/2007, 3/18/2008	WS
TI-1	Adjacent Old BGA School, SE corner	7/16/2007, 8/2/2007, 12/13/2007, 4/28/2008, 5/5/2008, 5/12/2008, 5/19/2008	AA
TI-2	Adjacent Old BGA School, NE corner	7/16/2007, 8/2/2007, 12/13/2007	AA
TI-2A	West side (RB) Liberty Crk at meander	4/28/2008, 5/5/2008, 5/12/2008, 5/19/2008	AA
TI-3	Near interceptor trench	7/16/2007, 8/2/2007, 12/13/2007, 4/28/2008, 5/5/2008, 5/12/2008, 5/19/2008	AA
TI-4	90 ft N of interceptor trench	7/16/2007, 8/2/2007, 12/13/2007, 4/28/2008, 5/5/2008, 5/12/2008, 5/19/2008	AA

Table 1 - Location Descriptions, Sampling Dates and Sample Matrices
ELMCO Facility, Franklin, TN

TI-5	Along Harpeth R. (RB), south of Daniels Dr.	4/28/2008, 5/5/2008, 5/12/2008, 5/19/2008	AA
TI-6	705 W. Statue (remote)	5/5/2008, 5/12/2008, 5/19/2008	AA
TI-7	115 Myles Manor (remote)	5/5/2008, 5/12/2008, 5/19/2008	AA
Watergate	Liberty Creek u.s. of main seep	11/9/2007, 12/10/2007, 1/28/2008, 2/15/2008, 4/2/2008, 5/7/2008	WS

Table 2 - Risk-Based Screening Values for Human Health Effects
ELMCO Human Health Risk Assessment

Parameter	Media	Surface Water		Air	
	Scenario	Recreational Trespasser		Residential	
	Units	mg/L		mg/m3	
	Units	HHSV	Basis	HHSV	Basis
1,2,3-Trimethylbenzene	mg/L	0.42	nc	n/a	n/a
1,2,4-Trimethylbenzene	mg/L	0.35	nc	n/a	n/a
1,3,5-Trimethylbenzene	mg/L	0.60	nc	n/a	n/a
Acetone	mg/L	370	nc	0.14	nc
Benzene	mg/L	0.046	c	0.00031	c
Di isopropyl ether	mg/L	15	nc	n/a	n/a
Ethylbenzene	mg/L	1.6	nc	n/a	n/a
Isopropylbenzene	mg/L	0.843	nc	n/a	n/a
Methylethylketone	mg/L	200	nc	n/a	n/a
n-Propylbenzene	mg/L	0.32	nc	n/a	n/a
Toluene	mg/L	2.0	nc	0.219	nc
Xylenes	mg/L	3.3	nc	n/a	n/a

Notes:

- nc - non-carcinogenic endpoint; carc - carcinogenic endpoint
- Standard exposure assumptions summarized for ELMCO were used to compute screening values unless otherwise noted
- n/a indicates not applicable

Table 3 - Exposure Factors for Recreational Trespassers – Surface Water Routes
ELMCO Human Health Risk Assessment

	Units	Child	Adult	Source
General Exposure Parameters				
Body weight (BW)	kg	15	70	Default body weight from USEPA standard exposure factors
Exposure duration (ED)	yr	6	24	Default duration assumptions for child and adolescent, adult is 30 year maximum minus child ED (where applicable)
Averaging time, non-carcinogenic (ATnc)	days	2190	--	ED x 365 days/year; most sensitive population only
Averaging time, carcinogenic (ATc)	days	25550		70 yr life expectancy x 365 days/year
Incidental Ingestion Parameters				
Water ingestion rate (IRw)	ml/hr	10		Default value for reasonable maximum exposure, wading
Parameter Concentration ([])	mg/L	Chemical-specific		Exposure point concentration
Dermal Parameters				
Skin surface area (SSA)	cm ²	5200	9070	Sum of 50 th percentile for hands, arms, head, feet, and legs
Dimensionless ratio: Kp thru stratum corneum/Kp across viable epidermis (B)	Unitless	Chemical-specific		USEPA RAGS Part E
Fraction absorbed water (FA)	Unitless	1		Assumed for all chemicals
Permeability constant (Kp)	cm/hr	Chemical-specific		10 [^] (-2.8 +0.66Kow - 0.0056 MW)
Water concentration (Cw)	mg/cm ³	Chemical-specific		Exposure point concentration; units converted
Lag time/event (τ-event)	hr/event	Chemical-specific		0.105 x 10 [^] (0.0056 x MW)
Time to reach steady state (t*)	hr/event	Chemical-specific		2.4 x τ-event; all less than 2 hr
Octanol-water partition coefficient (Kow)	Unitless	Chemical-specific		From literature
Molecular weight (MW)	g/mole	Chemical-specific		From literature
Pathway-specific Parameters				
Exposure frequency (EF)	days/yr	50	50	1 time/week for 50 weeks
Exposure time (ET)	hr/event	2		2 hours per event was assumed due to restrictions and assumed average recreational outing
Conversion factor, water (CFw)	L/ml	10 ⁻³		
Exposure Quantification (Dose) Formulae:				
Non-cancer effects, ingestion	Parameter [] x IRw x EF-c x ED-c x CFw x ET / (BW-c x ATnc-c)			
Non-cancer effects, dermal (DAD-nc)	DAevent x EV x ED x EF x SSA / (BW-c x ATnc-c)			

Table 3 - Exposure Factors for Recreational Trespassers – Surface Water Routes
ELMCO Human Health Risk Assessment

Cancer effects, ingestion	Parameter [] x IRw x ($\frac{\{EF-c \times ED-c \times ET\}}{BW-c}$) + ($\frac{\{EF-a \times ED-a \times ET-a\}}{BW-a}$) x CFw / ATc	
Cancer effects, dermal (DAD-c)	DAevent x EV x ((ED-c x EF-c x SSA-c/BW-c)+(ED-a x EF-a x SSA-a/BW-a))/ATc)	
Absorbed Dose/Event (DAevent) (ET > t*)	(mg/cm ² -event)	FA x Kp x Cw x ($\frac{[ET/1+B]+2}{1+B}$) x τ -event x ($\frac{1+3B+3B^2}{1+B^2}$)

¹ 'a' designator indicates adult exposure factor

² 'c' designator indicates child exposure factor

Table 4 - Summary of Human Health Toxicity Values for Direct Contact and Inhalation Routes
 ELMCO Facility, Franklin, TN

Parameter	RfD oral (mg/kg/d)	GI abs	Source	RfD derm (mg/kg/d)	UF/MF Factor	RfD Oral Confidence	RfD oral Source	RfD inh (mg/kg/d)	RfC inh (mg/m3)	UF/MF Factor	RfDinh/ RfC Confidence	RfD/RfC inh Source	WoE Class a	SFo (mg/kg/d)-1	SF _d (mg/kg/d)-1	SFo Source	Inhalation Unit Risk ((ug/m3)	Inhalation Unit Risk Source	Primary Target Organ	
1,2,3-Trimethylbenzene	b	0.05	1	Pt E	0.05	NA	NA	Surrogate	0.0017	NA	NA	NA	Surrogate	NA	n/a	n/a	n/a	n/a	n/a	Lungs, skin
1,2,4-Trimethylbenzene		0.05	1	Pt E	0.05	NA	NA	NCEA	0.0017	NA	NA	NA	NCEA	NA	n/a	n/a	n/a	n/a	n/a	Lungs, skin
1,3,5-Trimethylbenzene		0.05	1	Pt E	0.05	NA	NA	NCEA	0.0017	NA	NA	NA	NCEA	NA	n/a	n/a	n/a	n/a	n/a	Lungs, skin
Acetone		0.9	1	Pt E	0.90	1000	Medium	IRIS	0.9	NA	NA	NA	R to R	D	n/a	n/a	n/a	n/a	n/a	Kidney, liver
Benzene	e	0.004	1	Pt E	0.004	300	Medium	IRIS	0.0086	0.03	300	Medium	IRIS	A	5.50E-02	5.50E-02	n/a	7.80E-06	IRIS	Blood, clinical signs
Di isopropyl ether		0.11	1	Pt E	0.11	NA	NA	R to R	0.11	NA	NA	NA	NCEA	D	n/a	n/a	n/a	n/a	n/a	CNS, skin/eyes
Ethylbenzene		0.1	1	Pt E	0.1	1000	Low	IRIS	0.295	1	300	Low	IRIS	D	n/a	n/a	n/a	n/a	n/a	Liver/kidney, development
Isopropylbenzene		0.1	1	Pt E	0.1	1000	Low	IRIS	0.11	0.4	1000	Medium	IRIS	D	n/a	n/a	n/a	n/a	n/a	Kidney, adrenal
Methylethylketone		0.6	1	Pt E	0.6	1000	Low	IRIS	1.4	5	300	Medium	IRIS	D	n/a	n/a	n/a	n/a	n/a	Development, skeleton
n-Propylbenzene		0.04	1	Pt E	0.04	NA	NA	NCEA	0.04	NA	NA	NA	R to R	D	n/a	n/a	n/a	n/a	n/a	CNS, skin/eyes
Toluene		0.08	1	Pt E	0.08	3000	Medium	IRIS	1.43	5	10	High	IRIS	D	n/a	n/a	n/a	n/a	n/a	Kidney, neurological
Xylenes		0.2	1	Pt E	0.2	1000	Medium	IRIS	0.029	0.1	300	Medium	IRIS	D	n/a	n/a	n/a	n/a	n/a	Body weight, CNS

Notes:

- IRIS = USEPA's Integrated Risk Information System (online search 6/2008)
- NCEA = USEPA PPRTV from USEPA Region VI Medium-Specific Screening Values Table (2008)
- n/a = not applicable ; NA = not available
- GI abs = gastrointestinal absorption factor
- RfDd = RfDo * GI abs; SFd = Sfo/GI abs
- R to R = Route to route extrapolation

a - Weight of Evidence (WoE) Classification of potential carcinogenicity as used in IRIS

- A - Known human carcinogen
- B1 - Probable human carcinogen; limited evidence of carcinogenicity in humans
- B2 - Probable human carcinogen; adequate evidence in animals; but insufficient evidence in humans
- C - Possible human carcinogen
- D - Not classifiable as to carcinogenicity/data inadequate to assess carcinogenicity in humans
- E - Evidence against carcinogenicity in humans

b - RfDo and RfDi for 1,2,4-TMB used as surrogate

c - RfDo for 2-Methylnaphthalene used as surrogate

d - RfDi for Naphthalene used as surrogate

e - Benzene unit risk-inhalation is actually presented as a range (2.2 - 7.8E-6/ug/m3). The associated oral slope factor is also presented as a range (1.54 - 5.45E-6/mg/kg/day). The upper end of each was used.

- Pt E = Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim

- DEA = USEPA, Dermal Exposure Assessment: Principles and Applications, EPA/600/8-91/011B January 1992 Interim Report

- EPA IV is USEPA Region IV Supplemental Guidance to RAGS November 1995

Table 5 - Summary of Permeability Coefficients, Absorption Factors and Unit Dermal Dose for Water Exposure
 ELMCO Facility, Franklin, TN

Parameter	Kp (cm/hr)	Source	Calculated Kp (cm/hr)	Dermal Abs Factor	Source	MW	log Kow	τ-event	B	t*	FA	Unit DA-event (mg/cm ² -event)
1,2,3-Trimethylbenzene	NA		0.09	n/a	Pt E	120.2	3.66	0.495	0.3	1.19	1	2.46E-04
1,2,4-Trimethylbenzene	NA		0.11	n/a	Pt E	120.2	3.78	0.495	0.3	1.19	1	2.95E-04
1,3,5-Trimethylbenzene	NA		0.06	n/a	Pt E	120.2	3.42	0.495	0.3	1.19	1	1.71E-04
Acetone	0.00057	Pt E	0.00052	n/a	Pt E	58.08	-0.24	0.222	0	0.53	1	1.27E-06
Benzene	0.015	Pt E	0.015	n/a	Pt E	78	2.13	0.287	0.1	0.69	1	3.61E-05
Di isopropyl ether	NA		0.004	n/a	Pt E	102.2	1.52	0.392	0.05	0.94	1	1.17E-05
Ethylbenzene	0.049	Pt E	0.048	n/a	Pt E	106.2	3.15	0.413	0.2	0.99	1	1.28E-04
Isopropylbenzene	NA		0.09	n/a	Pt E	120.2	3.66	0.495	0.3	1.19	1	2.46E-04
Methylethylketone	0.00096	Pt E	0.00097	n/a	Pt E	72.11	0.29	0.266	0	0.64	1	2.46E-06
n-Propylbenzene	NA		0.09	n/a	Pt E	120.2	3.69	0.495	0.3	1.19	1	2.58E-04
Toluene	0.031	Pt E	0.031	n/a	Pt E	92.1	2.73	0.344	0.1	0.83	1	7.88E-05
Xylenes	0.053	Pt E	0.05	n/a	Pt E	106.2	3.12	0.413	0.2	0.99	1	1.23E-04

Notes:

- Pt E = Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim
- EPA IV is USEPA Region IV Supplemental Guidance to RAGS November 1995
- n/a = not applicable ; NA = not available
- Naphthalene used as surrogate for 1-Methynaphthalene and 2-Methylnaphthalene
- Kp calculated as $10^{(-2.8 + 0.66(\log Kow) - 0.0056MW)}$
- Absorbed Dose/Event (DAevent) (ET > t*) (mg/cm²-event) = $FA \times Kp \times Cw \times ([ET/1+B] + 2 \times \tau\text{-event} \times [1 + 3B + 3B^2]/\{1+B\}^2])$
- ET = 2 hrs per exposure scenario. Unit DAevent calculated assuming 1 mg/L for each parameter using calculated Kp values.
- 'B' values obtained (or estimated from) RAGS, Part E.

Table 6 - Surface Water Screening Analysis - Liberty Creek
 ELMCO Human Health Risk Assessment

Parameter	Units	Frequency of Detection	Average Detect	Minimum Detect	Maximum Detect	Location of Maximum	Range of Detection Limits	Human Health Screening Value a	HHSV Basis	Reference	Frequency of Exceedance	Surface Water COPC?	COPC Basis
1,2,3-Trimethylbenzene	mg/L	0 / 8	n/a	n/a	n/a	n/a	0.001 - 0.05	0.42	nc	RBC	0 / 8	No	BSL
1,2,4-Trimethylbenzene	mg/L	1 / 9	0.00055	0.00055	0.00055	LC-A	0.001 - 0.05	0.35	nc	RBC	0 / 9	No	BSL
1,3,5-Trimethylbenzene	mg/L	0 / 9	n/a	n/a	n/a	n/a	0.00019 - 0.05	0.60	nc	RBC	0 / 9	No	BSL
Acetone	mg/L	7 / 9	4.334	0.52	8.8	LC-PC	0.5 - 1	370	nc	RBC	0 / 9	No	BSL
Benzene	mg/L	0 / 8	n/a	n/a	n/a	n/a	0.001 - 0.05	0.046	c	RBC	0 / 8	No	BSL
Di isopropyl ether	mg/L	0 / 8	n/a	n/a	n/a	n/a	0.001 - 0.05	14.9	nc	RBC	0 / 8	No	BSL
Ethylbenzene	mg/L	3 / 9	0.0021	0.0016	0.0028	LC-A	0.01 - 0.05	1.6	nc	RBC	0 / 9	No	BSL
Isopropylbenzene	mg/L	0 / 9	n/a	n/a	n/a	n/a	0.0014 - 0.05	0.84	nc	RBC	0 / 9	No	BSL
Methylethylketone	mg/L	2 / 9	0.0154	0.0148	0.016	LC-PC	0.00056 - 0.5	200	nc	RBC	0 / 9	No	BSL
n-Propylbenzene	mg/L	0 / 9	n/a	n/a	n/a	n/a	0.00037 - 0.05	0.32	nc	RBC	0 / 9	No	BSL
Toluene	mg/L	9 / 9	5.378	2.6	8.1	LC-PC	n/a - n/a	2.0	nc	RBC	9 / 9	YES	BSL
Xylenes	mg/L	3 / 9	0.0094	0.0069	0.0113	LC-A	0.03 - 0.15	3.3	nc	RBC	0 / 9	No	BSL

Notes:

- NA = not applicable
- nc = non-carcinogenic endpoint; c = carcinogenic endpoint
- TDEC has not analyzed surface water samples for 1,2,3-Trimethylbenzene, benzene or diisopropylether to date.
- a - RBC = site-specific risk based concentration based on most conservative scenario applicable to this area (current recreational user) using conservative recreational scenario assumptions.
- ASL = Above screening level; BSL = Below screening level

Table 7 - Surface Water Screening Analysis - Harpeth River
 ELMCO Human Health Risk Assessment

Parameter	Units	Frequency of Detection	Average Detect	Minimum Detect	Maximum Detect	Location of Maximum	Range of Detection Limits	Human Health Screening Value a	HHSV Basis	Reference	Frequency of Exceedance	Surface Water COPC ?	COPC Basis
1,2,3-Trimethylbenzene	mg/L	-- / --	n/a	n/a	n/a	n/a	n/a - n/a	0.42	nc	RBC	-- / --	No	BSL
1,2,4-Trimethylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.0002 - 0.0002	0.35	nc	RBC	0 / 2	No	BSL
1,3,5-Trimethylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.00019 - 0.00019	0.60	nc	RBC	0 / 2	No	BSL
Acetone	mg/L	7 / 8	0.1459	0.00115	0.443	HR-C	0.0023 - 0.0023	370	nc	RBC	0 / 8	No	BSL
Benzene	mg/L	-- / --	n/a	n/a	n/a	n/a	n/a - n/a	0.046	c	RBC	-- / --	No	BSL
Di isopropyl ether	mg/L	-- / --	n/a	n/a	n/a	n/a	n/a - n/a	14.9	nc	RBC	-- / --	No	BSL
Ethylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.00009 - 0.00009	1.6	nc	RBC	0 / 2	No	BSL
Isopropylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.00014 - 0.00014	0.84	nc	RBC	0 / 2	No	BSL
Methylethylketone	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.00056 - 0.00056	200	nc	RBC	0 / 2	No	BSL
n-Propylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.00037 - 0.00037	0.32	nc	RBC	0 / 2	No	BSL
Toluene	mg/L	8 / 8	0.0629	0.0066	0.193	HR-C	n/a - n/a	2.0	nc	RBC	0 / 8	No	BSL
Xylenes	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.0018 - 0.0018	3.3	nc	RBC	0 / 2	No	BSL

Notes:

- NA = not applicable
- nc = non-carcinogenic endpoint; c = carcinogenic endpoint
- "- -" indicates TDEC has not analyzed surface water samples for 1,2,3-Trimethylbenzene, benzene or diisopropylether to date; ELMCO has conducted no Harpeth River sampling.
- a - RBC = site-specific risk based concentration based on most conservative scenario applicable to this area (current recreational user) using conservative recreational scenario assumptions.
- ASL = Above screening level; BSL = Below screening level

Table 8 - Exposure Factors for Residential – Air Pathway
 ELMCO Human Health Risk Assessment

	Units	Child	Adult	Source
General Exposure Parameters				
Body weight (BW)	kg	15	70	Default body weight from USEPA standard exposure factors
Exposure duration (ED)	yr	6	24	Default duration from USEPA standard exposure factors
Averaging time, non-carcinogenic (ATnc)	days	2190	--	ED x 365 days/year; most sensitive population only
Averaging time, carcinogenic (ATc)	days	25550		70 yr life expectancy x 365 days/year
Inhalation Parameters				
Inhalation Rate (IRa)	m3/d	10	20	Default from USEPA standard exposure factors
Parameter Concentration ([])	mg/m3	Chemical-specific		Exposure point concentration
Pathway-specific Parameters				
Exposure frequency (EF)	days/yr	350	350	Default frequency from USEPA standard exposure factors
Site exposure fraction (SEF)	unitless	1		Individuals resides and spends majority of time in area
Exposure Quantification Formulae:				
Non-cancer effects, inhalation	Parameter [] x IRa-c x EF-c x ED-c/(BW-c x ATnc-c)			
Cancer effects, inhalation	Parameter [] x ([IRa-c x EF-c x ED-c/BW-c] + [IRa-a x EF-a x ED-a/BW-a])/ATc)			

¹ 'a' designator indicates adult exposure factor

² 'c' designator indicates child exposure factor

- Benzene screening value computed using unit inhalation risk values.

Table 9 - Battleground Academy Lower School Air Screening Analysis
 ELMCO Human Health Risk Assessment

Parameter	Units	Frequency of Detection	Average Detect	Minimum Detect	Maximum Detect	Location of Maximum	Range of Detection Limits	Human Health Screening Value a	HHSV Basis	Reference	Frequency of Exceedance	Household Air COPC?	COPC Basis
Acetone	mg/m3	0 / 6	n/a	n/a	n/a	n/a	0.13 - 0.34	0.14	nc	RBC	0 / 6	No b	ND
Benzene	mg/m3	0 / 6	n/a	n/a	n/a	n/a	0.094 - 0.26	0.00031	c	RBC	0 / 6	No c	ND
Toluene	mg/m3	1 / 6	0.077	0.077	0.077	BGA-3	0.089 - 0.17	0.219	nc	RBC	0 / 6	No	BSL

Notes:

- n/a = not applicable

- nc = non-carcinogenic endpoint; c = carcinogenic endpoint

a - RBC = site-specific risk based concentration based on most conservative scenario applicable to this area (current resident) using USEPA default exposure assumptions. Benzene screening value computed using unit inhalation risk values.

b - Acetone detection limit is above human health screening value

c - Benzene detection limit is above human health screening value

- ND = Non-detect in all samples; ASL = Above screening level; BSL = Below screening level

Table 10 - Residential Air Screening Analysis
 ELMCO Human Health Risk Assessment

Parameter	Units	Frequency of Detection	Average Detect	Minimum Detect	Maximum Detect	Location of Maximum	Range of Detection Limits	Human Health Screening Value a	HHSV Basis	Reference	Frequency of Exceedance	Household Air COPC?	COPC Basis
Acetone	mg/m3	2 / 3	0.061	0.058	0.063	116 Daniels	0.058 - 0.058	0.14	nc	RBC	0 / 3	No	BSL
Benzene	mg/m3	0 / 3	n/a	n/a	n/a	n/a	0.04 - 0.04	0.00031	c	ORNL	0 / 3	No b	ND
Toluene	mg/m3	1 / 3	0.073	0.073	0.073	131 Daniels	0.046 - 0.047	0.219	nc	RBC	0 / 3	No	BSL

Notes:

- n/a = not applicable

- nc = non-carcinogenic endpoint; c = carcinogenic endpoint

a - RBC = site-specific risk based concentration based on most conservative scenario applicable to this area (current resident) using USEPA default exposure assumptions. Benzene screening value computed using unit inhalation risk values.

b - Benzene detection limit is above human health screening value

- ND = Non-detect in all samples; ASL = Above screening level; BSL = Below screening level

Table 11 - Ambient Air Screening Analysis
 ELMCO Human Health Risk Assessment

Parameter	Units	Frequency of Detection	Average Detect	Minimum Detect	Maximum Detect	Location of Maximum	Range of Detection Limits	Human Health Screening Value a	HHSV Basis	Reference	Frequency of Exceedance	Ambient Air COPC?	COPC Basis
Acetone	mg/m3	5 / 26	0.018	0.01	0.03	TI-2A	0.01 - 0.01	0.14	nc	RBC	0 / 26	No	BSL
Benzene	mg/m3	0 / 26	n/a	n/a	n/a	n/a	0.04 - 0.04	0.00031	c	RBC	0 / 26	No b	ND
Toluene	mg/m3	18 / 26	0.125	0.02	0.42	TI-2A	0.02 - 0.02	0.219	nc	RBC	10 / 26	YES	ASL

Notes:

- n/a = not applicable

- nc = non-carcinogenic endpoint; c = carcinogenic endpoint

a - RBC = site-specific risk based concentration based on most conservative scenario applicable to this area (current resident) using USEPA default exposure assumptions. Benzene screening value computed using unit inhalation risk values.

b - Benzene detection limit is above human health screening value

- ND = Non-detect in all samples; ASL = Above screening level; BSL = Below screening level

Table 12 - Surface Water Exposure Point Concentrations
 ELMCO Human Health Risk Assessment

Timeframe: Current							
Area: Liberty Creek below Main Seep							
Scenario(s): RecreationalUser							
Medium: Water							
Exposure Medium: Surface Water							
					Exposure Point Concentration		
Parameter	Units	Arithmetic Mean	95% UCL (Distribution)	Maximum Detect	Value	Statistic	Rationale
Toluene	mg/L	6.3	7.77 Norm	8.1	7.77	Student's t UCL	S-W

Notes:

- NA = not applicable
- G = gamma distribution; L = lognormal distribution; N = non-parametric distribution; Norm = normal distribution
- Approx gamma = approximate gamma; H-UCL = 95% UCL per Land; Student's t UCL = 95% UCL of mean by standard Student's method; 99% Chebyshev (mean) = standard Chebyshev 99% UCL of mean; 99% Chebyshev = Chebyshev minimum variance unbiased estimate UCL of me
- K-S = Kolmogorov-Smirnov Test; S-W - Shapiro-Wilks Test (for normality)
- Statistical analysis performed using USEPA's ProUCL Version 3.0

Table 13 - Ambient Air Exposure Point Concentrations
 ELMCO Human Health Risk Assessment

Timeframe: Current							
Area: Backyards/Open Areas around Liberty Creek							
Scenario(s): Residential							
Medium: Ambient Air							
Exposure Medium: Air							
					Exposure Point Concentration		
Parameter	Units	Arithmetic Mean	95% UCL (Distribution)	Maximum Detect	Value	Statistic	Rationale
Toluene	mg/m3	0.1136	0.18 G	0.42	0.18	Approx gamma	K-S

Notes:

- NA = not applicable
- G = gamma distribution; L = lognormal distribution; N = non-parametric distribution; Norm = normal distribution
- Approx gamma = approximate gamma; H-UCL = 95% UCL per Land; Student's t UCL = 95% UCL of mean by standard Student's method; 99% Chebyshev (mean) = standard Chebyshev 99% UCL of mean; 99% Chebyshev = Chebyshev minimum variance unbiased estimate UCL of me
- K-S = Kolmogorov-Smirnov Test; S-W - Shapiro-Wilks Test (for normality)
- Statistical analysis performed using USEPA's ProUCL Version 3.0

Table 14 - Surface Water Cancer Risk and Non-Cancer Hazards - Liberty Creek
 ELMCO Human Health Risk Assessment

Timeframe: Current
Receptor Population: Recreational User
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Parameter	Units	EPC	Cancer Risk Calculations			Non-Cancer Hazard Calculations		
							Average Daily Intake	CSF	Cancer Risk	Average Daily Intake	RfD	Hazard Quotient
Water	Surface Water	Along Liberty Creek below Main Seep	Ingestion	Toluene	mg/L	7.77	NA	NA	NA	1.42E-03	0.08	0.02
			Route Total						NA			0.02
			Dermal	Toluene	mg/L	7.77	NA	NA	NA	2.91E-02	0.08	0.36
			Route Total						NA			0.36
			Medium Total						NA			0.4

Notes:

- NA = not applicable
- EPC = exposure point concentration; CSF = cancer slope factor; RfD = reference dose
- Average daily intake in units of mg/kg/day
- CSF in units of (mg/kg/day)-1
- RfD in units of mg/kg/day

Current Recreational Trespasser ADI Example calculations:

Hazard - Ingestion $(7.77 \text{ mg/L} \times 10 \text{ ml/hr} \times 0.001 \text{ L/ml} \times 2 \text{ hr/event} \times 1 \text{ event/day} \times 50 \text{ days/yr} \times 6 \text{ years}) / (15 \text{ kg} \times 2190 \text{ days})$
 Dermal $(7.77 \text{ mg/L} \times \text{Unit DAD-nc})$

- Exposure factors and generic equations are provided in Table 3.

Table 15 - Ambient Air Cancer Risk and Non-Cancer Hazards
 ELMCO Human Health Risk Assessment

Timeframe: Current
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Parameter	Units	EPC	Cancer Risk Calculations			Non-Cancer Hazard Calculations		
							Average Daily Intake	CSF	Cancer Risk	Average Daily Intake	RfD	Hazard Quotient
Ambient Air	Air	Backyards/ Open Areas between BGA and Daniels Dr.	Inhalation	Toluene	mg/m3	0.18	NA	NA	NA	1.2E-01	1.43	0.08
			Route Total						NA			0.1
			Medium Total						NA			0.1

Notes:

- NA = not applicable
- EPC = exposure point concentration; CSF = cancer slope factor; RfD = reference dose
- Average daily intake in units of mg/kg/day
- CSF in units of (mg/kg/day)-1
- RfD in units of mg/kg/day

Residential Air ADI Example calculations:

Hazard Inhalation $(0.18 \text{ mg/m}^3 \times 350 \text{ days/year} \times 6 \text{ years} \times 10 \text{ m}^3/\text{day}) / (15 \text{ kg} \times 2190 \text{ days})$

- Exposure factors and generic equations are provided in Table 8.

Table 16 - Summary of RME Cancer Risk and Non-Cancer Hazards - ELMCO Residential Scenario
 ELMCO Human Health Risk Assessment

Timeframe: Current
Receptor Population: Recreational Trespasser
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Parameter	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Dermal	Inhalation	Total	Primary Target Organ(s)	Ingestion	Dermal	Inhalation	Total
Water	Surface Water	Along Liberty Creek below Main Seep	Toluene	NA	NA	NA	NA	Kidney	0.02	0.36	NA	0.4
		Exposure Point Total			NA	NA	NA	NA		0	0.4	NA
Surface Water Total							NA					0.4
Air	Ambient Air	Backyards/ Open Areas between BGA and Daniels Dr.	Toluene	NA	NA	NA	NA	Kidney	NA	NA	0.1	0.1
		Exposure Point Total			NA	NA	NA	NA		NA	NA	0.1
Ambient Air Total							NA					0.1
Total of Receptor Risk/Hazard Across All Media							NA					0.5

Notes:

- NA = not applicable
- EPC = exposure point concentration; CSF = cancer slope factor; RfD = reference dose
- Average daily intake in units of mg/kg/day
- CSF in units of (mg/kg/day)-1
- RfD in units of mg/kg/day
- Lead was evaluated separately using IEUBK and/or ALM .

Table 17 - Ecological Screening Values
ELMCO Ecological Assessment

Parameter		Ecological Benchmarks (mg/L)		
		Chronic	Acute	Source
1,2,3-Trimethylbenzene	a	0.017	0.31	Surrogate
1,2,4-Trimethylbenzene		0.017	0.31	MDEQ
1,3,5-Trimethylbenzene	a	0.045	0.81	MDEQ
Acetone		1.7	30	MDEQ
Benzene		0.053	0.53	EPA IV
Di isopropyl ether		NA	NA	NA
Ethylbenzene		0.453	4.53	EPA IV
Isopropylbenzene	c	0.453	4.53	Surrogate
Methylethylketone		2.2	40	MDEQ
n-Propylbenzene	c	0.453	4.53	Surrogate
Toluene		0.175	1.75	EPA IV
Xylenes		0.041	0.73	MDEQ

Notes:

- n/a = not applicable ; NA = not available
- a - 1,2,4-Trimethylbenzene used as surrogate
- b - 2-Methylnaphthalene used as surrogate
- c - Ethylbenzene used as surrogate
- EPA IV is USEPA Region IV Supplemental Guidance to RAGS November 1995
- MDEQ is Michigan Dept. of Environmental Quality Rule 57 Water Quality Values.
- EPA V is USEPA Region V Ecological Screening Values

Table 18 - Surface Water Screening Analysis - Liberty Creek
 ELMCO Ecological Assessment

Parameter	Units	Frequency of Detection	Average Detect	Minimum Detect	Maximum Detect	Location of Maximum	Range of Detection Limits	Chronic EcoSV	Acute EcoSV		Source	Frequency of Chronic EcoSV Exceedance	Surface Water COPEC?	COPEC Basis
1,2,3-Trimethylbenzene	mg/L	0 / 8	n/a	n/a	n/a	n/a	0.001 - 0.05	0.017	0.31	a	Surrogate	0 / 8	No	BSL
1,2,4-Trimethylbenzene	mg/L	1 / 9	0.00055	0.00055	0.00055	LC-A	0.001 - 0.05	0.017	0.31		MDEQ	0 / 9	No	BSL
1,3,5-Trimethylbenzene	mg/L	0 / 9	n/a	n/a	n/a	n/a	0.0002 - 0.05	0.05	0.81		MDEQ	0 / 9	No	BSL
Acetone	mg/L	7 / 9	4.334	0.52	8.8	LC-PC	0.5 - 1	1.7	30		MDEQ	5 / 9	YES	ASL
Benzene	mg/L	0 / 8	n/a	n/a	n/a	n/a	0.001 - 0.05	0.053	0.53		EPA IV	0 / 8	No	BSL
Di isopropyl ether	mg/L	0 / 8	n/a	n/a	n/a	n/a	0.001 - 0.05	NA	NA		NA	0 / 8	No	BSL
Ethylbenzene	mg/L	3 / 9	0.0021	0.0016	0.0028	LC-A	0.01 - 0.05	0.5	4.5		EPA IV	0 / 9	No	BSL
Isopropylbenzene	mg/L	0 / 9	n/a	n/a	n/a	n/a	0.0014 - 0.05	0.45	4.53	b	Surrogate	0 / 9	No	BSL
Methylethylketone	mg/L	2 / 9	0.0154	0.0148	0.016	LC-PC	0.0006 - 0.5	2.2	40		MDEQ	0 / 9	No	BSL
n-Propylbenzene	mg/L	0 / 9	n/a	n/a	n/a	n/a	0.0004 - 0.05	0.45	4.53	b	Surrogate	0 / 9	No	BSL
Toluene	mg/L	9 / 9	5.378	2.6	8.1	LC-PC	n/a - n/a	0.175	1.75		EPA IV	9 / 9	YES	ASL
Xylenes	mg/L	3 / 9	0.0094	0.0069	0.0113	LC-A	0.03 - 0.15	0.041	0.73		MDEQ	0 / 9	No	BSL

- Notes:
- n/a = not applicable ; NA = not available
 - nc = non-carcinogenic endpoint; c = carcinogenic endpoint
 - TDEC has not analyzed surface water samples for 1,2,3-Trimethylbenzene, benzene or diisopropylether to date.
 - ASL = Above screening level; BSL = Below screening level
 - a - 1,2,4-Trimethylbenzene used as surrogate
 - b - Ethylbenzene used as surrogate
 - EPA IV is USEPA Region IV Supplemental Guidance to RAGS November 1995
 - MDEQ is Michigan Dept. of Environmental Quality Rule 57 Water Quality Values.
 - EPA V is USEPA Region V Ecological Screening Values

Table 19 - Surface Water Screening Analysis - Harpeth River
 ELMCO Ecological Assessment

Parameter	Units	Frequency of Detection	Average Detect	Minimum Detect	Maximum Detect	Location of Maximum	Range of Detection Limits	Chronic EcoSV	Acute EcoSV		Source	Frequency of Chronic EcoSV Exceedance	Surface Water COPEC?	COPEC Basis
1,2,3-Trimethylbenzene	mg/L	-- / --	n/a	n/a	n/a	n/a	n/a - n/a	0.02	0.31	b	Surrogate	-- / --	No	BSL
1,2,4-Trimethylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.0002 - 0.0002	0.02	0.31		MDEQ	0 / 2	No	BSL
1,3,5-Trimethylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.0002 - 0.0002	0.05	0.81		MDEQ	0 / 2	No	BSL
Acetone	mg/L	7 / 8	0.1459	0.00115	0.443	HR-C	0.0023 - 0.0023	2	30		MDEQ	0 / 8	No	BSL
Benzene	mg/L	-- / --	n/a	n/a	n/a	n/a	n/a - n/a	0.053	0.530		EPA IV	-- / --	No	BSL
Di isopropyl ether	mg/L	-- / --	n/a	n/a	n/a	n/a	n/a - n/a	NA	NA		NA	-- / --	No	BSL
Ethylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	9E-05 - 9E-05	0.5	4.5		EPA IV	0 / 2	No	BSL
Isopropylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.0001 - 0.0001	0.45	4.53		Surrogate	0 / 2	No	BSL
Methylethylketone	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.0006 - 0.0006	2	40		MDEQ	0 / 2	No	BSL
n-Propylbenzene	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.0004 - 0.0004	0.45	4.53		Surrogate	0 / 2	No	BSL
Toluene	mg/L	8 / 8	0.0629	0.0066	0.193	HR-C	n/a - n/a	0.2	1.8		EPA IV	2 / 8	YES	BSL
Xylenes	mg/L	0 / 2	n/a	n/a	n/a	n/a	0.0018 - 0.0018	0.0	0.7		MDEQ	0 / 2	No	BSL

Notes:

- n/a = not applicable ; NA = not available
- nc = non-carcinogenic endpoint; c = carcinogenic endpoint
- TDEC has not analyzed surface water samples for 1,2,3-Trimethylbenzene, benzene or diisopropylether to date.
- ASL = Above screening level; BSL = Below screening level
- a - 1,2,4-Trimethylbenzene used as surrogate
- b - Ethylbenzene used as surrogate
- EPA IV is USEPA Region IV Supplemental Guidance to RAGS November 1995
- MDEQ is Michigan Dept. of Environmental Quality Rule 57 Water Quality Values.
- EPA V is USEPA Region V Ecological Screening Values

Table 20 - Surface Water Ecological HQ/HI Analysis - Liberty Creek and Harpeth River
 ELMCO Ecological Assessment

Stream	Location	Location Description	Sample Date	Acetone (mg/L)	Toluene (mg/L)	Acetone Chronic HQ	Toluene Chronic HQ	Sample Chronic HI	Mean HI	
Liberty Creek	Watergate	Liberty Creek u.s. of main seep	1/28/2008	0.52	2.6	0.3	15	15	25	
			2/15/2008	0.50	4.3	0.3	25	25		
			4/2/2008	3.0	7.0	2	40	42		
			5/7/2008	0.25	3.0	0.1	17	17		
	LC-PC	Liberty Creek at Personnel Crossing	1/28/2008	1.4	5.0	0.8	29	29	39	
			2/15/2008	5.3	8.1	3	46	49		
			3/18/2008	5.2	7.1	3	41	44		
			4/2/2008	6.1	4.4	4	25	29		
				5/7/2008	8.8	6.9	5	39	45	
	Harpeth River	HR-C	Harpeth River, u.s. Liberty Creek	10/31/2007	0.44	0.18	n/a	1	1	1
11/19/2007				0.36	0.19	n/a	1	1		
12/19/2007				0.083	0.028	n/a	0.2	0.16		
3/18/2008				0.001	0.051	n/a	0.3	0.29		
HR-A		Harpeth River, u.s. Franklin STP Outfall	10/31/2007	0.043	0.007	n/a	0.04	0.04	0.1	
			11/19/2007	0.055	0.015	n/a	0.08	0.08		
			12/19/2007	0.029	0.015	n/a	0.09	0.09		
			3/18/2008	0.006	0.012	n/a	0.07	0.07		

Notes:

- One-half detection limit substituted for non-detects
- HQ (hazard quotient) computed using chronic EcoSV values (Acetone: 1.7 mg/L; Toluene: 0.175 mg/L) in denominator using sample-specific data
- HI (hazard index) computed as sum of HQ across all COPECs; Acetone was not identified as a Harpeth River COPEC
- The LC-PC sample listed for 3/18/08 was actually collected by TDEC at location LC-A.

ECOVAC SERVICES

*The World Leader in Mobile Dual-Phase/Multi-Phase Extraction
Patented SURFAC[®]/ISCO-EFR[®]/COSOLV[®] Technologies*

June 20, 2008

T. Dwight Hinch
TriAD Environmental Consultants, Inc.
207 Donelson Pike, Suite 200
Nashville, Tennessee 37214
tdhinch@triadenv.com

**Subject: Enhanced Fluid Recovery (EFR[®]) and In-Situ Chemical Oxidation (ISCO-EFR[®]) Services
Egyptian Lacquer Manufacturing Company Site
Franklin, Tennessee**

Dear Dwight:

Thank you for the potential opportunity to provide innovative and cost effective environmental solutions to TriAD Environmental Consultants. EcoVac Services proposes our EFR[®] and proprietary ISCO-EFR[®] technologies (U.S. Patent No. 6,158,924) at the subject site. EFR[®] is a mobile dual-phase/multi-phase extraction process while ISCO-EFR[®] involves the combination technology of chemical oxidant injection combined with the multi-phase/dual-phase extraction process. **The ISCO-EFR[®] process described herein is patent-protected and represents the intellectual property of EcoVac Services.**

A key advantage of these processes is that they are mobile and can be implemented and completed in very abbreviated time frames. Our processes do not involve high injection pressures that can displace plumes and vapors into undesired areas.

EcoVac Services is also the world leader in mobile multi-phase/dual-phase extraction, having conducted over 8,000 EFR[®] events at over 1,500 sites throughout the United States (40 states) and Puerto Rico. EFR[®] has successfully removed over 1,000,000 gallons of petroleum fuels.

Proposed Remediation Approach

The goal of remediation at this site is to reduce the contaminant concentrations in the source area to mitigate downgradient migration. TriAD Environmental Consultants will install wells in areas of GP-25, GP-26, GP-27, and GP-28 in advance of our field work. It is highly recommended that soil oxidant demand (SOD) testing be performed on the recovered soil cuttings (approximately \$600.00/test).

EcoVac Services proposes a phased approach, inclusive of initially implementing pilot testing utilizing EFR[®]. The objective of the pilot testing phase is to (1) achieve contaminant removal by

105 Weatherstone Drive, Suite 610 – Woodstock, Georgia 30188
(770) 592-1001 - Fax (770) 592-1801
www.ecovacservices.com

the multi-phase/dual-phase extraction process, (2) reduce the aerial and vertical extent of the plume, (3) evaluate the radius of influence, (4) determine the location/construction of additional treatment (injection) wells, if necessary, (5) estimate the chemical oxidant injection volumes, concentrations, and injection well sequencing, and (6) determine the duration of the chemical oxidant injection events.

The second phase will be the implementation of additional EFR[®] events to minimize the source material to “manageable” levels to enhance the likelihood of success of the ensuing phase, which will include implementation of our ISCO-EFR[®] process. The ISCO-EFR[®] process will further reduce the dissolved and adsorbed phase concentrations.

Our proposed scope of work is detailed below. The costs and scope of work will be reviewed and updated following receipt of the full site information and the results of the pilot test.

<u>Work Description</u>	<u>Lump Sum Cost</u>
<u>Phase 1: Pilot Testing:</u> Pilot testing will be conducted for three consecutive days, utilizing offgas (vapor) treatment, to: (1) achieve contaminant removal by the multi-phase/dual-phase extraction process, (2) reduce the aerial and vertical extent of the plume, (3) evaluate the radius of influence, (4) determine the location/construction of additional treatment (injection) wells, if necessary, (5) estimate the chemical oxidant injection volumes, concentrations, and injection well sequencing, and (6) determine the duration of the chemical oxidant injection events.	\$18,955.00
<u>Phase 2: EFR[®]:</u> Additional EFR [®] events (two consecutive 8-hour extraction events) will be conducted to minimize the source material to “manageable” levels to enhance the likelihood of success of the ensuing phase, which will include implementation of our ISCO-EFR [®] process.	\$10,950.00/ Two Day Event
<u>Phase 3: ISCO-EFR[®]:</u> Extraction and chemical oxidant injection will be implemented to reduce the dissolved phase concentrations. This phase is assumed to consist of four days of extraction and emplacement of sodium persulfate (activated with chelated iron). An allocation for a maximum of 2,000 pounds of ISCO oxidant (in addition to the activation chemical) is included in our lump sum cost.	\$36,823.00

Thank you once again for this opportunity. Please contact myself or David M. Goodrich, P.G. should you have any questions.

Sincerely,

EcoVac Services



Nick Athens

ATTACHMENT A
ASSUMPTIONS UTILIZED IN DEVELOPING
ECOVAC SERVICES' LUMP SUM COSTS (6/20/08)
TriAD Environmental Consultants
Egyptian Lacquer Manufacturing Company Site
Franklin, Tennessee

- The cost estimate contains no contingencies for costs or delays that may result from severe weather conditions, client or regulatory delays, access delays, or any other conditions beyond the control of EcoVac Services. EFR[®]/ISCO-EFR[®] at this site will be conducted during scheduled mobilizations to Tennessee.
- Payment terms are net 30 days. The invoice will be submitted in lump sum form only. This quotation is valid for a period of 90 days. Level D personal protective equipment (PPE) will be utilized in the field. TriAD Environmental Consultants will be responsible for securing any and all regulatory permits (including the UIC permit), and making all regulatory notifications.
- Recovered fluid will be placed in onsite containers provided by TriAD Environmental Consultants. Any potential present or future liability relating to any and all wastes generated during this investigation is the sole responsibility of TriAD Environmental Consultants and your client.
- The amount of chemical oxidant is based upon stoichiometry and does not take in account kinetics or speed of the reaction, and represents the minimum necessary to mineralize the contaminants and compensate for soil oxidant demand (SOD - assumed to be 1). An SOD of 1 is fairly typical, however, in unusual cases it can range as high as 3 or 4 (which essentially would increase the amount of chemical required by 3 to 4 times). Oxidant demand and treatability testing is necessary to more accurately determine the amount of oxidant/activator required. It is highly recommended that SOD testing be conducted on the recovered soil cuttings (approximately \$600.00/test).
- EcoVac Services will make every effort with our unique delivery method to minimize exposure of subsurface tanks/piping, subsurface utilities, etc. to the temporal chemical and/or physical changes that may occur with the ISCO process. However, EcoVac Services is not responsible for any such damage that may occur.
- Temporary onsite storage of the ISCO chemicals is assumed.



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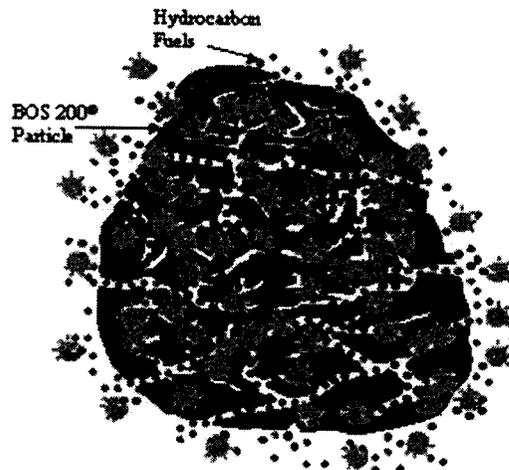
Products

Trap & Treat® BOS 200® for Petroleum Hydrocarbon

RPI has designed Trap & Treat® BOS 200® to take advantage of the natural anaerobic state of most hydrocarbon sites by promoting oxidation through a system of sulfate reduction. The material is a blend of selected micronutrients and a time-release source of sulfate within an adsorbent matrix designed to trap contaminants. Bacteria specially designed to consume hydrocarbons are added in the field.

After installation, contamination is rapidly trapped within the system and consumed by the bacteria. Often, rates of degradation are more rapid than the rates seen when using current technology. As trapped contaminants are degraded, new contaminants are ensnared, and the cycle is repeated until the microcosm runs out of food. Byproducts include carbon dioxide, water, and a variety of fermentation products.

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MSDS BOS 200®](#)



Benefits of BOS 200®:

- Rapidly reduces hydrocarbon contamination;
- Quickly meets regulatory standards;
- Protects groundwater throughout treatment;
- Is safe and easy to use;
- Reduces overall remediation costs;
- Accelerates remediation and site closure;
- Reduces landowner liability; and
- Accelerates property transfer.

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Free Project Assessment

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Remediation Products Incorporated (RPI)
6390 Joyce Drive, Suite 150 West
Golden, CO 80403
phone: 303.487.1001
fax: 303.487.1083

created by
HarnessTheWeb.com

Material Safety Data Sheet

Trap & Treat[®] BOS 200[®]



REMEDICATION PRODUCTS, INC.

Section I

Manufacturer's Name <i>Remediation Products Inc.</i>	Emergency Telephone Number <i>303.487.1000</i>
Address (Number, Street, City, State, and ZIP Code) <i>6390 Joyce Drive, Suite 150 W, Golden, CO 80403</i>	Telephone Number for Information <i>303-487-1000</i>
Prepared by <i>T. Mecum</i>	Date Prepared <i>12/2/02</i>
	Signature of Preparer (optional)

Section II - Hazard Ingredients/Identity Information

Non-hazardous components are listed at 3 percent (%) or greater. This is not intended to be a complete compositional disclosure.

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% (optional)
Carbon	5mg/M ³ (respirable)	10mg/M ³ (Total)	N/A	77
Calcium Sulfate (Gypsum)	"	"	N/A	19
N/A = Not Applicable PELs and TLVs are 8-hour TWAs unless otherwise noted.				

Section III - Physical/Chemical Characteristics

Boiling Point	N/A	Specific Gravity (H ₂ O = 1)	2.33 g/cc real density
Vapor Pressure (mm Hg.)	N/A	Melting Point	Decomposes at 1450°C
Vapor Density (AIR = 1)	N/A	Evaporation Rate (Butyl Acetate = 1)	N/A
Solubility in Water: Negligible			
Appearance and Odor: Black powder. No odor.			

Section IV - Fire and Explosion Hazard Data

Flash Point (Method Used) Not combustible	Flammable Limits	LEL N/A	UEL N/A
Extinguishing Media Flood with plenty of water			
Special Fire Fighting Procedures None			
Unusual Fire and Explosion Hazards Contact with strong oxidizer, such as ozone, liquid oxygen, chlorine, permanganate, etc., may result in fire.			
NFPA Rating: Health=0; Reactivity=0; Flammability=1			

Section V - Reactivity Data

Stability	Unstable	<input type="checkbox"/>	Conditions to Avoid
	Stable	<input checked="" type="checkbox"/>	None
Incompatibility (<i>Materials to Avoid</i>)			
Strong oxidizers, such as ozone, liquid oxygen, chlorine, permanganate, etc., and acids.			
Hazardous Decomposition	May Occur	<input checked="" type="checkbox"/>	Conditions to Avoid
	Will Not Occur	<input type="checkbox"/>	Above 1450° - SO ₂ & CaO

Section VI - Health Hazard Data

Route(s) of Entry:	Inhalation?	Skin?	Ingestion?
	Yes	Yes	Yes
Health Hazards (<i>Acute and Chronic</i>)			
<p>The effects of long-term, low-level exposures to carbon have not been determined. Safe handling of this material on a long-term basis should emphasize the avoidance of all effects from repetitive acute exposures.</p> <p>Persons subjected to excessive dust will be forced to leave area because of nuisance; i.e., coughing, sneezing and nasal irritation.</p> <p>CAUTION!!! This material, when wet, removes oxygen from air causing a severe hazard to workers inside carbon vessels and enclosed or confined spaces. Before entering such an area, sampling and work procedures for low oxygen levels should be taken to ensure ample oxygen availability, observing all local, state, and federal regulations.</p>			
Carcinogenicity:	NTP?	IARC Monographs?	OSHA Regulated?
	N/A	N/A	No
Signs and Symptoms of Exposure			
<p>Effects and Hazards of Eye Contact: The physical nature of this product may produce eye irritation, if exposed to dusting conditions without protective eye equipment.</p> <p>Effects and Hazards of Skin Contact: The product is not a primary skin irritant. The primary skin irritation (Rabbit) is 0.</p> <p>Effects and Hazards of Inhalation Breathing: This product is practically non-toxic through inhalation. The acute inhalation LD₅₀ (Rat) is >6.4 mg/l (nominal concentration). Could cause irritation to respiratory passages, if exposed to dusting conditions without protective respiratory equipment.</p> <p>Effects and Hazards of Ingestion (Swallowing): Material is non-toxic through ingestion. The acute oral LD₅₀ (Rat) is >10g/kg.</p>			
Medical Conditions Generally Aggravated by Exposure			
N/A			
Emergency and First Aid Procedures			
<p><u>Eyes:</u> Flush with plenty of water for at least 15 minutes. Call physician if irritation continues.</p> <p><u>Skin:</u> Wash with soap and water.</p> <p><u>Inhalation:</u> Move to fresh air.</p> <p><u>Ingestion:</u> N/A</p>			

Section VII - Precautions for Safe Handling and Use

Steps to Be Taken in Case Material is Released or Spilled
Sweep or vacuum material from spillages into a waste container for disposal or repackage. Avoid dusting conditions.
Waste Disposal Method
Dispose of unused product in waste container. Dispose of in accordance with local, state, and federal or national regulations.
Precautions to Be Taken in Handling and Storing
CAUTION!!! This product, when wet, removes oxygen from air causing a severe hazard to workers inside carbon vessels and enclosed or confined spaces. Before entering such an area, sampling and work procedures for low oxygen levels should be taken to ensure ample oxygen availability, observing all local, state, and federal or national regulations. Be sure proper ventilation and respiratory and eye protection are used under dusting conditions.
Other Precautions
Wash thoroughly after handling. Exercise caution in the storage and handling of all chemical substances.

Section VIII - Control Measures

Respiratory Protection (<i>Specify Type</i>) Carbon-A NIOSH-approved particulate filter respirator is recommended, if excessive dust is generated.		
Ventilation	Local Exhaust Recommended, when used indoors or in confined spaces	Special Not Required
	Mechanical (<i>General</i>) Recommended, when used indoors or in confined spaces	Other Not required
Protective Gloves Recommended	Eye Protection Safety glasses or goggles recommended	
Other Protective Clothing or Equipment Not required		
Work/Hygienic Practices Use of Tyvek® or Nomex® suits is suggested to protect skin from becoming excessively dirty and clothing from being ruined by contact with product.		