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NSA MID SOUTH
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ALTERNATE CONCENTRATION LIMITS TECHNICAL MEMORANDUM SOLID WASTE MANAGEMENT AREA 2 (SWMU 2) SOUTHSIDE LANDFILL REVISION 2 MILLINGTON SUPPACT TN

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ENSAFE

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ALTERNATE CONCENTRATION LIMITS TECHNICAL MEMORANDUM SWMU 2 — SOUTHSIDE LANDFILL

NAVAL SUPPORT ACTIVITY MID-SOUTH MILLINGTON, TENNESSEE

Revision: 2

Prepared for:

NAVFAC
Naval Facilities Engineering Command

Department of the Navy
Naval Facilities Engineering Command

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List of Acronyms

3Q20	3 day, 20-year low flow
7Q10	7 day, 10-year low flow
ACL	alternate concentration limit
BCT	Base Cleanup Team
CFS	cubic foot per second
cis-1,2-DCE	cis-1,2-dichloroethylene
CO_2	carbon dioxide
CMS	Corrective Measures Study
DO	dissolved oxygen
mg/L	milligram per liter
MACL	maximum allowable concentration limit
MNA	monitored natural attenuation
MW	monitoring well
nM	nanoMolar
NOAA	National Oceanic and Atmospheric Administration
NSA	Naval Support Activity
ORP	oxidation-reduction potential
POC	point of compliance
POE	point of exposure
RFI	RCRA Facility Investigation
SWMU	Solid Waste Management Unit
TCE	Trichloroethylene
TDEC	Tennessee Department of Environment and Conservation
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
µg/L	microgram per liter
VC	vinyl chloride
VOC	volatile organic compound

1.0 INTRODUCTION/BACKGROUND

This technical memorandum proposes an alternate concentration limit (ACL) as a groundwater protection standard for chlorinated solvents in groundwater at the Solid Waste Management Unit (SWMU) 2, Southside Landfill at Naval Support Activity Mid-South (Figure 1). The presence of daughter products and other indicator parameters suggested that monitored natural attenuation (MNA) was a viable remedy for site management of trichloroethylene (TCE) contamination detected in the southeast corner of the landfill. The objectives and procedures to implement MNA as the long-term remedy were presented in the *SWMU 2 Corrective Measures Study (CMS) Report* (EnSafe, February 2004) and the *SWMU 2 MNA Work Plan* (EnSafe, June 2005) — approved by the United States Environmental Protection Agency (USEPA) and Tennessee Department of Environment and Conservation (TDEC) in letters dated July 17, 2005, and August 31, 2005, respectively. As outlined in the work plan, MNA monitoring had been conducted on an annual basis. However, beginning in 2007, the monitoring frequency was increased to semi-annual because of increases in TCE and daughter product concentrations detected in groundwater. Figure 2 illustrates the extent of total volatile organic compound (VOC) concentrations for the November 2008 groundwater sampling event which shows the maximum concentrations are in monitoring wells 002G03DA and 002G28DA, with VOC concentrations diminishing in down gradient monitoring wells 002G24DA, 002G25DA, and 002G26DA.

The Big Creek Drainage Canal (Big Creek) is a groundwater discharge body for groundwater migrating in the deep alluvium with Big Creek receiving groundwater from the north and south sides of the drainage canal. Figure 3 provides a cross section showing the hydrogeology for the site. Groundwater monitoring wells screened in the deep alluvium on the north side of Big Creek, adjacent to and hydraulically downgradient from the landfill, have shown concentrations of TCE and its degradation products cis-1,2-dichloroethylene (cis-1,2-DCE) and vinyl chloride (VC). Monitoring wells screened in the same unit on the south side of Big Creek are free of VOC impacts. VOCs have historically been absent in both surface water and groundwater samples collected beneath Big Creek, which is believed to be the result of destructive (e.g., biological) and non-destructive (e.g., dilution) mechanisms. Similarly, the shallower wells screened in the upper alluvium (orange shaded unit in Figure 3) have had no VOC detections.

Spikes in chlorinated solvent concentrations, particularly during the May 2006 groundwater sampling event, triggered the Base Cleanup Team (BCT) to re-evaluate whether MNA was a viable remedy. A comparison of recent data with historical data (Table 1 and Figures 5 through 9) indicated that chlorinated solvent concentrations were not showing a discernable downward trend, indicating a finite mass was not present in the landfill, and leading the BCT to conclude that MNA may not be an effective remedy in achieving human health cleanup goals. The TDEC Division of Solid Waste recommended that the Navy evaluate an ACL as a groundwater protection that would be protective of surface water and consider removing MNA as the site remedy.[1] A summary of the processes used to develop the ACLs for the chlorinated solvents detected in groundwater is provided below.

[1] The impacted aquifer was concluded in the *RCRA Facility Investigation (RFI) SWMU 2 — Southside Landfill* (EnSafe, 2001) not to pose a threat to human health due to the absence of potable water wells screened in the aquifer on or near the base and availability of municipal water supplies in the area.

2.0 DEVELOPING THE ACLS

Since Big Creek is the receiving stream for groundwater leaving SWMU 2, it is considered the point of exposure (POE) for contaminants migrating with groundwater from the site. Big Creek is approximately 100 feet south of monitoring wells 002G24DA , 002G25DA, and 002G26DA (Figure 2) which are considered point of compliance (POC) wells that will be used in verifying that the ACLs are not being exceeded in subsequent site monitoring.

MACLs

Table 2 lists the acute and chronic maximum allowable concentration limits (MACLs) for surface water from the Tennessee Water Quality Criteria (Chapter 1200-4) and the Screening Quick Reference Tables provided by National Oceanic and Atmospheric Administration (NOAA, 1999). The Tennessee Water Quality Standard applied was for surface water that is for recreational purposes, "organisms only" criteria, and not a domestic water supply. For contaminants without a listed concentration, the NOAA Screening Quick Reference Table values were applied. The most stringent of the chronic MACL was selected as the benchmark to compare to detected concentrations. The maximum chlorinated solvent concentrations detected at the three POC wells (002G24DA, 002G25DA, and 002G26DA) also have been added to Table 2, and as noted, VC and cis-1,2-DCE have been historically detected in the POC wells in concentrations exceeding the most stringent MACLs. These two contaminants would pose an ecological risk to surface water if the amounts detected in the POC wells were discharging directly into the surface water of Big Creek at the detected concentrations, with no provisions for dilution via downgradient mixing with groundwater and surface water.

Dilution Factor

As contaminants migrate with groundwater and discharge into Big Creek, they undergo dilution from mixing with surface water. The amount of dilution is proportional to the ratio of groundwater to surface water, which is the dilution factor; therefore, the ACL is the MACL divided by the dilution factor.

To estimate flow in Big Creek, a 3 day, 20-year low flow (3Q20) for Big Creek was used, which is a more conservative estimate than the 7 day, 10-year (7Q10) low flow recommended by the TDEC Division of Water Pollution Control (de-minimis flow as defined in Chapter 1200-4-3-0.04). Flow data were provided by the U.S. Geological Survey (USGS) Tennessee Water Science Center (Appendix A). Mr. George Law with the USGS performed a regression analysis of low-flows and flow durations at Big Creek Drainage Canal near SWMU 2. Mr. Law used the TDEC v2.0.3 low-flow and flow-duration computer program to estimate the stream flow near SWMU 2, which is based on data obtained from three flow stations located along Big Creek near SWMU 2. Based on Mr. Law's computer model and his interpolation from the 7Q10 values, the 3Q20 for Big Creek near SWMU 2 is estimated to be 1.0 cubic foot per second (CFS)[2]. The USGS computer model output is included as Appendix A.

To account for the groundwater flow and potential contaminant discharge into Big Creek, the groundwater flux, or flow through a unit area over time, is estimated along the base of the drainage canal, coincident with an area 175 feet in length and 15 feet wide. The length is based on a transect of the TCE plume, parallel to Big Creek and measuring 175 feet between the 100 ppb contours (shown on Figure 5). The width is based on the assumption that groundwater from the north side of Big Creek discharges along the north ½ of the canal base (with groundwater from the south side of Big Creek discharging along the south ½ of the canal). Using a mean groundwater velocity of 0.15 feet per day[3] an estimated volume of 0.004 CFS (or 397 cubic feet per day) of groundwater discharges into Big Creek from the area impacted by TCE. Groundwater flow calculations are provided in Appendix B.

Table 3 shows the calculated and proposed ACLs for the chlorinated solvents detected in groundwater. The allowable contaminant concentrations at the point of discharge to Big Creek, and thus that at the POC, were back-calculated by dividing the MACL by the above calculated dilution factor (calculations are provided in Table 3). As shown in the table, ACL concentrations are well above the maximum detections at SWMU 2 POC wells. As an added level of safety, 1/10th of the proposed ACL will be used for future POC monitoring. As shown in the table, detected concentrations remain below the 1/10th of ACL.

[2] USGS Methodology: USGS ran TDECv203 to compute the region-of-influence (regression) estimates and the regional-regression equations (RRE) estimates. Estimates were made using several observed measurements at Big Creek at Highway 51 made in 1952 and 1995. Drainage area ratios were used to move the Highway 51 estimates upstream to SWMU 2. These estimates were averaged for each flow statistic. For example: 7Q10 = (1.33+1.79+1.02)/3 = 1.38 for Big Creek Drainage Canal at SWMU 2. The 3Q20 was estimated by interpolating down from the 7Q10 estimate to a more conservative 1.0 CFS.

[3] Groundwater velocity calculations are provided in Section 2 of the *SWMU 2 RCRA Facility Investigation* (EnSafe, 2001).

3.0 CONCLUSIONS AND RECOMMENDATIONS

SpectraTech/EnSafe recommends that the calculated ACLs summarized in the table below be adopted for SWMU 2 as the groundwater protection standards. Given the absence of human receptors, a standard protective of ecological risk in surface water is appropriate for the site. It is recommended that groundwater samples continue to be collected from all monitoring wells in the southeast corner of SWMU 2 and analyzed on a semi-annual basis for VOCs to ensure compliance with the ACLs. Semi-annual surface-water sampling of Big Creek should also continue which will provide verification that VOCs are not impacting Big Creek.

Calculated Alternate Concentration Limits
NSA Mid-South SWMU 2
(units in ug/L)

Constituent	Calculated ACL (2)	Proposed ACL (1/10 Calculated)	Above the ACL?
Vinyl Chloride	5,217	522	No
Trans-1,2-Dichloroethene	252,174	25,217	No
cis-1,2-Dichloroethene	252,174	25,217	No
Trichloroethene	65,217	6,522	No
1,1,2-Trichloroethane	34,783	3 478	No

(1) See Table 1 for methodology to determine which MACLs were most stringent

(2) Alternate Concentration Limit (ACL) calculated using the following equation:

ACL = MACL/R
MACL = chronic MACL
where R = dilution factor = Vgw/Vsw or 0.0046/1 = 0.0046

Vgw = 0.0046 cubic feet per second (cfs) to Big Creek (see Appendix A for Groundwater Flow Calculations)
Vsw = 3-day 20-yr low flow = 1.0 cfs for Big Creek (see Appendix B for USGS Streamflow Estimate and Calculations)

4.0 REFERENCES

EnSafe Inc. (2001, December 11). *RCRA Facility Investigation Report — SWMU 2 Southside Landfill, Revision 1.* EnSafe: Memphis, Tennessee.

— (2004, February 27). *Corrective Measures Study Report, SWMU 2— Southside Landfill, Revision 1.* EnSafe: Memphis, Tennessee.

— (2005, June 30). *Monitored Natural Attenuation Work Plan, SWMU 2 — Southside Landfill, Revision 1*. EnSafe: Memphis, Tennessee.

— (2006, October 26). *Monitored Natural Attenuation Effectiveness Progress Report, Naval Support Activity Mid-South, SWMU 2 — Southside Landfill, Revision 1. EnSafe: Memphis, Tennessee.*

Figure Section

Figure 1
SWMU 2 Location Map
NSA Mid-South
Millington, TN

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Figure 2
November 2008 VOC Concentrations
SWMU 2 - Southside Landfill
ACL Technical Memorandum

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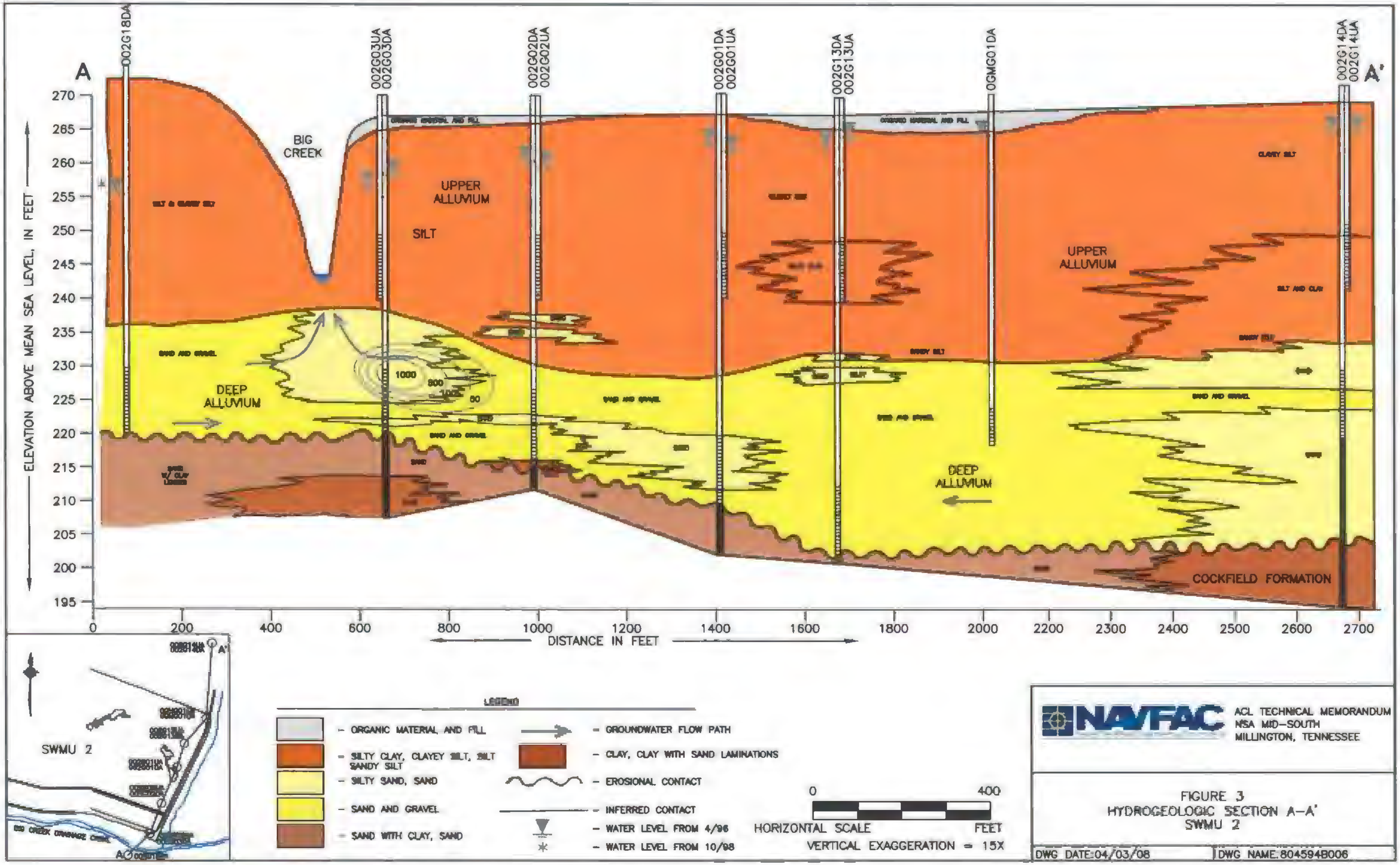
A
A'
002G18DA
002G03UA
002G03DA
002G02DA
002G02UA
002G01DA
002G01UA
002G13DA
002G13UA
OGMG01DA
002G14DA
002G14UA
BIG CREEK
UPPER ALLUVIUM
SILT
DEEP ALLUVIUM
COCKFIELD FORMATION
1000
500
100
50
ELEVATION ABOVE MEAN SEA LEVEL, IN FEET
270
265
260
255
250
245
240
235
230
225
220
215
210
205
200
195
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2300
2400
2500
2600
2700
DISTANCE IN FEET
SWMU 2
LEGEND
- ORGANIC MATERIAL AND FILL
- SILTY CLAY, CLAYEY SILT, SILT SANDY SILT
- SILTY SAND, SAND
- SAND AND GRAVEL
- SAND WITH CLAY, SAND
- GROUNDWATER FLOW PATH
- CLAY, CLAY WITH SAND LAMINATIONS
- EROSIONAL CONTACT
- INFERRED CONTACT
- WATER LEVEL FROM 4/96
- WATER LEVEL FROM 10/98
0
400
HORIZONTAL SCALE
FEET
VERTICAL EXAGGERATION = 15X
NAVFAC
ACL TECHNICAL MEMORANDUM
NSA MID-SOUTH
MILLINGTON, TENNESSEE
FIGURE 3
HYDROGEOLOGIC SECTION A-A'
SWMU 2
DWG DATE:04/03/08
DWG NAME:804594B006

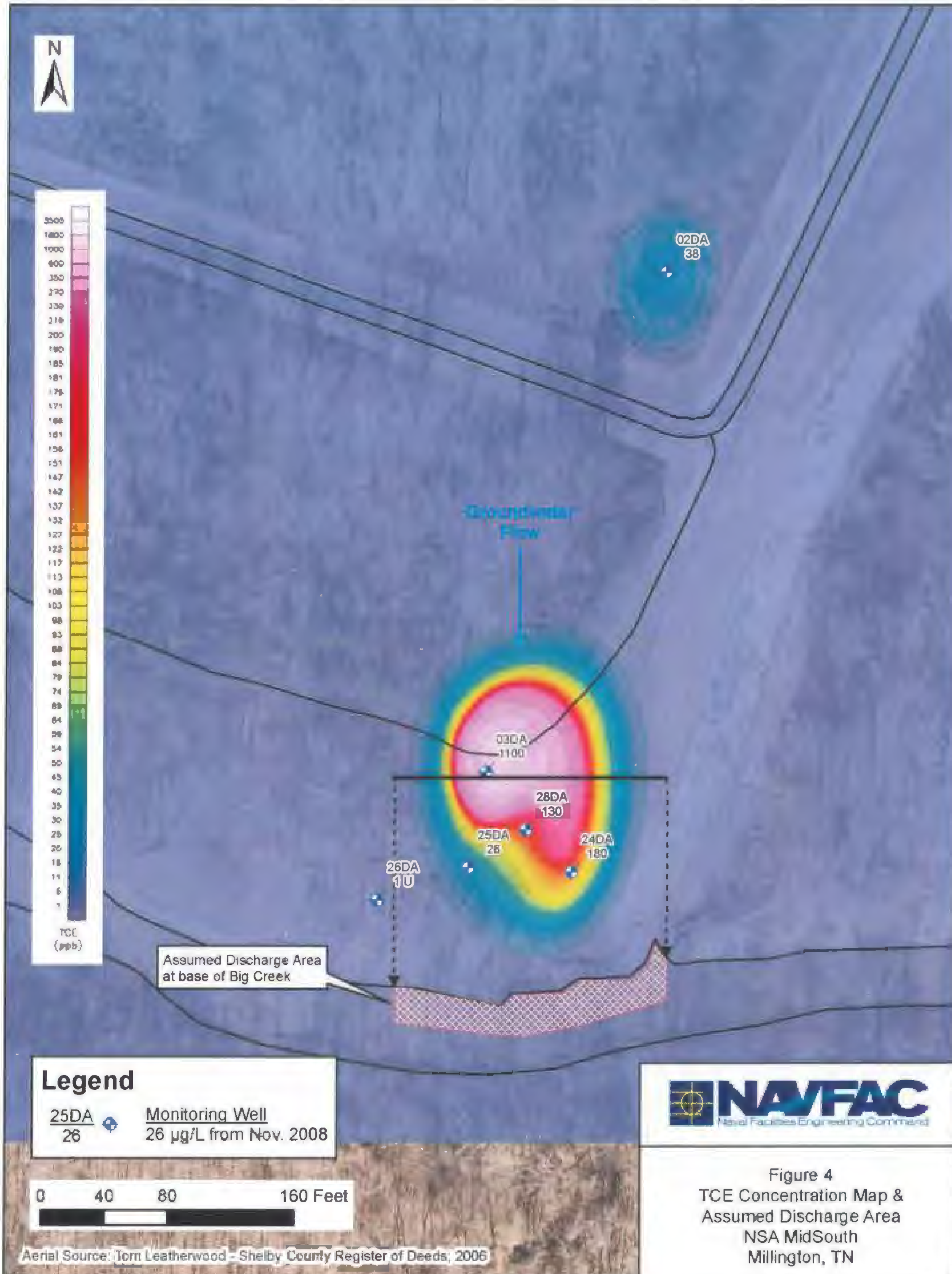

Figure 4
TCE Concentration Map &
Assumed Discharge Area
NSA MidSouth
Millington, TN

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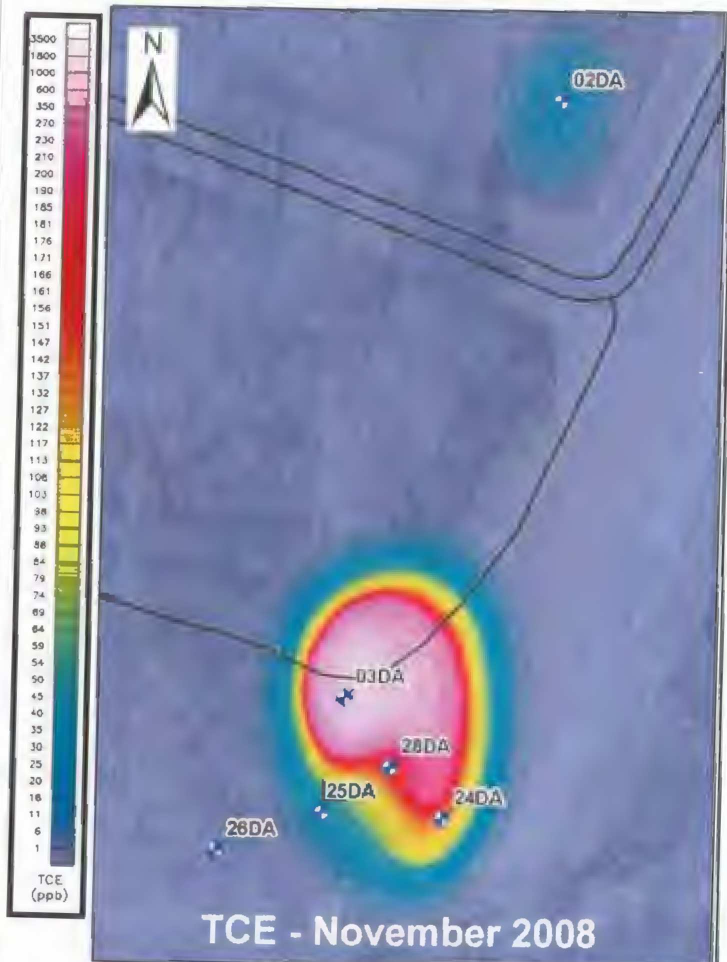


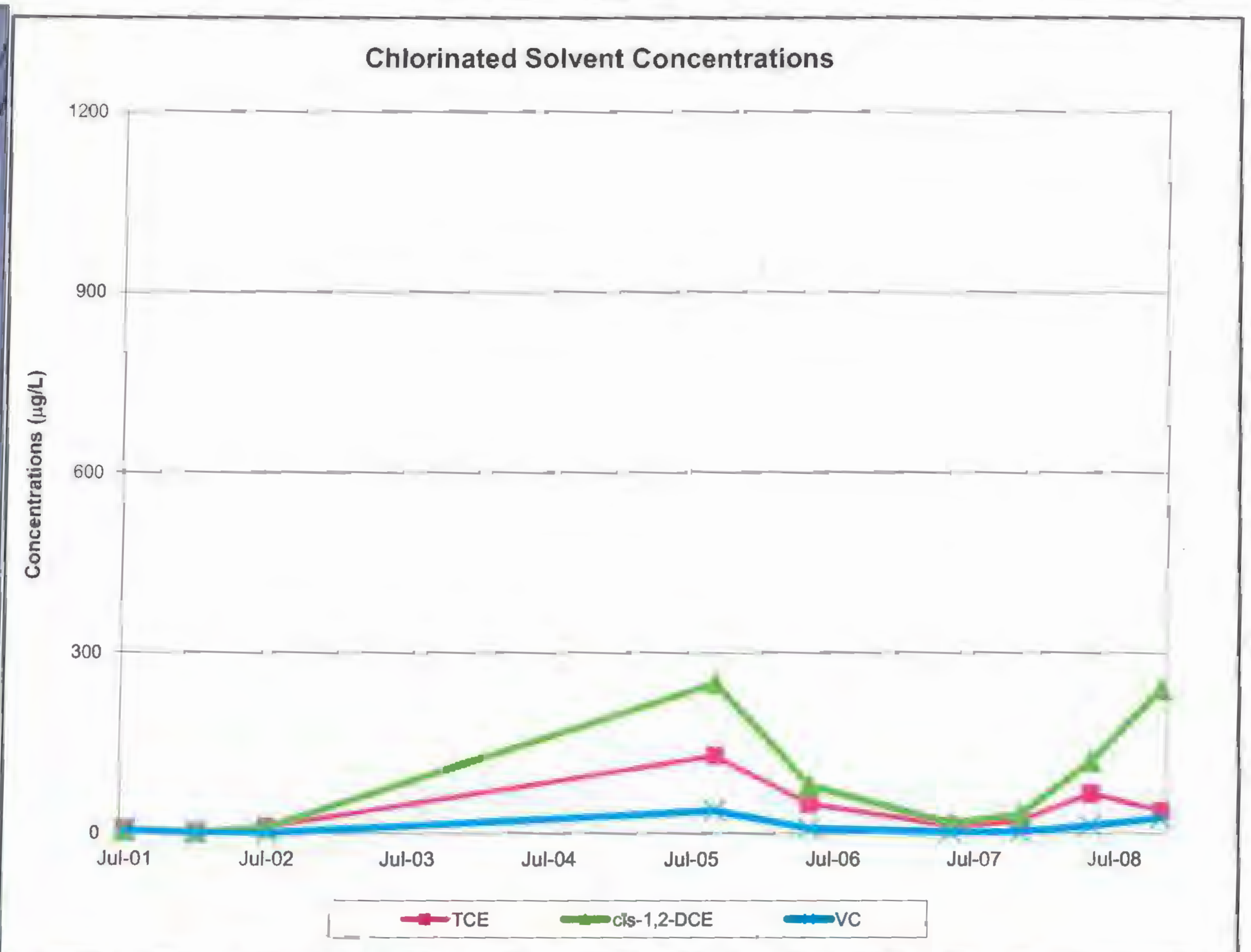
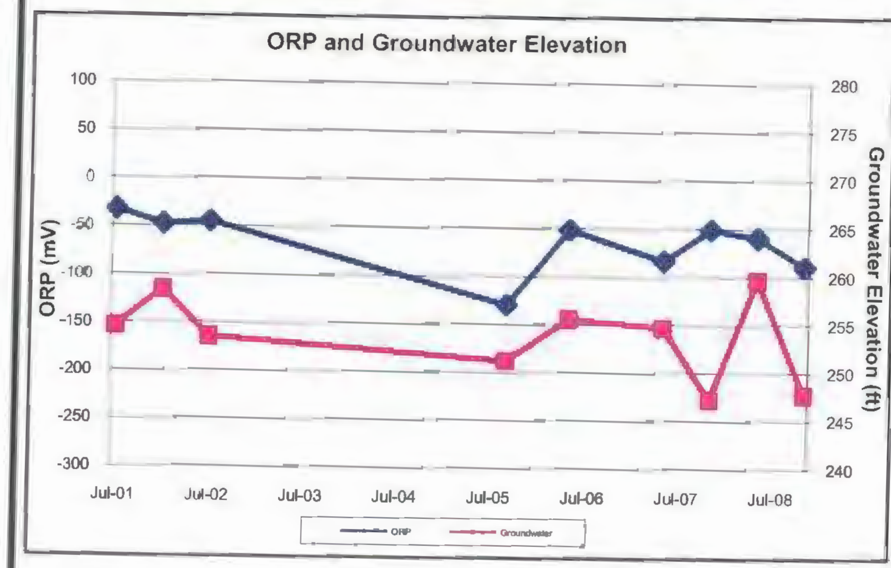


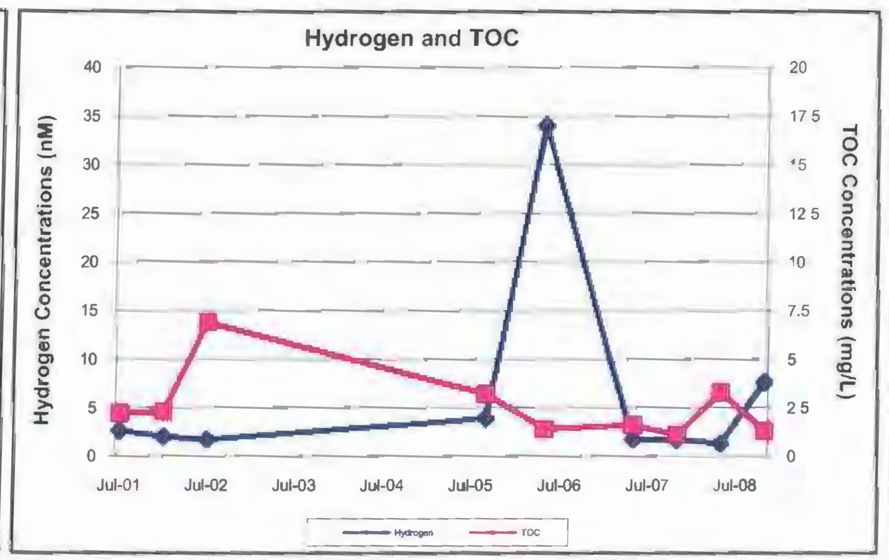
Figure 5
SWMU 2:
MW 002G02DA

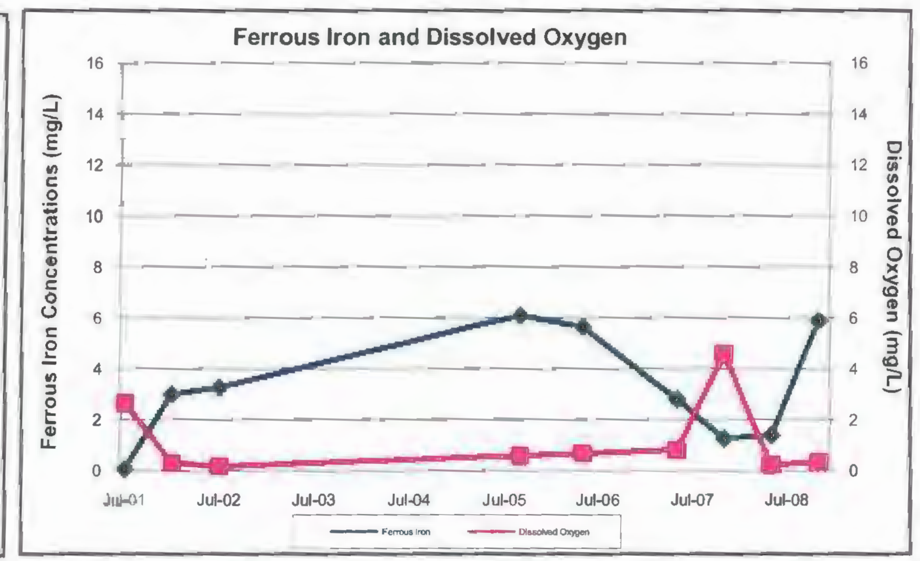
Date	Contaminants (µg/L)		
	TCE	cis-1,2-DCE	VC
Jul-01	7	5	5 U
Jan-02	2	2	1 U
Jul-02	11	10	0.5
Sep-05	130	250	38
May-06	50	80	8
May-07	13	17	2 J
Nov-07	21	32	3
May-08	67	120 J	13
Nov-08	38	240	25

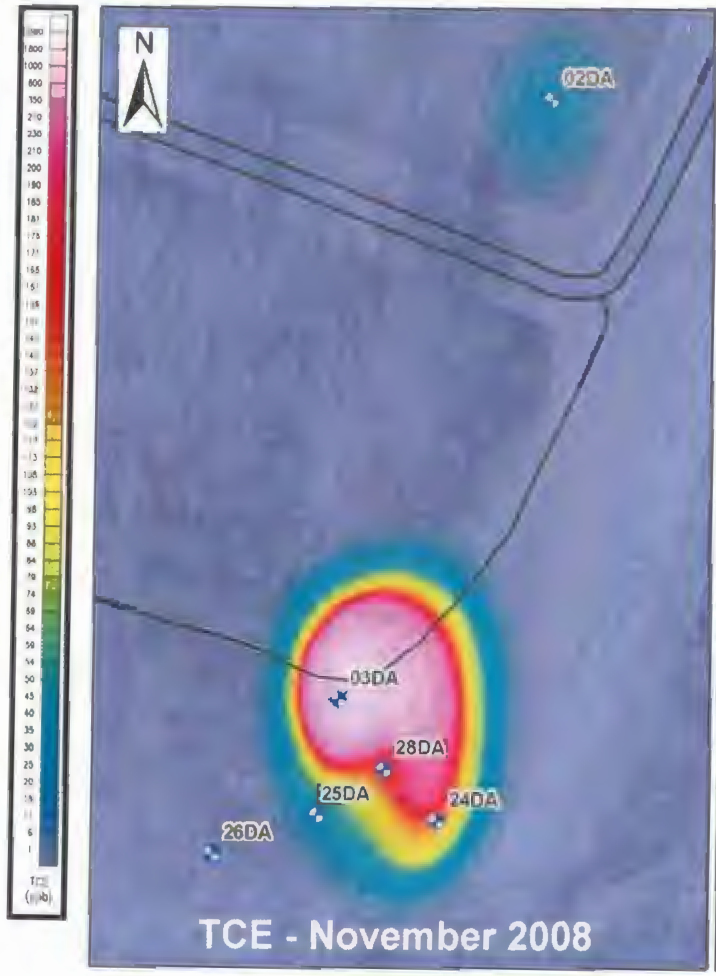
Notes:

µg/L	micrograms per liter
TCE	trichloroethene
cis-1,2-DCE	cis-1,2-dichloroethene
VC	vinyl chloride
J	Estimated
U	Undetected at the limit indicated









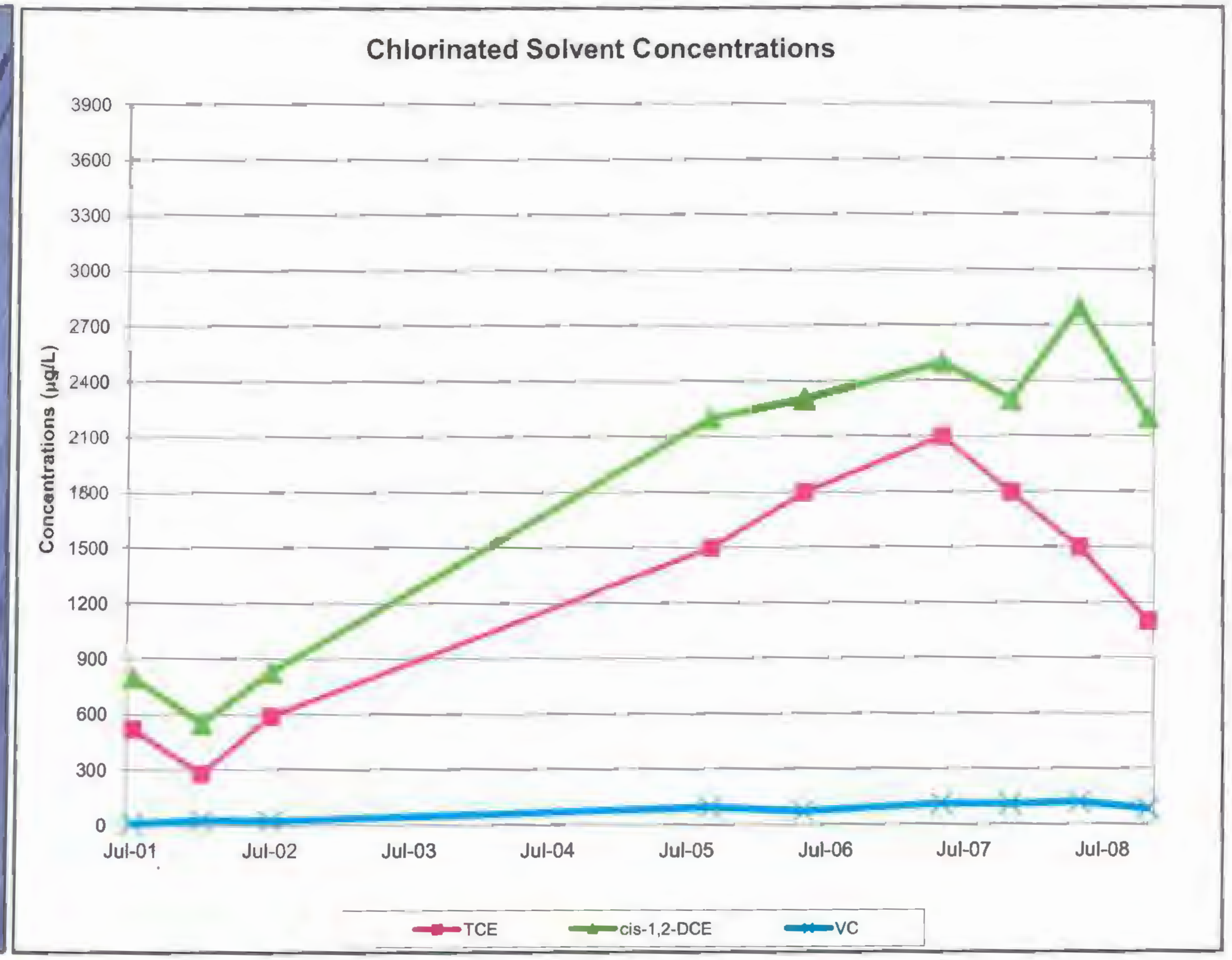
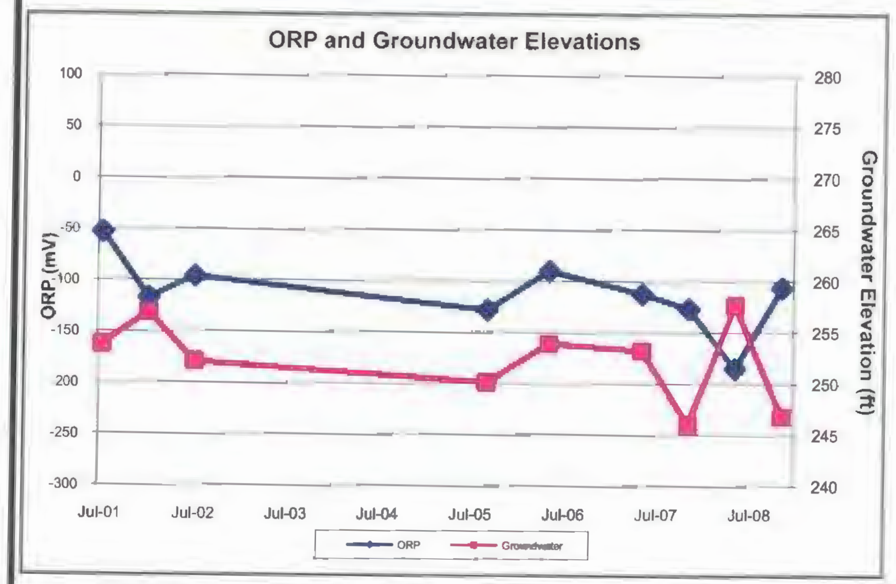


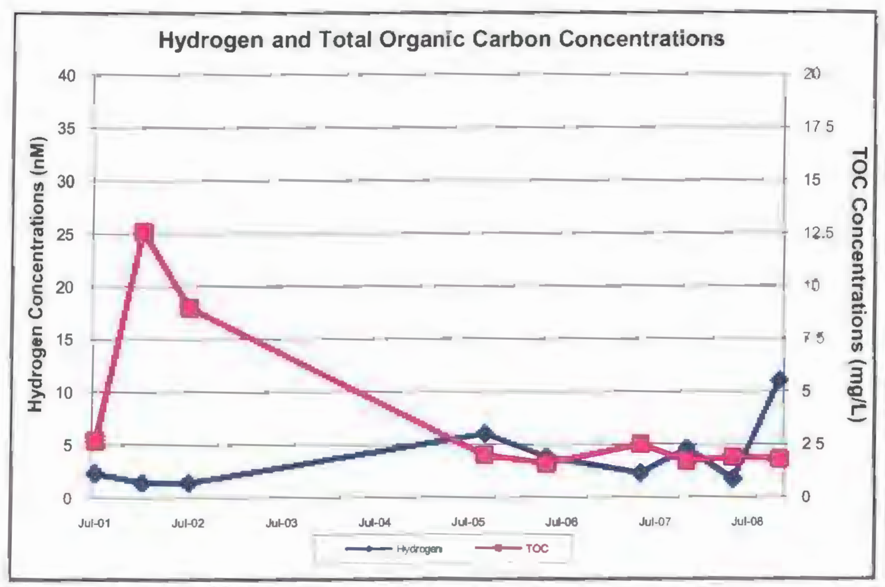
Figure 6
SWMU 2:
MW 002G03DA

Date	Contaminants (µg/L)		
	TCE	cis-1,2-DCE	VC
Jul-01	520	800	5 U
Jan-02	280	550	26
Jul-02	590	830	22
Sep-05	1,500	2,200	94
May-06	1,800	2,300	72
May-07	2,100	2,500	110
Nov-07	1,800	2,300	110
May-08	1,500 J	2,800 J	120
Nov-08	1,100	2,200	82

Notes

µg/L	micrograms per liter
TCE	trichloroethene
cis-1,2-DCE	cis-1,2-dichloroethene
VC	vinyl chloride
J	Estimated
U	Undetected at the limit indicated





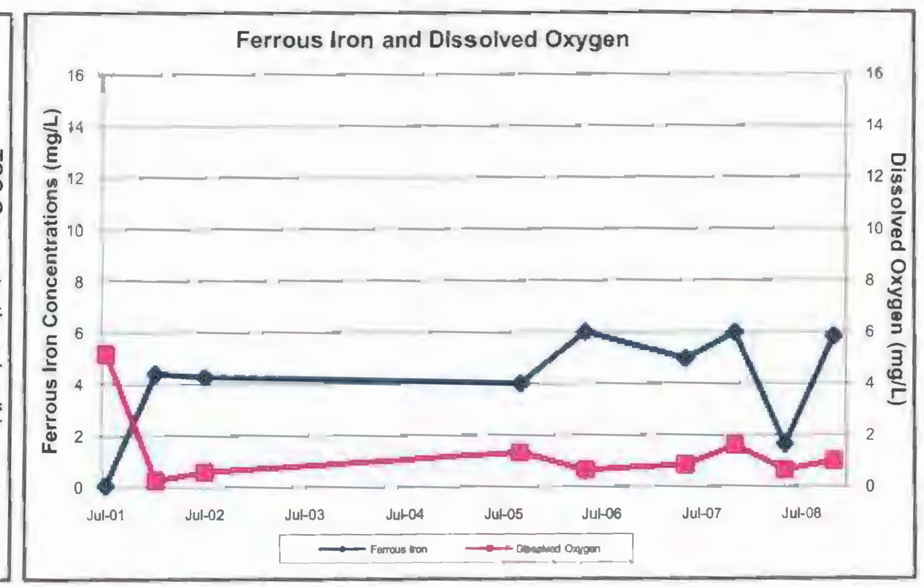
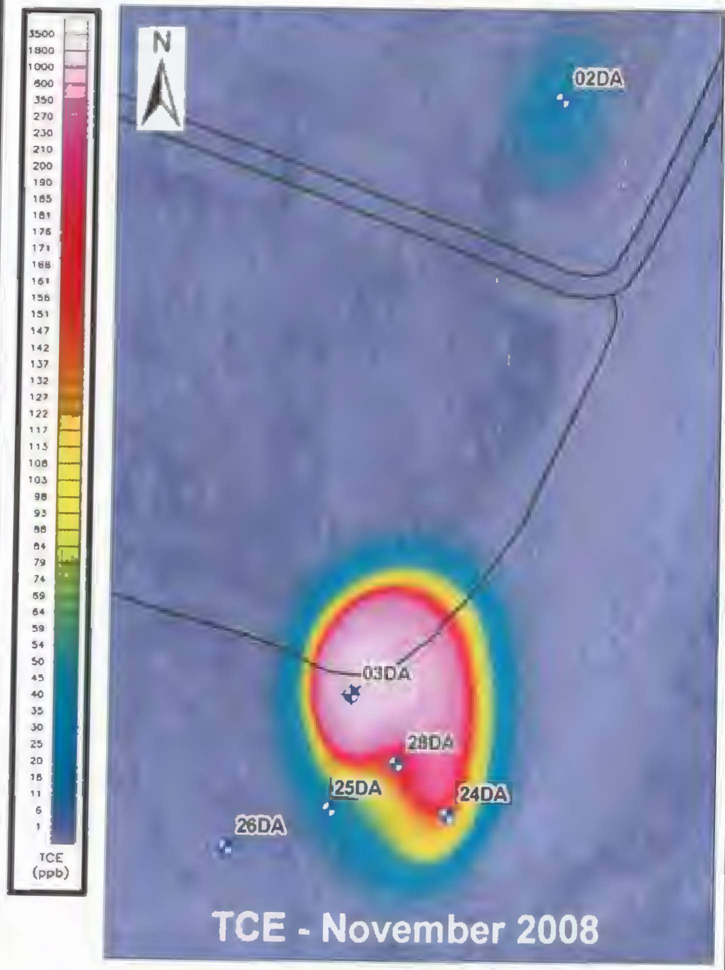
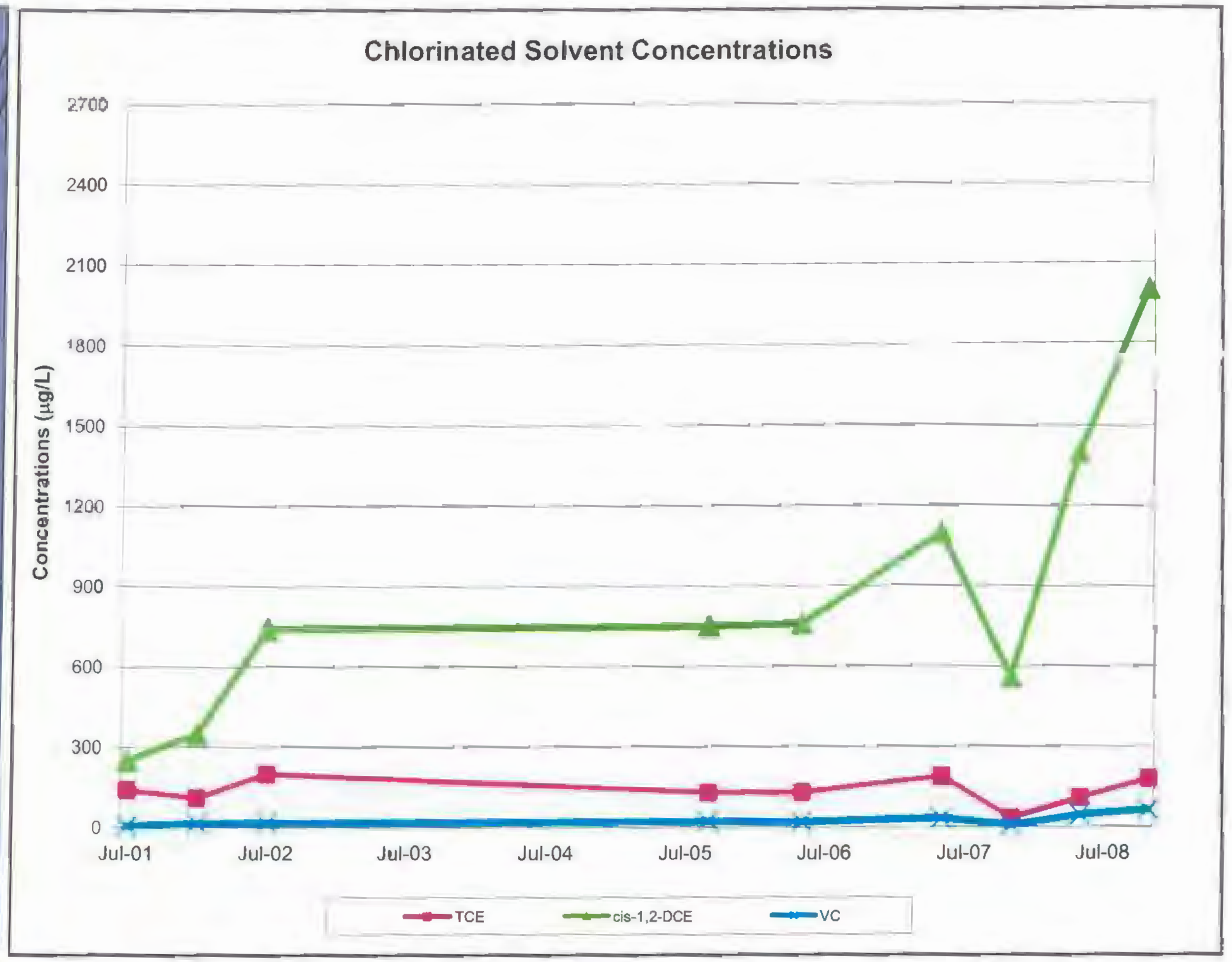


Figure 7
SWMU 2:
MW 002G24DA

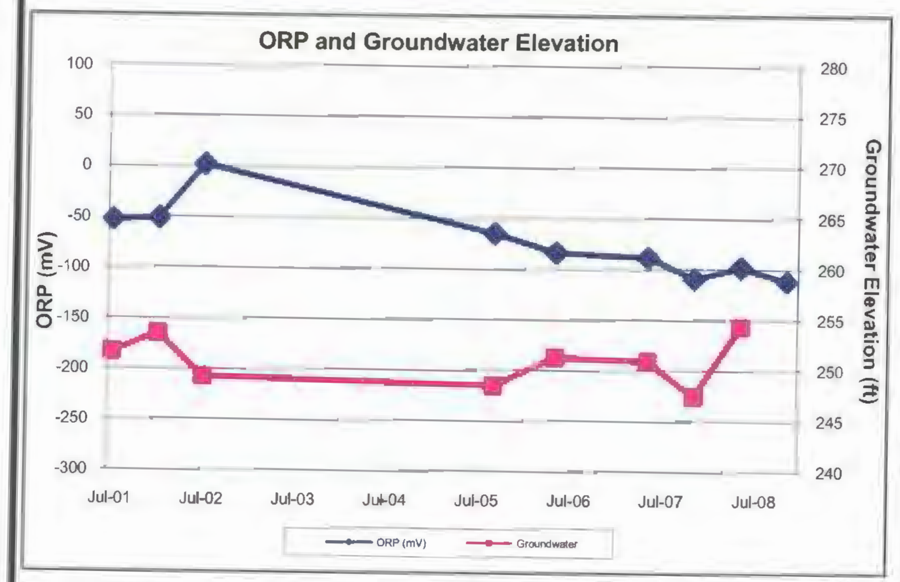


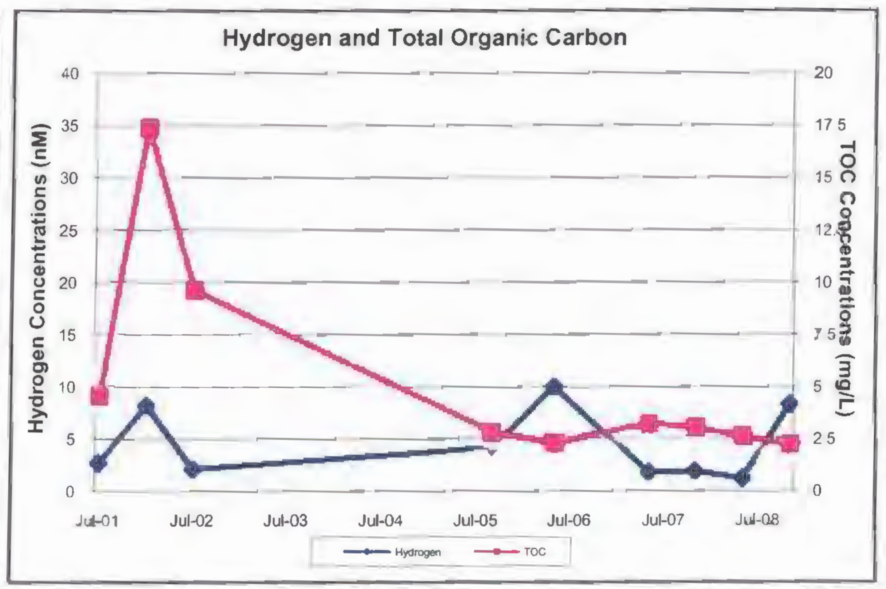


Date	Contaminants (µg/L)		
	TCE	cis-1,2-DCE	VC
Jul-01	140	250	5 U
Jan-02	110	350	14
Jul-02	200	740	16
Sep-05	130	750	21
May-06	130	760	19
May-07	190	1,100	32
Nov-07	35	560	7
May-08	110	1,400	45
Nov-08	180	2,000	63

Notes:

µg/L	micrograms per liter
TCE	trichloroethene
cis-1,2-DCE	cis-1,2-dichloroethene
VC	vinyl chloride
J	Estimated
U	Undetected at the limit indicated





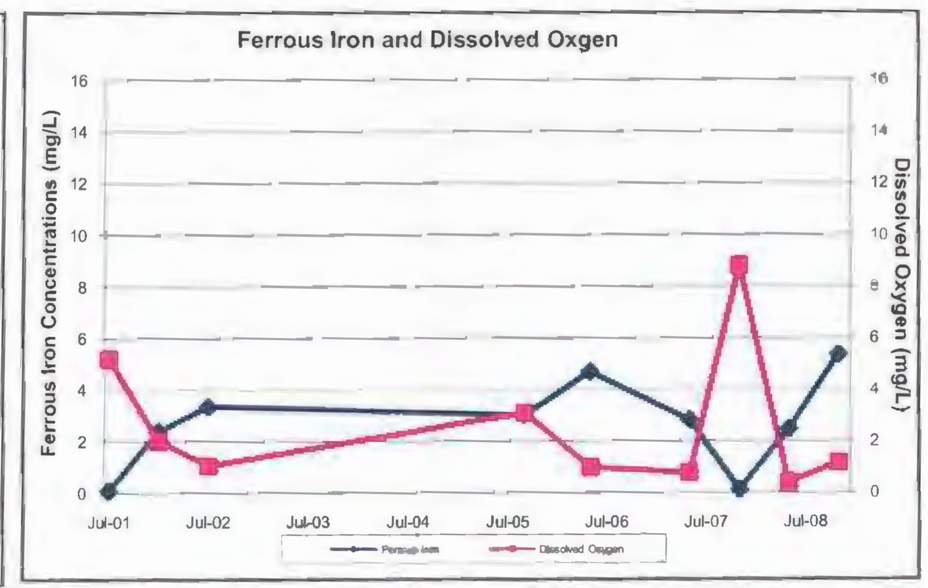
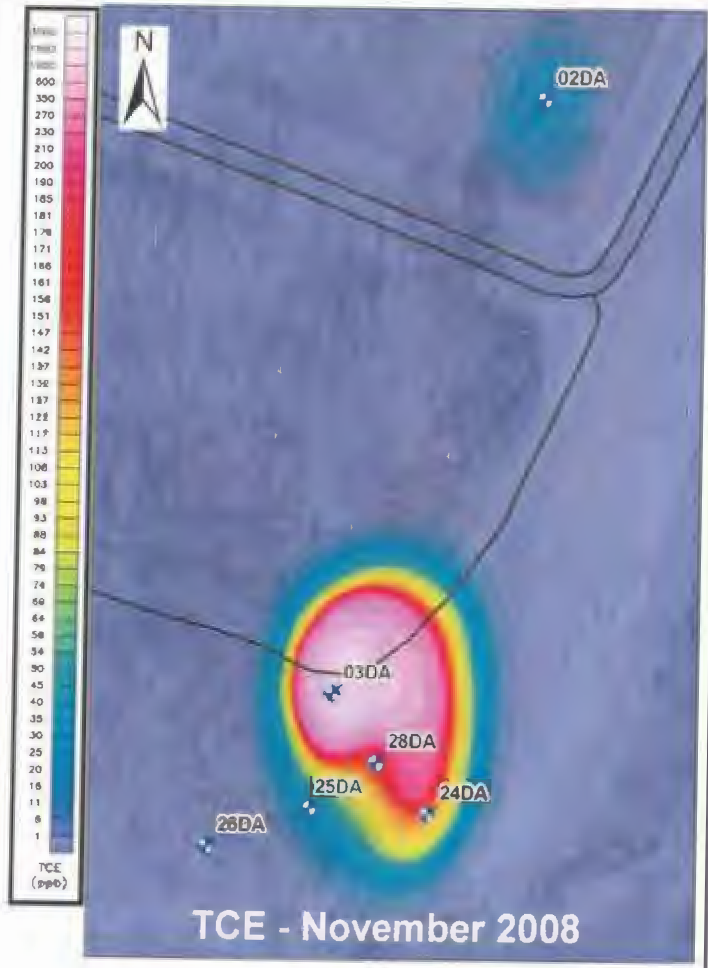
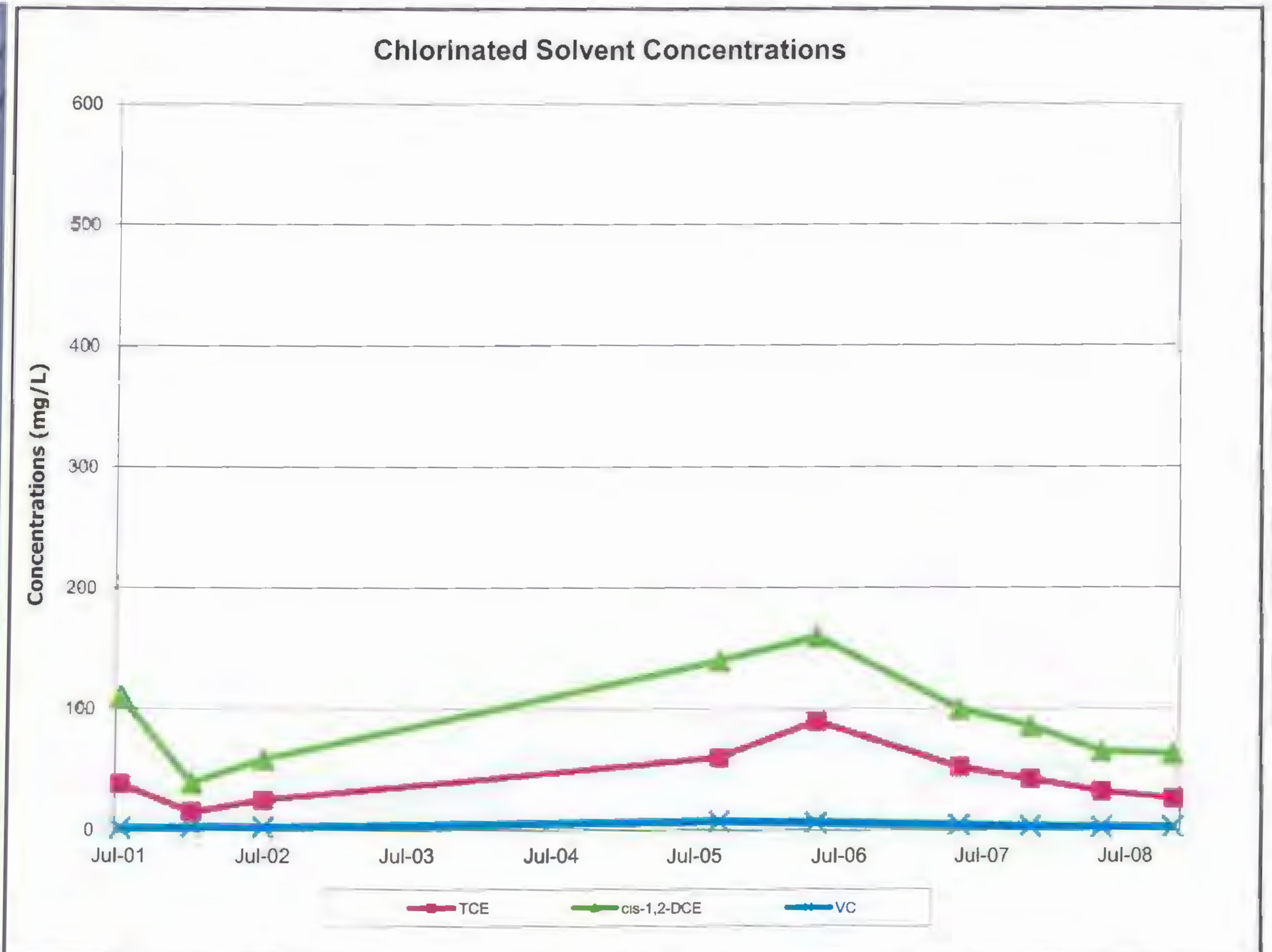


Figure 8
SWMU 2:
MW 002G25DA

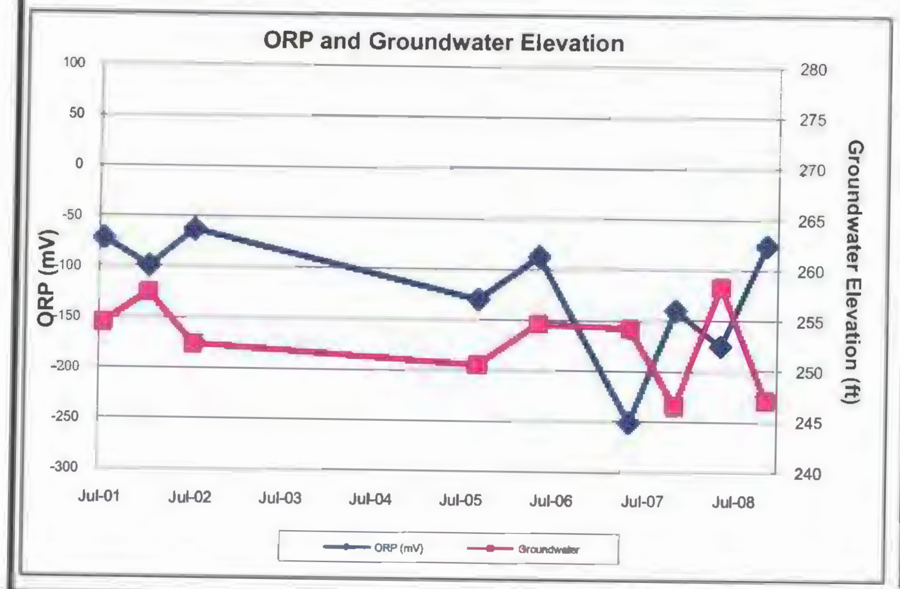


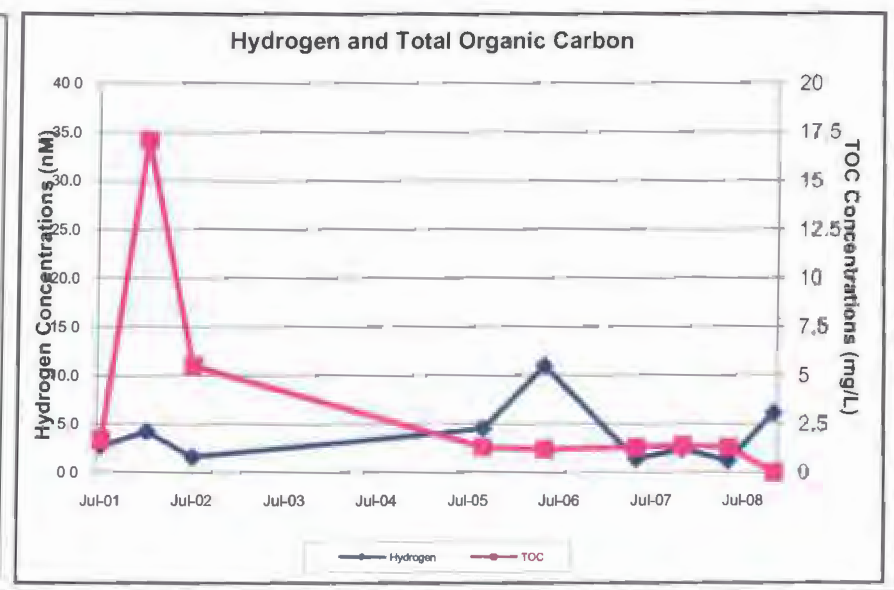


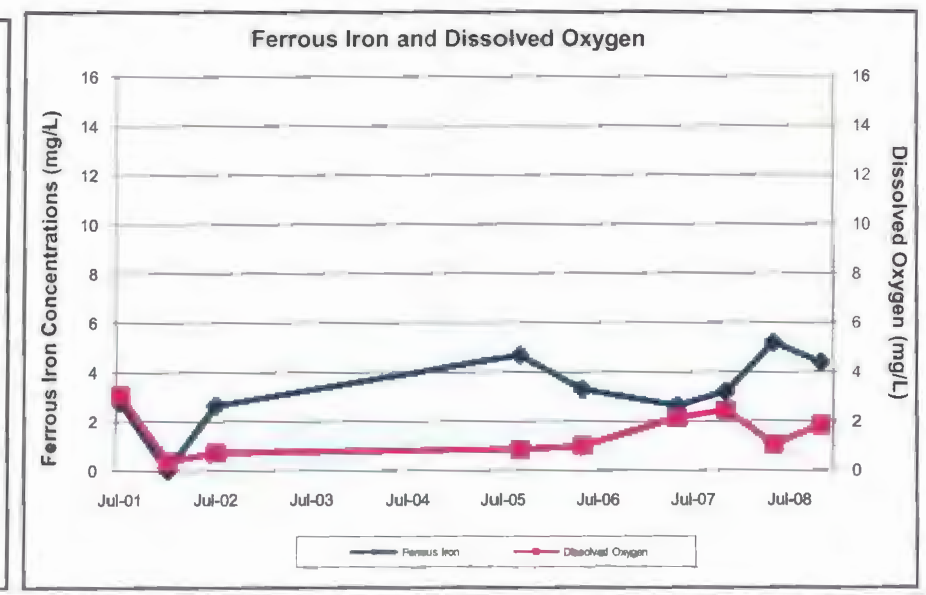
Date	Contaminants (µg/L)		
	TCE	cis-1,2-DCE	VC
Jul-01	38	110	1 U
Jan-02	15	39	2
Jul-02	25	59	2
Sep-05	60	140	7
May-06	90	160	6
May-07	52	100	4
Nov-07	42	86	3
May-08	32	65 J	2
Nov-08	26	63	2

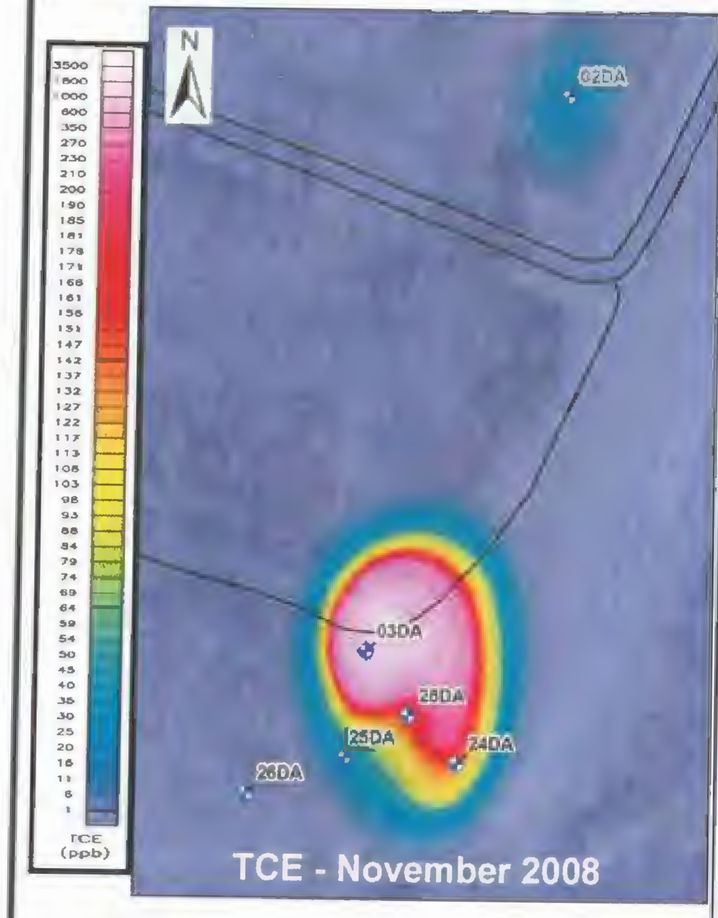
Notes

µg/L	micrograms per liter
TCE	trichloroethene
cis-1,2-DCE	cis-1,2-dichloroethene
VC	vinyl chloride
J	Estimated
U	Undetected at the limit indicated









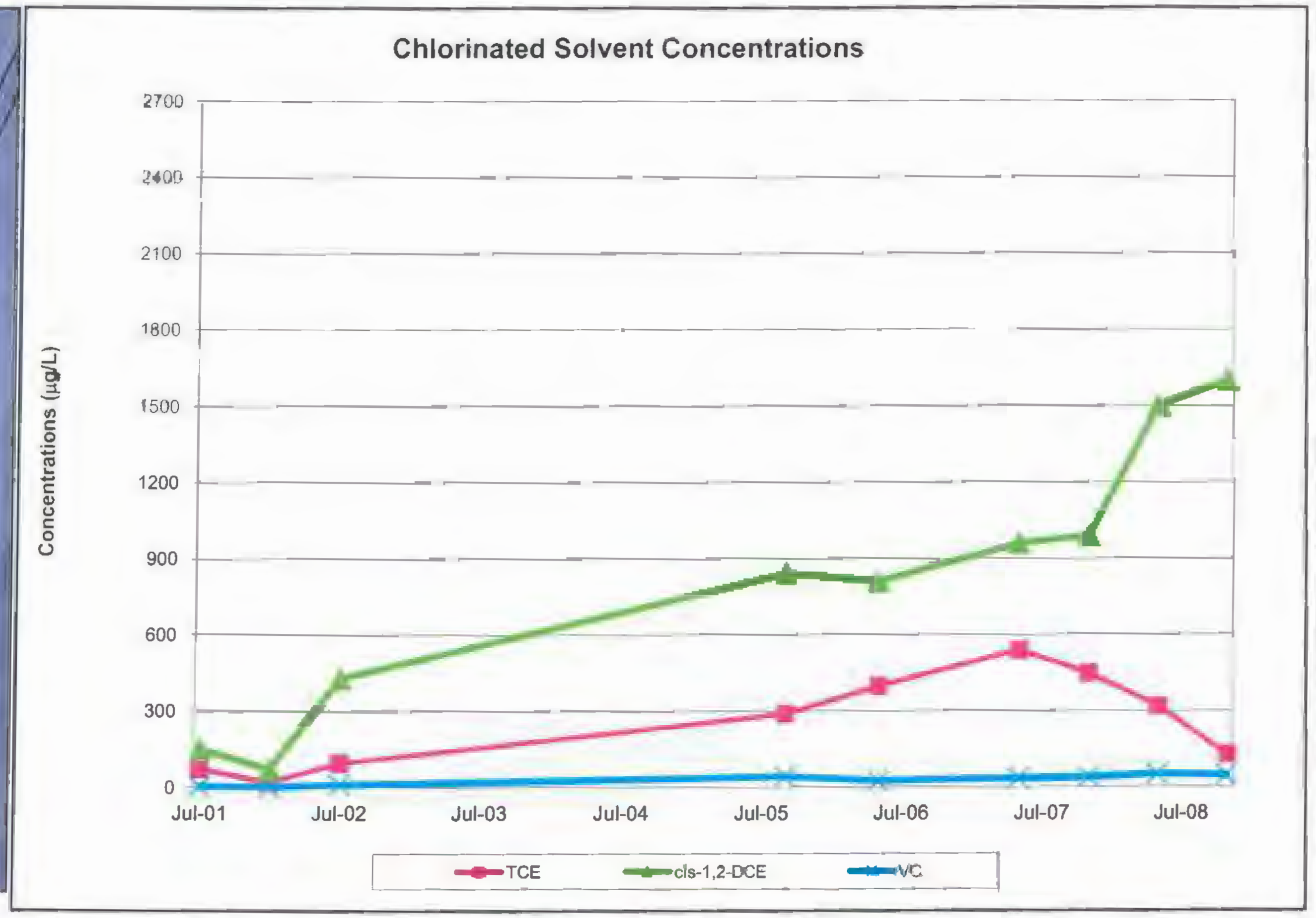
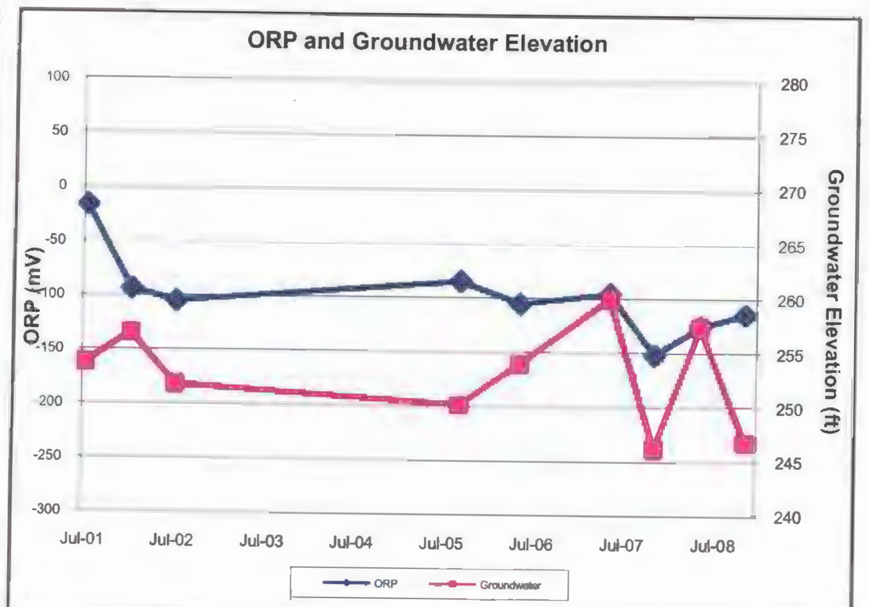


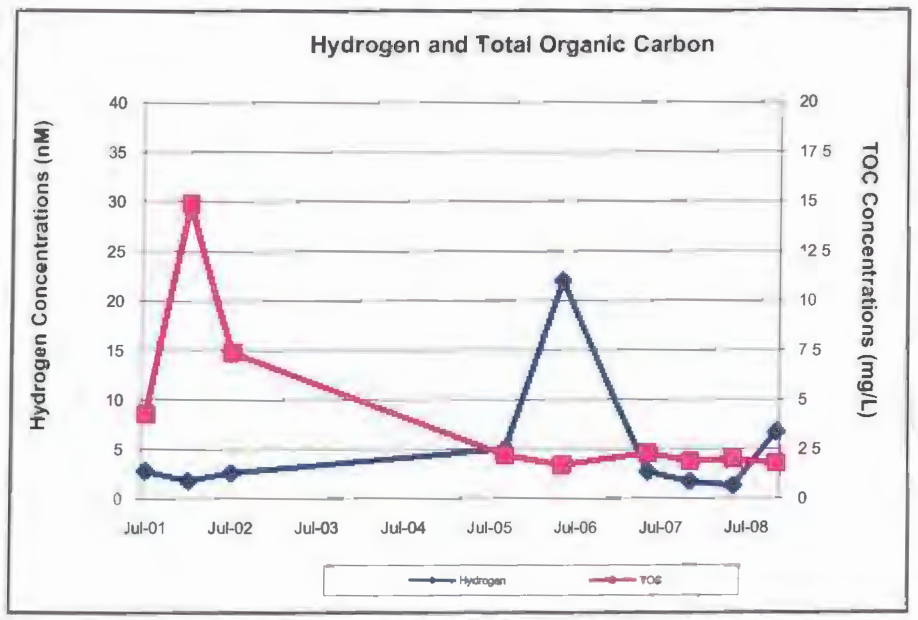
Figure 9
SWMU 2:
MW 002G28DA

Date	Contaminants (µg/L)		
	TCE	cis-1,2-DCE	VC
Jul-01	74	150	5 U
Jan-02	21	71	2
Jul-02	97	430	11
Sep-05	290	840	42
May-06	400	810	25
May-07	540	960	35
Nov-07	450	990	39
May-08	320 J	1,500 J	51
Nov-08	130	1,600	47

Notes:

µg/L	micrograms per liter
TCE	trichloroethene
cis-1,2-DCE	cis-1,2-dichloroethene
VC	vinyl chloride
J	Estimated
U	Undetected at the limit indicated





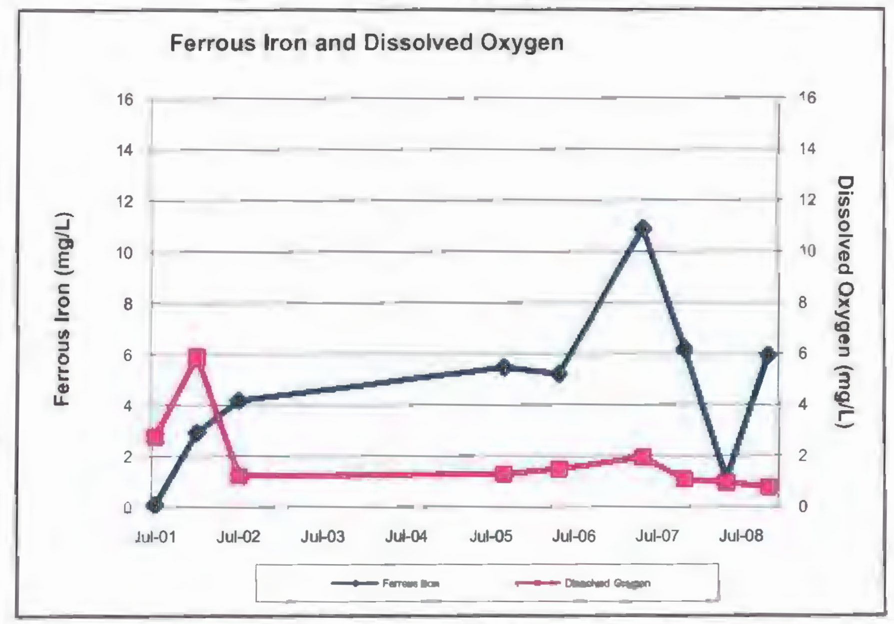


Table Section

Table 1
VOC Detections
SWMU-2 NSA-Midsouth

Monitoring Well	Constituent	Concentration (µg/L)								
		Jul-01	Jan-02	Jul-02	Sep-05	May-06	May-07	Nov-07	May-08	Nov-08
002G01DA	TCE	ND	ND	ND	NS	NS	NS	NS	NS	NS
	cis-1,2-DCE	ND	ND	ND	NS	NS	NS	NS	NS	NS
	trans-1,2DCE	ND	ND	ND	NS	NS	NS	NS	NS	NS
	VC	ND	ND	ND	NS	NS	NS	NS	NS	NS
002G02DA	TCE	7	2	11	130	50	13	21	67	38
	cis-1,2-DCE	5	2	10	250	80	17	32	120 J	240
	trans-1,2-DCE	ND	ND	2	47	ND	4	6	24	48
	VC	ND	ND	0.5 J	38	8	2 J	3	13	25
002G03DA	TCE	520	280	590	1,500	1,800	2,100	1,800	1,500 J	1,100
	1,1-DCE	ND	5	ND	3	4	5	4	6	4
	cis-1,2-DCE	800	550	830	2,200	2,300	2,500	2,300	2,800 J	2,200
	trans-1,2-DCE	190	ND	ND	580	650	680	630	690	590
	VC	ND	26	22	94	72	110	110	120	82
	1,1,2-TCA	5 J	2 J	2	ND	ND	ND	ND	ND	ND
	Xylenes	ND	ND	ND	0.6 J	ND	ND	ND	ND	ND
	Benzene	ND	ND	ND	0.8 J	ND	ND	ND	ND	ND
002G24DA	TCE	140	110	200	130	130	190	35	110	180
	1,1-DCE	ND	ND	0.8 J	0.8 J	1 J	2	ND	3	4
	cis-1,2-DCE	250	350	740	750	760	1,100	560	1,400 J	2,000
	trans-1,2-DCE	72	77	160	190	220	350	100	400	520
	VC	5	14	16	21	19	32	7	45	63
	Bromoform	ND	2	ND	ND	ND	ND	ND	ND	ND
	Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	0.3 J
	1,1,2-TCA	ND	0.4 J	ND	ND	ND	ND	ND	ND	ND
	Benzene	ND		ND	ND	ND	ND	ND	ND	ND
002G25DA	TCE	38	15	25	60	90	52	42	32	26
	Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	0.3 J
	cis-1,2-DCE	110	39	59	140	160	100	86	65 J	63
	trans-1,2-DCE	27	10	21	40	51	33	26	20	18
	1,1,2-TCA	ND	ND	ND	ND	0.6 J	ND	ND	ND	ND
	VC	ND	2	2	7	6	4	3	2	2
002G26DA	TCE	ND	7	ND	ND	ND	ND	ND	ND	ND
	cis-1,2-DCE	ND	35	ND	ND	1	ND	ND	ND	ND
	trans-1,2-DCE	ND	5	ND	ND	ND	ND	ND	ND	ND
	VC	ND	ND	ND	ND	ND	ND	ND	ND	ND
002G27DA	TCE	ND	0.8 J	ND	0.4	ND	ND	NS	NS	NS
	cis-1,2-DCE	ND	ND	ND	0.7 J	0.5 J	ND	NS	NS	NS
	trans-1,2-DCE	ND	0.5 J	ND	ND	ND	ND	NS	NS	NS
	VC	ND	ND	ND	ND	ND	ND	NS	NS	NS
002G28DA	Acetone	ND	ND	ND	ND	ND	ND	ND	ND	2 J
	TCE	74	21	97	290	400	540	450	320 J	130
	carbon disulfide	ND	0.1 J	ND	ND	ND	ND	ND	ND	ND
	1,1-DCE	ND	ND	ND	1 J	1 J	2 J	1 J	3	3
	cis-1,2-DCE	150	71	430	840	810	960	990	1,500 J	1,600
	trans-1,2-DCE	36	18	77	220	220	260	280	330	350
	VC	ND	ND	11	42	25	35	39	51	47
Surface Water Samples										
002WCENT	Acetone	ND	ND	ND	ND	4 J	ND	ND	ND	5 J
002WWEST	Acetone	ND	ND	ND	ND	ND	ND	ND	ND	5 J
	Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	0.3 J
002WEAST	Acetone	ND	ND	ND	ND	4 J	ND	ND	ND	0.3 J
	Chloromethane	ND	ND	ND	ND	ND	ND	ND	ND	0.3 J

Notes:

µg/L	micrograms per liter
NS	not sampled
ND	analyte not detected above the method detection limit
J	Estimated value

Table 2
Maximum Allowable Concentration Limits (MACLs)
NSA Mid-South SWMU 2

Constituent	SWMU 2 VOCs [a]	Source 1 Ecological MACL-acute (μg/L)	Source 1 Ecological MACL-chronic (μg/L)	Source 2 Ecological MACL-acute (μg/L)	Source 2 Ecological MACL-chronic (μg/L)	Most Stringent MACL	Notes
Vinyl Chloride	8.20E+01	NA	NA	2.40E+02	2.40E+01	2.40E+01	(4)
Trans-1,2-dichloroethene	3.50E+02	1.16E+04	1.16E+03	1.00E+05	1.00E+04	1.16E+03	(3)
cis-1,2-dichloroethene	2.80E+03	1.16E+04	1.16E+03	NA	NA	1.16E+03	(3)
Trichloroethene	2.10E+03	4.50E+04	2.19E+04	3.00E+03	3.00E+02	3.00E+02	(4)
1,1,2-Trichloroethane	5.00E+00	1.80E+04	9.40E+03	1.60E+03	1.60E+02	1.60E+02	(4)

Notes:

(1) NOAA (1999) Screening Quick Reference Tables, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration, September 1999.
(2) Tennessee Water Quality Criteria, Chapter 1200-4,Rule 3-.03(3)(g) — Organisms Only Criteria 3/10/2008 phone meeting with Clayton Bullington of TDEC, these numbers are chronic only.
(3) MACL — chronic was developed as 1/10 the MACL-acute
(4) MACL— acute was developed as 10 times the MACL-chronic.
(oval) Indicates concentration at or above the most stringent MACL
a - Represents the maximum detection up to November 2008
μg/L -micrograms per liter

Table 3
Calculated Alternate Concentration Limits
NSA Mid-South SWMU 2
(units in μg/L)

Constituent	Calculated ACL (2)	Proposed ACL (1/10 Calculated)	Above the ACL?
Vinyl Chloride	5,217	522	No
Trans-1,2-Dichloroethene	252,174	25,217	No
cis-1,2-Dichloroethene	252,174	25,217	No
Trichloroethene	65,217	6,522	No
1,1,2-Trichloroethane	34,783	3,478	No

Notes:

(1) See Table 1 for methodology to determine which MACLs were most stringent

(2) Alternate Concentration Limit (ACL) calculated using the following equation:

ACL = MACL/R

MACL = chronic MACL

where R = dilution factor = Vgw/Vsw or 0.0046/1 = 0.0046

Vgw = 0.0046 cubic feet per second (cfs) to Big Creek (see Appendix A for Groundwater Flow Calculations)

Vsw = 3-day 20-yr low flow = 1.0 cfs for Big Creek (see Appendix B for USGS Streamflow Estimate and Calculations)

Appendix A
USGS Flow Duration and Low-Flow Frequency Analysis of Big Creek Drainage Canal at SWMU 2

Flow-duration and low-flow-frequency computer program, TDEC Version 2.0.3

Streamflow estimates for:

Big Creek at SWMU 2 at NSA Mid-South at Millington, Tenn.

LAT: 35 19 16 LNG: 89 51 46 West Tennessee Region

Explanatory variables:

DA: 65.50 GF: 32.0 CF: 2.40300 SF: 89.0 USS: 1.23

Method specifications:

Number of sites in region-of-influence (ROI) = 30
ROI selection metric = f(DA,GF,CF)
ROI regression = f(DA,GF-30,SF)
Number of sites in regional-regression (RRE) = 124
RRE regression = f(DA,GF-30,CF,SF,USS)

Region-of-influence method data:

MNO	STANO	LAT	LNG	DA	GF	CF	SF	USS	LOCATION
1221	7030352	35.334	89.917	91.0	32	2.403	89	1.23	BIG CR MILLINGTON TN
0350	7032200	35.050	89.819	68.2	32	2.438	42	1.06	NONCONNAH CR GERMANTN TN
1183	7026100	36.180	89.254	52.3	32	2.362	46	1.07	REEDS CR TRIMBLE TN
1216	7030100	35.756	89.551	33.9	32	2.391	67	1.15	CANE CR RIPLEY TN
1220	7030250	35.320	89.658	145.5	32	2.405	63	1.14	BEAVER CR ARLINGTON TN
1177	7025200	36.278	88.984	73.8	40	2.354	43	1.12	MUD CR SIDONIA TN
0323	3610545	36.780	88.468	68.3	32	2.337	58	2.44	W FK CLARKS R BREWERS KY
0334	7026500	36.442	89.296	110.5	32	2.346	72	1.20	REELFOOT CR SAMBURG TN
0327	7023500	36.686	88.726	36.9	36	2.341	44	1.50	OBION CR PRYORSBURG KY
1182	7026030	36.262	89.212	17.5	32	2.357	71	1.17	RICHLAND CR OBION TN
1184	7027100	36.310	89.386	15.0	32	2.352	92	1.27	PAW PAW CR PUSH TN
0993	3593307	35.142	88.371	33.2	65	2.418	40	1.12	OWL CR HURLEY TN
0991	3593115	35.093	88.340	31.4	65	2.428	46	1.02	LICK CR HAMBURG TN
0321	3610000	36.593	88.300	90.0	63	2.340	33	0.97	CLARKS R MURRAY KY
0322	3610500	36.873	88.347	229.4	44	2.307	49	1.65	CLARKS R BENTON KY
1010	35941625	35.418	88.159	18.8	64	2.400	40	1.11	STEWMAN CR UNITY TN
0290	3592800	34.901	88.293	143.8	69	2.440	86	2.22	YELLOW CR DOSKIE MS
1194	7027700	35.678	89.133	24.9	69	2.396	37	1.07	MUD CR BELLS TN
0317	3604800	35.899	88.127	45.6	75	2.372	63	1.76	BIRDSNG CR 2 HOLLADAY TN
1179	7025350	36.404	88.719	36.8	73	2.348	65	1.71	CYPRESS CR LATHAM TN
0992	3593303	35.175	88.389	9.8	65	2.416	51	1.25	CLEAR CR W SHILOH TN
0300	3594480	35.580	88.152	8.4	63	2.392	39	1.09	TURKEY CR DECATURV TN
0289	3592718	34.835	88.287	25.6	87	2.443	85	2.20	LTL YELLW CR BURNSV MS
1135	3604750	35.881	88.144	15.6	80	2.372	77	2.14	BIRDSNG CR 1 HOLLADAY TN
0294	3594058	35.372	88.384	46.7	98	2.407	54	1.63	WHITE OAK CR MLLEDGV TN
0291	3593300	35.220	88.427	50.2	100	2.413	42	1.42	SNAKE CR ADAMSVILLE TN
1203	7029350	35.015	88.739	328.9	85	2.444	46	1.41	TUSCUMBIA R CYPRESS TN
0295	3594120	35.416	88.361	46.1	110	2.405	42	1.39	MIDDLETON CR MLLEDGV TN
0346	7030280	35.281	89.766	504.9	83	2.405	56	1.24	LOOSAHATCHIE R BRSWCK TN
1188	7027290	35.431	88.641	40.0	121	2.403	57	1.62	SUGAR CR HENDERSON TN

Flow-duration and low-flow-frequency computer program, TDEC Version 2.0.3

Streamflow estimates for:

Big Creek at SWMU 2 at NSA Mid-South at Millington, Tenn.

LAT: 35 19 16 LNG: 89 51 46

Summary of regression results in cubic ft/s:

Rv	ROI VALUE	90% PREDICTION INTERVAL		EY	RRE VALUE
7Q10	1.33	0.09	19.23	0.28	1.02
30Q5	1.71	0.22	13.38	0.46	1.42
MA	94.30	68.91	129.05	7.81	89.55
MS	33.09	14.54	75.32	2.83	30.06
q99.5	1.26	0.09	17.25	0.34	0.94
q99	1.36	0.15	12.66	0.41	1.08
q98	1.47	0.19	11.52	0.47	1.21
q95	1.68	0.23	12.48	0.46	1.43
q90	1.99	0.28	13.99	0.45	1.64
q80	2.82	0.45	17.83	0.44	2.33
q70	3.45	0.60	19.81	0.45	2.97
q60	4.55	0.93	22.18	0.57	2.96
q50	6.89	1.75	27.15	0.79	5.09
q40	11.78	3.55	39.14	1.07	10.24
q30	23.12	9.21	58.07	1.56	23.33
q20	71.60	37.29	137.46	2.55	75.15
q10	184.05	125.18	270.59	8.91	166.28

ROI regression equations:

Rv	PARAMETER	COEFFICIENT	SE	T:BETA=0	P-VALUE
7Q10	CONSTANT	-6.4323	1.8473	-3.4820	0.0018
	log(DA)	0.9618	0.2765	3.4786	0.0018
	log(GF-30)	0.3927	0.1919	2.0465	0.0509
	log(SF)	2.4060	0.9767	2.4634	0.0207
30Q5	CONSTANT	-4.7613	1.4215	-3.3495	0.0025
	log(DA)	0.9371	0.2128	4.4046	0.0002
	log(GF-30)	0.3727	0.1477	2.5236	0.0181
	log(SF)	1.6314	0.7516	2.1705	0.0393
MA	CONSTANT	-0.5904	0.2168	-2.7232	0.0114
	log(DA)	1.0230	0.0325	31.5263	0.0001
	log(GF-30)	0.0413	0.0225	1.8320	0.0784
	log(SF)	0.3562	0.1146	3.1076	0.0045
MS	CONSTANT	-1.9804	0.5683	-3.4847	0.0018
	log(DA)	1.1290	0.0851	13.2732	0.0001
	log(GF-30)	0.0403	0.0590	0.6831	0.5006
	log(SF)	0.7374	0.3005	2.4539	0.0211
q99.5	CONSTANT	-6.4178	1.8078	-3.5501	0.0015
	log(DA)	0.9712	0.2706	3.5895	0.0014
	log(GF-30)	0.3836	0.1878	2.0429	0.0513
	log(SF)	2.3797	0.9558	2.4897	0.0195

q99	CONSTANT	-5.6183	1.5419	-3.6438	0.0012
	log(DA)	0.9473	0.2308	4.1048	0.0004
	log(GF-30)	0.3745	0.1602	2.3382	0.0273
	log(SF)	2.0102	0.8152	2.4658	0.0206
q98	CONSTANT	-5.1109	1.4219	-3.5946	0.0013
	log(DA)	0.9367	0.2128	4.4015	0.0002
	log(GF-30)	0.3795	0.1477	2.5693	0.0163
	log(SF)	1.7766	0.7518	2.3632	0.0259
q95	CONSTANT	-4.8655	1.3845	-3.5143	0.0016
	log(DA)	0.9350	0.2072	4.5125	0.0001
	log(GF-30)	0.4161	0.1438	2.8933	0.0076
	log(SF)	1.6765	0.7320	2.2902	0.0304
q90	CONSTANT	-4.7640	1.3490	-3.5316	0.0016
	log(DA)	0.9462	0.2019	4.6866	0.0001
	log(GF-30)	0.4604	0.1401	3.2856	0.0029
	log(SF)	1.6440	0.7132	2.3049	0.0294
q80	CONSTANT	-4.6888	1.2736	-3.6816	0.0011
	log(DA)	1.0050	0.1906	5.2723	0.0001
	log(GF-30)	0.4832	0.1323	3.6520	0.0012
	log(SF)	1.6256	0.6734	2.4140	0.0231
q70	CONSTANT	-4.1229	1.2086	-3.4114	0.0021
	log(DA)	1.0289	0.1809	5.6884	0.0001
	log(GF-30)	0.4979	0.1256	3.9657	0.0005
	log(SF)	1.3551	0.6390	2.1206	0.0437
q60	CONSTANT	-3.5500	1.0944	-3.2438	0.0032
	log(DA)	1.0434	0.1638	6.3699	0.0001
	log(GF-30)	0.4884	0.1137	4.2960	0.0002
	log(SF)	1.1112	0.5786	1.9204	0.0658
q50	CONSTANT	-2.9022	0.9481	-3.0612	0.0051
	log(DA)	1.0357	0.1419	7.2989	0.0001
	log(GF-30)	0.4539	0.0985	4.6090	0.0001
	log(SF)	0.8836	0.5013	1.7627	0.0897
q40	CONSTANT	-2.1323	0.8297	-2.5698	0.0163
	log(DA)	1.0163	0.1242	8.1835	0.0001
	log(GF-30)	0.3885	0.0862	4.5074	0.0001
	log(SF)	0.6364	0.4387	1.4507	0.1588
q30	CONSTANT	-1.2306	0.6363	-1.9339	0.0641
	log(DA)	0.9812	0.0952	10.3025	0.0001
	log(GF-30)	0.3001	0.0661	4.5396	0.0001
	log(SF)	0.3705	0.3364	1.1013	0.2809
q20	CONSTANT	-0.4670	0.4508	-1.0360	0.3098
	log(DA)	0.9481	0.0675	14.0528	0.0001
	log(GF-30)	0.1298	0.0468	2.7718	0.0102
	log(SF)	0.2877	0.2383	1.2072	0.2382
q10	CONSTANT	-0.0332	0.2663	-0.1248	0.9016
	log(DA)	1.0234	0.0399	25.6710	0.0001
	log(GF-30)	0.0484	0.0277	1.7478	0.0923
	log(SF)	0.2180	0.1408	1.5480	0.1337

END PROGRAM

Katherine Terry

From:	George S Law [gslaw@usgs.gov]
Sent:	Tuesday, February 26, 2008 10:41 AM
To:	Katherine Terry
Subject:	Dear Katherine, I have performed an analysis of low-flows and flow durations at Big Creek at SWMU-2 at NSA Mid-South at Millington, Tenn.
Attachments:	millington.doc; ATT698552.jpg

Ms. Katherine Terry
ENSAFE, Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134

Dear Katherine,

I have performed a regression analysis of low-flows and flow durations at Big Creek at SWMU-2 at NSA Mid-South at Millington, Tenn. I used the TDECv2.0.3 low-flow and flow-duration computer program estimate various streamflow statistics at Big Creek at SWMU-2 at NSA Mid-South at Millington. **Using the attached data I estimated a 3Q20 at the site of 1.0 CFS.**

See the graphic below for explanation of analysis. I ran TDECv203 to compute the region-of-influence (regression) estimates and the regional-regression equations (RRE) estimates (see attachment below the graphic). Next, I made an estimate using several observed measurements at Big Creek at US51 made in 1952 and 1995. Next, I used drainage area ratio to move the US51 estimates upstream to SWMU-2 (red numbers). This gives us 3 estimates that we can average to estimate each flow statistic (blue numbers). For example:

7Q10 = (1.33+1.79+1.02)/3 = 1.38

NOTE: To estimate 3Q20 I interpolated down from the 7Q10 estimate.

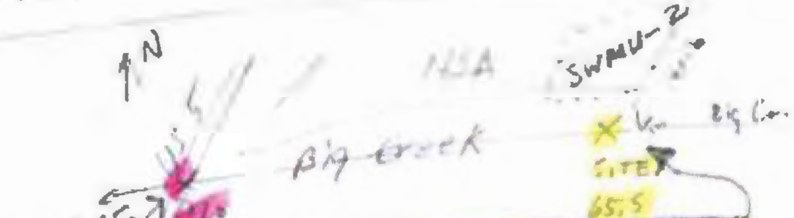
Please let me know if you have questions of need additional information.

Sincerely yours,

George S. Law
Hydrologist
USGS Tennessee Water Science Center
Nashville, Tennessee
615-837-4732

Millington, Big Creek @ WMU-2 @ NAS-Mid South.

Log 65.5 Regression CFS	91.0 At-Station CFS	(65.5/91) ⇓ CFS	65.5 RRE CFS	weighted CFS
7Q10 = 1.33	2.49	(.72) 1.79	1.02	= 1.38
30Q5 = 1.71	2.86	2.06	1.42	= 1.73
MA = 94.3	134	96.5	89.6	= 93.5
MS = 33.1	43.5	31.3	30.1	= 31.5
g99.5 = 1.26	2.24	1.61	.94	= 1.27
g99 = 1.36	2.39	1.72	1.08	= 1.39
g98 = 1.47	2.60	1.87	1.21	= 1.52
g95 = 1.68	2.71	1.95	1.43	= 1.69
g90 = 1.99	2.90	2.09	1.64	= 1.91
g80 = 2.82	3.25	2.34	2.33	= 2.50
g70 = 3.45	3.50	2.52	2.97	= 2.98
g60 = 4.55	3.79	2.72	3.20	= 3.49
g50 = 6.89	4.31	3.10	5.09	= 5.03
g40 = 11.78	7.60	5.47	10.24	= 9.16
g30 = 23.12	19.0	13.7	23.33	= 20.0
g20 = 71.6	88.6	63.8	75.2	= 70.2
g10 = 184	210	(.72) 151	166	= 167



USE 1.0 CFS for 3Q20

2-26-2008

Appendix B
Groundwater Flow Calculations

Appendix B
Groundwater Velocity and Volume Calculations

Objective: Calculating the volume of groundwater discharging into Big Creek Drainage Canal, that corresponds with an area measuring 175 feet long (width of TCE plume) by 15 feet wide (1/2 bottom width of drainage canal).

GW_{vel} [a]	0.15 ft/day	mean groundwater velocity (from SWMU 2 RFI, EnSafe 2001)
L [b]	175 feet	length perpendicular to plume where TCE > 100 ppb
W [c]	15 feet	1/2 width of Big Creek stream bed

$V_{gw} = GW_{vel} * (L * W \text{ of discharge area})$

$V_{gw} =$ *393.75 cft/day*

$V_{gw} =$ **0.00456** cft/sec

Notes -

a - mean groundwater velocity from SWMU 2 RFI (EnSafe, 2001)

b - from Figure 1-2 in *MNA Effectiveness Monitoring Report* (EnSafe, 2006)

c - stream bed width estimated from Figure 1-2 in *Effectiveness Monitoring Report* (EnSafe, 2006). Since stream is receiving groundwater from both its north and south side, 1/2 the width is assumed to represent discharge of contaminated groundwater.