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FINAL

Report for Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater

Offutt Air Force Base, Nebraska
Building 301

Prepared for the Air Force Center for Environmental Excellence, Brooks City-Base, TX and the 55th Civil Engineering Squadron, Offutt AFB, NE

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Prepared By:
Groundwater Services, Inc
2211 Norfolk, Suite 1000, Houston, TX 77098 (713) 522-6300

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GROUNDWATER SERVICES, INC.

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FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

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1.0 OVERVIEW

This report discusses the installation of a 500 ft mulch wall to remediate chlorinated hydrocarbon-impacted groundwater west of Building 301 at Offutt Air Force Base, Nebraska. The mulch wall was configured to extend southward approximately 400 feet from the existing pilot mulch wall to capture the complete width of the plume. The mulch wall was filled with coarse sand mixed with mulch produced at the Base. The mulch wall was designed to act as a permeable reactive wall, containing a slow-release long-lasting source of electron donor. The organic matter in the mulch ferments, producing hydrogen that can be used to stimulate reductive dechlorination of chlorinated hydrocarbons in groundwater passing through the wall.

The conceptual model for the stimulation of reductive dechlorination is that bioavailable organic constituents in the mulch act as a source of carbon for aerobic bacteria, thereby lowering the dissolved oxygen concentration and redox potential in the aquifer. Once anaerobic conditions are created, fermentation of the organic constituents generates hydrogen and acetate, which can be used to promote biological reductive dechlorination (Holliger et al., 1993; Carr and Hughes, 1998; He et al., 2002). Trichloroethylene (TCE) undergoes reductive dechlorination stepwise through cis-1,2-dichloroethylene (cis-DCE), vinyl chloride (VC), ethene, and ethane. Chlorinated solvent removal may also occur via sorption and other biological and abiotic processes.

2.0 SITE DESCRIPTION AND HYDROGEOLOGIC SETTING

Offutt AFB is located approximately five miles south of Omaha, Nebraska. Building 301 (B301) is located in the northwestern part of the Base, approximately 1500 ft from the railway tracks and 4300 ft from Papillion Creek (Figure 1).

B301 is situated on a dissected Pleistocene alluvial terrace remnant of the Missouri River with moderately sloping rolling hills. To the west of B301, the ground surface slopes steeply downward into the Papillion Creek alluvial valley. More gradual downward slopes are present to the south and east of the building. Much of the area surrounding B301 is paved for the numerous roadways and parking lots that serve B301 as shown in Figure 2.

The 500-ft mulch wall was installed about 150 feet east of MW-9S. In this area, the subsurface soil material consists of approximately 1-3 feet of fill, overlying either a stiff, black, low plastic, silty clay (topsoil) or a stiff to very stiff, light to reddish brown, low plastic, silty clay (Peoria and Loveland Loess). Near and west of the Base boundary, depth to groundwater is only 3 to 10 bgs. Depth to groundwater is approximately 6 ft bgs near MW-9S. A groundwater seep is located near the B301-MW-19 cluster at the west property boundary (Figures 2 and 3).

The groundwater flow is predominantly westward, toward Papillion Creek. The hydraulic conductivity in the alluvial silt and clay near MW-9S averaged 3.5 ft/day or 1.2 E-3 cm/sec (mean of 5 slug tests in alluvial silt and clay). The hydraulic gradient was 0.01 ft/ft. Using an assumed effective porosity of 0.15, the groundwater seepage

velocity was calculated to be 0.23 ft/day or 85 ft/yr (Parsons Engineering Science, 1997). The measured hydraulic conductivity at MW-19S (located 300 ft south of MW-9S) in 1997 was 26 ft/day or 9 E-3 cm/sec. No north-south cross-sections of the area were available prior to wall installation.

3.0 AFFECTED ENVIRONMENTAL MEDIA

Groundwater quality data obtained during previous groundwater investigations at the site indicated that chlorinated solvents were the primary contaminants of concern in the groundwater. TCE was the most prevalent chlorinated solvent constituent in both extent and concentration in the groundwater at B301. The TCE distribution based on Spring 2000 long-term monitoring (LTM) and historical sample results are presented in Figure 2. The source of TCE contamination appeared to be located beneath the northwestern corner of B301, as evidenced by the relatively elevated TCE concentration (8,700 ug/L in the groundwater from MW-18I measured on 4/24/00). The plume extended westward approximately 3,300 ft from the suspected source area. An east-west cross-section of the plume is presented in Figure 3. The location of the cross-section corresponds to the A-A' transect shown on Figure 2.

4.0 PILOT-SCALE MULCH WALL RESULTS

In January, 1999, a pilot-scale mulch wall (100 ft long x 1 ft wide x 23 ft deep) was installed at Site B301, Offutt AFB, NE to evaluate the technology for its effectiveness for the treatment of TCE-contaminated groundwater. The mulch wall successfully turned the aerobic aquifer anaerobic and facilitated the treatment of TCE-impacted groundwater (GSI, 2001). TCE concentrations averaging 800 ug/L decreased 70%, with minimal generation of vinyl chloride, reduction in performance, or fouling. Because of these favorable results, a full-scale mulch wall was commissioned at Offutt AFB to treat the entire width and depth of the plume near the western Base boundary.

5.0 INSTALLATION OF FULL-SCALE MULCH WALL

5.1 Remedial Objectives

At the direction of the Air Force Center for Environmental Excellence, a full-scale mulch wall was commissioned to treat the entire width and depth of the plume just upgradient of the pilot wall location. The mulch wall was intended to be used as a polishing step in conjunction with an upgradient zero valent iron wall (Figure 3) to reduce chlorinated constituents to maximum contaminant level (MCL) concentrations at the Base boundary. The mulch wall was installed before the iron wall due to the availability of funding. Therefore, this report focuses on the performance of the mulch wall alone and the efficacy of it and the pilot wall on reducing concentrations in MW-9S near the Base boundary.

5.2 Mulch Wall Dimensions

A plan view of the mulch wall relative to the TCE plume is shown on Figure 4. The mulch wall was constructed to intercept the complete width and depth of the chlorinated hydrocarbon plume, based on data collected during the Spring 2000 LTM program (Figures 2 and 3) conducted by URS of Omaha, Nebraska. Accordingly, the mulch wall was constructed to a depth of 25 feet below existing grade, a width of 18 inches, and a length of 500 feet (which included full overlap with the existing 100-ft length pilot-test mulch wall). The overlap provided a double wall to increase treatment of the groundwater in the area where concentrations of chlorinated hydrocarbons were the greatest. At a minimum, the mulch wall was designed to intercept all groundwater with chlorinated hydrocarbons concentrations greater than 10 ug/L. The mulch wall was not extended north beyond the pilot wall as MW-25S (Figure 4) did not yield any water.

5.3 Mulch Wall Installation

The mulch wall was installed in July 2001 by DeWind Dewatering of Holland, Michigan with a trencher that cut and backfilled continuously. To attain the design depth of 25 feet below grade, the trenching contractor utilized the 25-feet depth cutting capacity of the trencher. A plan view of the mulch wall with its associated monitoring wells is shown on Figure 4. A schematic wall construction diagram can be found in Figure 5.

Equal volumes of coarse sand and mulch, as had been used in the pilot study, were mixed on the surface with a front-end loader. A front end loader was used to transport the mulch-sand mixture from the mixing area to the trencher. The mulch wall was backfilled with the sand:mulch mixture to a level approximately even with existing grade.

Prior to excavation, the locations of a 24-inch diameter storm sewer constructed of corrugated galvanized steel and a 4-inch diameter active natural gas line were determined and clearly marked. Although preliminary plans called for the mulch wall to be continuous under the gas line, the design was modified in the interest of safety. Consequently, the mulch wall was completed in two segments that started at the closest safe distance from the gas line and moved north and south, respectively, away from the gas line (Figure 4).

As a first step, the gas line was exposed to determine its exact location, depth, and the condition of the line. To begin trenching, the cutting arm of the trencher was positioned on the ground surface a few feet from the gas line. As the cutting arm began digging, the mulch-sand mix was added and the cutting arm was lowered until it achieved full depth of 25 feet at a distance of approximately 25 feet from the gas line. The trencher then moved north as more mulch-sand mix was fed into the hopper to backfill the excavated trench.

A storm sewer line was located about 80 feet north of the gas line (Figure 4). To install the mulch wall across the storm sewer line, the line was exposed with a backhoe, a section of the line was cut and removed, and the trencher proceeded through the gap.

After the mulch wall was installed, the storm sewer was rebuilt to a serviceable condition. After crossing the storm sewer, the path of the mulch wall was directed to the east to regain the planned location parallel and east of the existing pilot mulch wall (Figure 4).

To begin installation of the south leg of the mulch wall, the trenching machine was positioned with the cutting arm parallel to the gas line. The trenching machine moved east along the gas line until full depth was achieved. Then, the path of the mulch wall was curved to the south to regain the planned location of the mulch wall (see Figure 4). This maneuver was performed so that the mulch wall would be at full 25-ft depth next to the gas line to minimize the gap created by not trenching beneath the gas line.

Soil cuttings, which accumulated on the surface next to the mulch wall, were allowed to stand for several days to dry, and then worked with earthmoving equipment to form a gently sloped cap over the top of the wall. Soil sampling performed by GSI at MW-22S, MW-23S, MW-24S, MW-25S and MW-26S in 1998 during installation of the pilot mulch wall showed all TCLP values for chlorinated solvents were below detection, indicating that spreading of the soil was acceptable (GSI, 2001).

5.4 Monitoring Well Installation

5.4.1 Groundwater Monitoring Wells. After installation of the mulch wall was completed, 13 additional monitoring wells (MW-45S through MW-57S) were installed by Geotechnical Services, Inc. of Omaha, Nebraska. A plan view of the well locations can be found in Figure 4. At monitoring well locations MW-45S, MW-47S, and MW-55S, the soil was continuously sampled to a depth of 20 feet using Shelby tube or split spoon sampling devices to confirm stratigraphy described in previous borings. The sampling tools were decontaminated between each sampling interval. Boreholes were drilled with hollow stem augers, or, if soil conditions permitted, with solid flight augers. The borehole diameters were a minimum of six inches to provide a minimum 2-inch annular space between the monitoring well casing and the borehole. Representative as-built well construction diagrams and logs are provided in Appendix A along with surveying information.

Each monitoring well was installed to a depth of approximately 20 feet and constructed with 2-inch diameter PVC. A ten-foot length of 0.01-inch slot PVC screen was installed from a depth of 10 to 20 feet below ground surface. A sand pack consisting of 20-40 grade silica sand was installed opposite the screened section. The well annulus above the sand pack was sealed with bentonite pellets and topped with cement bentonite grout to within 3 to 4 feet of the surface. Wells were completed with above-ground completions consisting of concrete pads and locking steel well covers installed to a minimum depth of 2 feet below grade in concrete. The concrete extends a minimum 3 feet below grade, to prevent frost heaving of the well and well pad. Bollards, constructed of steel pipe 4 inches in diameter and six feet in length, and set in concrete to a depth of two to three feet below grade, were placed around each well pad. Locks, keyed to Master Lock #3303, were installed on the well covers.

5.4.2 Mulch Wall Monitoring Wells. Hollow stem augers were used to install five 2-inch diameter monitoring wells in the mulch wall as shown in Figure 4. The boreholes were drilled with slow rotation and with a drilling plug in the lead auger. The boreholes were advanced one to two feet into the natural formation beneath the bottom of the mulch wall to seat the augers and prevent the flow of sand and mulch into the hollow stem augers when the drilling plug was removed. After the well was installed inside the augers, the augers were pulled and the sand-mulch wall backfill material collapsed around the well screen.

Mulch wall monitoring wells were constructed with two-inch diameter PVC with the screened section installed in the same depth interval as the groundwater monitoring wells (i.e., 10 to 20 feet below grade). Accordingly, the mulch wall wells have blank extending from 25 to 20 feet below grade, 0.02 inch slot well screen extending from 20 to 10 feet below grade, and blank extending from 10 feet below grade to the surface. The surface completions of the mulch wall wells are above grade with concrete well pads and locking steel well covers set in concrete that extends to a minimum 3 foot depth below grade. A representative as-built diagram is shown in Appendix A.

5.4.3 Monitoring Well Development: Monitoring wells were developed by extended pumping with an electric submersible pump. A minimum of ten casing volumes of groundwater was removed from each monitoring well. Development continued until the temperature, pH, and specific conductivity of the discharged fluid did not vary more than 5% between successive casing evacuations. Fluid purged from the monitoring wells during development and groundwater sampling was containerized and scanned with a PID meter for the presence of volatile organic compounds. The PID readings were less than 5 ppm; so the fluid was disposed of in a sanitary sewer at Offutt AFB.

6.0 SAMPLING PROGRAM

The performance of the mulch wall was evaluated over a 24-month period from July 2001 to July 2003 with a monitoring program that included periodic sampling of all monitoring wells associated with the pilot and full-scale mulch wall. In addition, the program included sampling of the five monitoring wells installed within the full-scale mulch wall.

6.1 Parameter List

Sampling for VOCs (TCE, cis-DCE, and VC), alternate electron acceptors/by-products (nitrate, sulfate, ferrous iron, methane, ethene, and ethane), total organic carbon, alkalinity, dissolved oxygen, pH, temperature, redox potential, and specific conductance occurred after installation and at 6 month intervals thereafter for the duration of 24 months (a total of 5 sampling events). Sampling for VOCs only was performed three months after installation of the full-scale mulch wall and every six months thereafter for a period of 18 months (a total of 4 sampling events).

VOCs were analyzed by EPA Method 8021b, nitrate and sulfate were measured using EPA Method 300, and total organic carbon was analyzed using EPA Method 9060 by

Southern Petroleum Laboratories of Houston. Hydrogen, methane, ethane, and ethene were collected using the bubble-strip method and analyzed by gas chromatography using Method AM20GAX by Microseeps, Pittsburgh, PA. Alkalinity and ferrous iron were analyzed in the field using Hach kits.

6.2 Sampling Protocols

Monitoring wells were sampled under low flow conditions (300 ml/min.) using a peristaltic pump. Each well was purged until field parameters (i.e., pH, temperature, specific conductivity, ORP, and D.O.) stabilized. A flow-through cell was used to obtain field measurements of dissolved oxygen, redox potential, temperature, pH, and specific conductance. Headspace gases (hydrogen, methane, ethene, and ethane) were collected using the bubble-strip method, following the Microseeps' procedure and using their flow-through cell. Gas samples were submitted to Microseeps, Inc., Pittsburgh, PA for gas chromatographic analysis. All other aqueous samples were submitted to Southern Petroleum Laboratories (SPL), Houston, TX for analysis using standard EPA methods.

6.3 Other Measurements

Quarterly, the static water levels in all the wells were measured. At start-up and annually, the permeability of the mulch wall was assessed by conducting rising head slug tests in the wells installed within the mulch wall.

At the end of the test, mulch samples were obtained from the mulch wall for VOC analysis, to assess the amount of sorption in the mulch wall, and for foc analysis. Mulch samples were collected by using a hand auger with a stainless steel sample bucket.

7.0 RESULTS

7.1 Direction of Groundwater Flow Through the Test Area

Static water level measurements were taken every quarter after the installation of the mulch wall. Representative potentiometric surface maps can be found in Appendix B for the following dates: October 11, 2001, July 2, 2002, and July 31, 2003. The direction of groundwater flow was generally east to west for the north part of the mulch wall, with the direction of groundwater becoming north-westerly over time. The gradient for the last two transects of wells in the south portion of the mulch wall (i.e., MW-52S, BW-4, MW-53S, and MW-54S and MW-55S, BW-5, MW-56S, and MW-57S) is very low. There also appears to be groundwater flow northward on the upgradient side of the south portion of the mulch wall. The seep to the west of the wall also contributes to the stagnant conditions to the west of the south portion of the wall.

7.2 Evaluation of Mulch Wall Permeability

Shortly after the installation of the wells within the mulch wall and then annually thereafter, the hydraulic conductivity of the mulch wall was evaluated by performing rising head slug tests. The Bouwer-Rice method was used to calculate the hydraulic conductivities of the sand:mulch fill surrounding mulch wall wells, BW-1 through BW-5. The results are shown in Table 1. By July 2002, one year after the wall was installed, the hydraulic conductivities of the fill decreased, in general, but the changes were much less than one order of magnitude. By July 2003, there were 70-80% decreases in permeability for all of the wells, a reduction in permeability of almost one order of magnitude. It is not known whether the reduction in permeability was due to settling, inorganic fouling, or organic fouling.

7.3 Geochemical Changes

7.3.1 Dissolved Oxygen. Dissolved oxygen is the most thermodynamically-favored electron acceptor used by microbes for the biodegradation of organic carbon. The presence of organic matter released from the mulch, provides a source of organic substrate for native aerobic bacteria. The intended result is the depression of the dissolved oxygen, as aerobic bacteria consume the organics and respire the dissolved oxygen. Depression of the dissolved oxygen concentrations is required to achieve a reduced groundwater environment, conducive to reductive dechlorination and other anaerobic processes.

Dissolved oxygen concentrations are presented in Figures 6, for the upgradient and mulch wall wells and for wells 15 ft and 30 ft downgradient from the wall. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

The dissolved oxygen concentration in the upgradient wells was very variable. With the exception of monitoring wells, MW-49S, MW-27S, and MW-22S, the dissolved oxygen was greater than 1 mg/L. By comparison, the dissolved oxygen concentrations in the mulch wall wells were generally less than 1 mg/L, with the exception of BW-4, which had a dissolved oxygen concentration that was frequently in the 1 to 2 mg/L range.

The dissolved oxygen concentrations in the wells 15 and 30 ft downgradient from the wall demonstrated similar trends to each other. Within 3-6 months after installation of the wall, dissolved oxygen concentrations generally became depressed (i.e., less than 1 mg/L) and remained so over the course of the two-year monitoring period due to the depletion of oxygen in the groundwater that passed through the mulch wall.

There were some exceptions to this: monitoring wells MW-53S, MW-56S, MW54-S, and MW-57S (located at the south end of the test area) had very high levels of dissolved oxygen, in the 2-7 mg/L range. Groundwater at the south end of the test area bypassed or moved north, north-west instead of passing through the wall. The result was no depression of the dissolved oxygen in this area.

7.3.2 Redox Potential. The reduction-oxidation potential is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. The redox potential, measured in mV, is presented in Figure 7 for upgradient, mulch wall, and downgradient wells. Groundwater with redox potentials lower than 50 mV are generally considered to be suitable for reductive dechlorination (USEPA, 1998). The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

With the exception of MW-49S, all the upgradient wells had positive redox potentials in July 2001 when the wall was installed. During the two year monitoring period, the redox potential was quite variable in upgradient wells.

In contrast, mulch wall wells had lower redox potentials that were generally less than zero, because of the presence of a bioavailable carbon source and bacteria that depleted the available electron acceptors. Monitoring wells BW-1 and BW-4 were exceptions, which during some monitoring events had positive redox potentials.

The wells 15 and 30 ft downgradient from the mulch wall generally showed positive redox potentials, with the exception of MW-50S and MW-51S, which are downgradient from MW-49S and BW-3. Because redox potential readings are not always reliable, measurement of electron acceptors and metabolic by-products are better indicators of whether the groundwater is sufficiently reduced to promote reductive dechlorination. Alternate electron acceptors and metabolic by-products are discussed in the following sections.

7.3.3 Nitrate. After oxygen, nitrate is the next more thermodynamically-favorable electron acceptor. Depletion of nitrate is indicative of reduced conditions, with concentrations less than 1 mg/L typically associated with conditions conducive to reductive dechlorination (USEPA, 1998).

Nitrate levels for upgradient, mulch wall, and downgradient wells are shown in Figure 8. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

With the exception of MW-49S, nitrate levels in upgradient wells were generally above 1 mg/L. By contrast nitrate levels in wells within the mulch wall were generally less than 1 mg/L, indicating active denitrification. The exceptions were monitoring wells BW-1 and BW-4, which at times had nitrate levels greater than 1 mg/L.

Six months after mulch wall installation nitrate levels were less than 1 mg/L for most of the wells 15 and 30 ft downgradient from the mulch wall. The exceptions, again, were monitoring wells MW-53S, MW-54S, MW-56S, and MW-57S in the south-west section of the test area.

7.3.4 Ferrous Iron. Ferric iron, associated with aquifer material, is another alternate electron acceptor that can be used by iron-degrading bacteria in the degradation of organic compounds and some chlorinated constituents, such as cis-DCE and vinyl chloride (Bradley and Chapelle, 1996). The ferric iron is reduced, resulting in soluble ferrous iron that can be more easily measured. Therefore, high levels of ferrous iron indicate more reduced conditions, with levels of 1 mg/L or greater indicative of conditions suitable for reductive dechlorination (USEPA, 1998). Ferrous iron can also react with sulfide, produced through sulfate reduction, generating ferrous sulfide. Ferrous sulfide precipitates out masking the total amount of ferrous iron produced through ferric iron reduction reactions.

Ferrous iron levels in upgradient, mulch wall, and downgradient wells are shown in Figure 9. Elevated ferrous iron concentrations were evident in the mulch wall itself, due to the reduced conditions and available carbon within the mulch wall, particularly for BW-5. Ferrous iron levels were generally less than 2 mg/L in wells downgradient from the mulch wall, with the exception of MW-50S, where the ferrous iron concentrations varied from 2 to 11.7 mg/L.

7.3.5 Sulfate. Sulfate is another electron acceptor that can be used for anaerobic biodegradation. It is thermodynamically less favorable than ferric iron. When sulfate is reduced, sulfide is produced. Sulfate reduction is indicative of redox conditions appropriate for reductive dechlorination (Bouwer, 1994).

Sulfate concentrations in upgradient, mulch wall, and downgradient wells were measured for the first three sampling events only and are shown in Figure 10. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

Upgradient wells generally had sulfate levels in the 30 to 45 mg/L range, which decreased over time. MW-55S had an anomalous sulfate concentration of 110 mg/L in January of 2002, for which there is no explanation.

Sulfate concentrations in mulch wall wells were generally lower than corresponding wells directly upgradient, indicating sulfate reduction was occurring and that redox conditions were conducive to reductive dechlorination.

Sulfate concentrations in wells 15 ft downgradient from the mulch wall generally decreased by more than 50%. The exceptions again were MW-53S, and MW-56S at the south end of the test area. Sulfate concentration in wells 30 ft downgradient from the mulch wall also decreased but to a lesser extent. Sulfate concentrations did not decrease in MW-54S, and MW-57S at the south end of the test area.

7.3.6 Methane. Methane is the product of methanogenesis. During methanogenesis acetate is degraded to form carbon dioxide and methane or carbon dioxide is used as an electron acceptor and is reduced to methane. Methanogenesis occurs under deeply reduced conditions, generally after oxygen, nitrate, and sulfate have been depleted in

the treatment zone. The presence of methane is a better indicator of reduced conditions than redox potential or dissolved oxygen concentrations as the measurement of these parameters can sometimes be inaccurate due to entrainment of air during measurement. Methane concentrations in excess of 0.5 mg/L are generally indicative of conditions suitable for reductive dechlorination (USEPA, 1998).

Methane concentrations in all upgradient, mulch wall, and downgradient wells are shown in Figure 11. The legends on all the graphs present the well names, which from top to bottom represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

Methane concentrations in upgradient wells were very low, with all wells having methane concentrations less than 0.5 mg/L. In contrast, the methane levels in the mulch wall wells were much higher, ranging from 2 to 8 mg/L, representing conditions suitably reduced for reductive dechlorination.

Six months after the installation of the mulch wall, the methane concentrations 15 ft downgradient of the wall were elevated relative to upgradient wells, with concentrations in the 1 to 7 mg/L range. The exceptions again were MW-53S and MW-56S, which had very low levels of methane. Wells 30 ft downgradient from the wall generally had low methane concentrations (i.e., <0.1 mg/L) with the exception of MW-29S, which in 2002 had methane concentrations greater than 3 mg/L.

The difference in methane concentrations between wells 15 ft downgradient and those 30 ft downgradient was quite pronounced. Either the methane was removed through volatilization or through methanotrophic biodegradation. The latter reaction occurs under low dissolved oxygen conditions (i.e., 0.5 to 2 mg/L) and may be a loss mechanism for methane and possibly for TCE, cis-DCE, and vinyl chloride as they move downgradient (Wilson and Wilson, 1985; Dolan and McCarty, 1994).

7.3.7 Alkalinity. Alkalinity can be used as an indirect measurement of microbial activity. Increases in alkalinity result from the dissolution of aquifer material as a result of the microbial production of carbon dioxide (USEPA, 1998).

Alkalinity levels for upgradient, mulch wall, and downgradient wells are shown in Figure 12. Generally the alkalinity hovered in the 500 mg/L range in the mulch wall wells, but increased over time in upgradient and downgradient wells, indicating increased microbial activity. The highest alkalinity concentration was consistently found in BW-5 where the alkalinity ranged from over 1000 mg/L to over 2500 mg/L, more than twice the levels measured in the other wells. BW-5 also had the highest ferrous iron and TOC levels as discussed in Section 7.3.8.

7.3.8 Total Organic Carbon. To create hydrogen needed for reductive dechlorination, organic carbon from the mulch leaches into the groundwater where it is biodegraded and fermented to form hydrogen. Table 2 gives an indication of the spatial and temporal distribution of total organic carbon (TOC) in the test area. The total organic carbon in upgradient wells was generally less than 2-3 mg/L with the exception of BW-5 in July of 2002, which had a TOC value of 33 mg/L. TOC concentrations were

elevated in mulch wall wells BW-2 through BW-5, a month after installation of the wall. After 6 months the TOC levels in BW-2 through BW-5 dropped off dramatically, by 57-99%.

In July 2001 (one week after wall installation), TOC levels were high 15 ft downgradient (2 months travel time) from the mulch wall, presumably due to stray mulch at the surface, which leached TOC during rainfall events, or possibly to the presence of preferential flow paths. TOC levels 30 ft downgradient were generally less than 2.5 mg/L, similar to upgradient TOC levels. The exception was high TOC levels near the south end of the mulch wall during the July 2002 sampling event. TOC levels in the two most-southerly transects had TOC levels ranging from 25-63 mg/L, probably due to the marshy nature of the aquifer in this area.

7.4 Transformation and Removal of Chlorinated Constituents

7.4.1 Trichloroethylene. Trichloroethylene is the main contaminant of concern to be treated. TCE concentration distributions for July 2001, July 2002, and July 2003 are shown in Figures 13 through 15. Upgradient TCE concentrations are generally below the MCL of 5 ug/L in the southern part of the test area over the two-year monitoring period, indicating that the southerly extent of the mulch wall was overly conservative, despite using the TCE concentration isopleth data from 2000 (Figure 2). Lack of TCE contamination in this area was fortuitous in that there appears to be no flow through the wall in the southernmost 100-150 feet of the mulch wall.

The north end of the wall generally was effective in dramatically reducing TCE concentrations 15 ft downgradient of the wall. TCE concentrations upgradient of the mulch wall were quite variable over the two year monitoring period. Nevertheless, 95% reductions in TCE concentrations were observed, on average, between July 2001 and July 2003. Good treatment effectiveness was observed in the middle of the wall, with lesser treatment efficiency noted in the northern most portion of the wall, possibly due to short-circuiting around the northern end of the wall or from groundwater with higher TCE concentrations moving in a northwest direction across the wall.

Unusually high TCE concentrations also showed up downgradient of the pilot wall in July 2003 at wells MW-33S and MW-34S. TCE concentrations in MW-33S and MW-34S before and after the full-scale wall installation in July 2001 are presented in Table 3. TCE data from MW-24S, directly upgradient from MW-33S and MW-34S, and from MW-29S, a monitoring well downgradient of the central portion of the north section of the full-scale wall are also shown in Table 3. January 1999 data represent baseline data prior to the pilot mulch wall installation. The TCE concentrations in MW-24S were quite variable until the full-scale mulch wall was installed, which acted to significantly reduce the concentrations in MW-24S. TCE concentrations in MW-33S and MW-34S were variable during the pilot test but were generally 50-60% less overall than those in MW-24S. After the installation of the full-scale wall in July 2001, concentrations in MW-33S and MW-34S decreased significantly until July 2003 when they were significantly higher than in MW-24S, suggesting the untreated TCE groundwater was short-circuiting around the north end of the treatment area. TCE concentrations in MW-29S remained low for the two-year monitoring period following the installation of the full-scale wall.

Further sampling of MW-33S, MW-34S, and MW-26S north of the treatment system should be conducted to evaluate the source of increased concentrations in that area.

7.4.2 *cis-1,2-dichloroethylene.* Cis-1,2-dichloroethene is a daughter product of the reductive dechlorination of TCE. In July 2001, cis-DCE was present at highest concentrations within the north end of the mulch wall and downgradient of the existing 100-ft pilot-scale wall, as shown in Figure 16. Concentrations were less than 100 ug/L. One year after wall installation, cis-DCE concentrations were still less than 100 ug/L, with the highest concentrations located in the north end of the mulch wall and downgradient of the pilot scale wall (Figure 17). Two years after mulch wall installation, cis-DCE concentrations increased between the pilot and full scale walls (Figure 18). More time and higher TCE concentrations resulted in increased cis-DCE concentrations.

7.4.3 *Vinyl Chloride.* Vinyl chloride is the daughter product of the reductive dechlorination of cis-DCE. It is considered a human carcinogen and has an MCL of 2 ug/L. Excessive accumulation of vinyl chloride must be avoided when reductive dechlorination is stimulated via the introduction of an electron donor.

Vinyl chloride concentrations in the test area during July 2001, July 2002, and July 2003 sampling events can be found in Figures 19 through 21. In July 2001, only MW-27S and MW-32S had vinyl chloride concentrations greater than 2 ug/L. One year after installation of the 500 ft wall, vinyl chloride concentrations in excess of 2 ug/L were observed in eight wells, but all had concentrations less than 27 ug/L (Figure 20). By July 2003, vinyl chloride concentrations had declined as shown in Figure 21. Only three wells (MW-24S, MW-23S, and MW-50S) had concentrations greater than 2 ug/L.

7.4.4 *Ethene and Ethane.* Ethene and Ethane are the products of the complete reductive dechlorination of TCE. Ethene is produced through reduction of vinyl chloride and ethane is produced through reduction of ethene. Figures 22 through 24 present the combined concentration (sum of ethene and ethane concentration) for the July 2001, July 2002, and July 2003 sampling events.

In July 2001 (Figure 22), right after wall installation, ethene and ethane concentrations were below 0.7 ug/L. Wells MW-32S and MW-31S had higher concentrations (i.e.,14 ug/L) due to their location downgradient of the pilot wall. One year after installation of the 500 ft wall, ethene/ethane concentrations increased dramatically downgradient of the north portion of the wall, with concentration ranging from 1 to 26 ug/L (Figure 23). The highest concentrations were found at the north end where TCE concentrations had been the highest. Similar results were found in July 2003 (Figure 24). Increased concentrations of ethene and ethane is evidence of enhanced reductive dechlorination.

7.4.5 *Molar cis-DCE:TCE Ratio.* The molar concentration ratio of cis-DCE to TCE gives an indication of the degree of reductive dechlorination. As the ratio increases, the amount of reductive dechlorination increases. The molar concentration ratio of cis-DCE:TCE for upgradient, mulch wall, and downgradient wells is found in Figure 25. The legends on all the graphs present the well names, which from top to bottom

represent well locations from north to south. The exact location of the wells can be seen on Figure 4.

Upgradient ratios are generally very low (i.e., <0.5), indicating that very little reductive dechlorination was occurring via natural attenuation in the absence of the mulch material. The exception was MW-49S where some reductive dechlorination was evident. Even within the mulch wall the cis-DCE:TCE ratios are low, with the exception of BW-3 where the ratio ranged from 1.5 to 12. BW-3 is west and downgradient of MW-49S.

Downgradient wells showed much different trends. Three months after the wall installation, the cis-DCE:TCE ratio ranged from 2 to 23. The increase in the cis-DCE:TCE ratio from less than 0.5 to 2-23 indicated that appreciable reductive dechlorination was occurring downgradient of the wall. The exception to this was the two most southerly wells (MW-53S and MW-56S), which showed very little transformation.

8.0 PERFORMANCE EVALUATION FOR NORTH SECTION OF MULCH WALL

8.1 Removal of TCE and Total Chlorinated Compounds

The evaluation of the effectiveness of mulch as a medium to remove TCE and its daughter products was determined for the north section of the full-scale mulch wall only. The south section was not included in this evaluation because groundwater appeared to not be passing through the south end and TCE concentrations in that area were very low. Short-circuiting, if any, around the north end of the wall was also not included in this evaluation because it could not be quantified.

Performance data for the north section of the mulch wall is shown in Table 4. The mean percent removal of TCE 15 ft downgradient of the wall over the two year monitoring period was 95% and the mean % removal of total chlorinated solvents was 80%. These removals are greater than those determined during the pilot test due to additional residence time in the 1.5 ft wide wall compared with the 1 ft reaction width used in the pilot test (GSI, 2001).

A molar balance of the sum of chlorinated ethenes, ethene, and ethane entering and leaving the wall was determined as shown in Table 4. The mean total ethene and ethane concentration entering the wall over the two-year monitoring period was 2.29 uM and the mean total ethene and ethane concentration leaving the wall (to the west) during the same period was 0.55 uM, for a molar balance closure of 24.2%. In other words, the removal of TCE could not be accounted for entirely by the production of reductive dechlorination daughter products such as cis-DCE, VC, ethene, and ethane.

There are several possible fates for TCE and its daughter products. First, TCE will adsorb to the mulch in the wall, given the high organic content of the mulch (see Section 8.2). In addition, there are several biological processes by which TCE's daughter products, cis-DCE and vinyl chloride, can be degraded. Vinyl chloride and cis-

DCE can be converted to carbon dioxide under methanogenic conditions, because of the presence of the mulch. Bradley et al. (1998) have shown that humic acids can act as electron acceptors for the anaerobic microbial oxidation of vinyl chloride and dichloroethene. VC anaerobic oxidation under iron reducing conditions (Bradley and Chapelle, 1996) and direct VC oxidation in aerobic microenvironments (Hartmans et. al., 1985; Hartmans and de Bont, 1992) are other possible biological loss mechanisms. In addition, ferrous sulfide precipitates in the mulch or aquifer can act to catalyze the abiotic reduction of TCE (Butler and Hayes, 2000).

8.2 Effect of Sorption

Because less than 25% of the chlorinated compound removal could be attributed to reductive dechlorination, sorption was evaluated as a possible removal mechanism because of the high carbon content of the mulch fill.

Samples of the mulch/sand fill were analyzed for organic carbon (foc) and for VOCs at the end of the test, and the results are presented in Table 5. Three samples were obtained from 5 feet below the water table, one 5 feet north, one 5 feet south, and a third 10 ft south of BW-1. TCE and trans-DCE were found at concentrations of 0.5-1 ug/Kg. cis-DCE and VC were not detected. These results indicated that sorption was not significant at these locations. Samples from deeper areas of the wall may have shown different sorbed concentrations.

Using an assumed porosity and bulk density of 0.3 and 1.3 kg/L, respectively, a measured foc of 0.018 (Table 5), and a Koc of 183, a retardation factor of 15 was calculated. Using the reported seepage velocity of 85 ft/yr (Parson's Engineering Science, 1997), the TCE velocity through the wall was calculated to be 5.7 ft/yr or about a 3-month residence time. Modeling, using an analytical groundwater transport model, indicated that after 1 year the water leaving the wall would be within 90% of steady-state conditions, at which point sorption would not be a significant removal mechanism. Therefore, early decreases in TCE in downgradient wells may be attributable to sorption, but after the attainment of steady-state or near-steady state conditions, sorption should not have been a significant loss mechanism in TCE removal. Column studies are needed to more accurately assess the contribution of sorption for this technology.

8.3 Effectiveness in Reducing Concentrations near Base Boundary

To evaluate the effectiveness of the pilot- and full-scale mulch walls in reducing the concentrations of chlorinated constituents at the Base boundary, the concentrations of TCE, cis-DCE, and vinyl chloride in MW-9S were plotted over time (Figure 26). MW-9S is about 2 years groundwater travel time away from the mulch walls. About two years after the installation of the pilot wall in 1999, the concentrations of all the constituents began to decline. By October 2003, TCE, cis-DCE, and vinyl chloride were below their respective drinking water MCLs of 5, 70, and 2 ug/L. Therefore, the mulch walls have been effective in reducing the concentration of these constituents to levels below the MCLs, even without the installation of the upgradient zero valent iron wall.

Despite these favorable results, attention should be paid to wells MW-33S and MW-34S, which suggest that the plume may be circumventing the treatment area. Wells north of the treatment system (MW-25S and MW-26S) should be sampled to evaluate this possibility.

9.0 RECOMMENDATIONS AND LESSONS LEARNED

1. Future full-scale mulch wall installations should employ column studies to estimate the required residence times to meet remedial objectives.

2. Some engineering measure, such as lower permeability fill, should be employed at the ends of the wall to prevent transverse flow. The length of the wall should employ a safety factor to account for changes in groundwater flow direction.

3. The fill permeability should be engineered to be several orders of magnitude more permeable than the aquifer matrix to account for loss of permeability due to settling or fouling.

4. Column studies and/or microcosm studies are required to elucidate the mechanisms of TCE removal.

10.0 EXECUTIVE SUMMARY

To reduce, TCE and its daughter products to MCLs at the base boundary, a 500 ft mulch wall was installed upgradient of an existing pilot-scale mulch wall. The intent was for the mulch wall to act as a polishing step after the groundwater was treated by an upgradient zero valent iron wall. Due to the availability of funding, the mulch wall was installed before the zero valent iron wall. The focus of this report is on the effectiveness of the mulch wall alone.

The mulch wall was installed across the complete width and depth of the plume to intercept all groundwater at concentrations greater than 10 ug/L TCE. Due to the presence of an active gas line running parallel to the plume, the wall was installed in two sections. The wall was installed using a continuous trencher to a depth of 25 ft. The wall was backfilled with a 1:1 by volume mixture of sand and mulch as the wall was installed. The wall started 30 feet east of the pilot wall and was 500 ft long. Two-inch diameter monitoring wells with 10 feet of screen were installed upgradient, within, and downgradient of the wall.

Static water level measurements were conducted quarterly and slug tests were performed on the wells within the wall annually. Wells were sampled semi-annually or quarterly for volatile organic compounds, alternate electron acceptors/byproducts and water quality parameters.

Potentiometric surface maps showed the groundwater to move west, north-west through the wall. The exception was the most southerly 150 ft of the south portion of the wall. In this area the aquifer was sandier than anticipated. In addition there was a seep to the west of the south wall. The result was that groundwater appeared to flow north instead of through the wall. Fortuitously, the upgradient TCE concentrations at the south end were below the MCL.

Annual slug tests showed that the wall permeability decreased over time. After one year, there was some loss in permeability in some wells, but the losses were considerably less than one order of magnitude. By the second year, permeability losses of 70-80% were observed. It is not know whether the permeability loss is due to settling or fouling.

Dissolved oxygen, redox potential, nitrate, and sulfate concentration were generally depressed downgradient of the wall as a result of the introduction of the mulch. Ferrous iron was elevated within the wall and methane concentrations were elevated within and downgradient of the wall, indicating the attainment of conditions sufficiently reduced for reductive dechlorination. The exception was the area west of the south portion of the wall, where groundwater did not flow effectively through the wall.

The following summarizes the performance for the north section of the wall:

- 95% TCE removed
- 80% Total Chlorinated Solvents removed

The middle part of the wall was more effective than the north end. Some increases in cis-DCE, VC, ethene, and ethane were observed. The performance of the south portion of the wall was not assessed due to upgradient TCE concentrations being below the MCL and short-circuiting.

A molar balance showed that less than 25% of the chlorinated compounds entering the north section of the wall could be accounted for by a balance on chlorinated ethenes and ethanes exiting the wall. Removal mechanisms such as sorption, and other biological or abiotic processes may be at work in removing these constituents. Other biological processes can mineralize these compounds to carbon dioxide, which was not measured.

The objective of the mulch wall installation was to aid in treating the groundwater to MCLs at the Base boundary. The installation of the pilot and full-scale walls successfully decreased the concentrations of TCE, cis-DCE, and vinyl chloride to less than MCLs near the Base boundary at MW-9S as shown in Figure 26.

Reductions in permeability of the wall and possible short-circuiting around the north end of the wall, as suggested by increasing concentrations in monitoring wells MW-33S and MW-34S, should be investigated and actions taken, if necessary, to continue to achieve the remedial objectives.

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April 13, 2004

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LIST OF TABLES

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

GROUNDWATER SERVICES, INC.

TABLE 1
HYDRAULIC CONDUCTIVITY CHANGES IN WELLS WITHIN THE MULCH WALL

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Well No.	Hydraulic Conductivity (cm/sec) 2001	2002	2003	K Ratio 2003/2001
B301-BW1	1.18E-03	1.03E-03	3.60E-04	0.31
B301-BW2	2.05E-03	9.03E-04	4.26E-04	0.21
B301-BW3	1.96E-03	2.04E-03	6.14E-04	0.31
B301-BW4	1.56E-03	1.37E-03	3.02E-04	0.19
B301-BW5	7.44E-04	5.40E-04	1.36E-04	0.18

NOTES

1. Bouwer-Rice method for slug test calculation.
2. Rising head tests included in analysis. If more than one rising head test was performed, the average is shown.
3. Based on URS Monitoring Reports for 2001 - 2003.

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TABLE 2

TOTAL ORGANIC CARBON IN GROUNDWATER

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Date	TOC (mg/L) in Upgradient Wells							TOC (mg/L) in Mulch Wall Wells					TOC (mg/L) in Wells 15 ft Downgradient							TOC (mg/L) in Wells 30 ft Downgradient				
	B301-MW45S	B301-MW46S	B301-MW22S	B301-MW27S	B301-MW49S	B301-MW52S	B301-MW55S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5	B301-MW24S	B301-MW23S	B301-MW47S	B301-MW48S	B301-MW50S	B301-MW53S	B301-MW56S	B301-MW29S	B301-MW28S	B301-MW51S	B301-MW54S	B301-MW57S
Jul-01	<1	1.49	1.28	<1	-	1.66	1.53	2.84	6.29	37.9	266	1130	11.8	6.16	4.73	7.70	94.90	<1	1.17	<1	2.31	1.61	1.18	<1
Jan-02	1.60	2.60	2.80	1.50	1.90	<1	<1	3.30	2.70	4.50	3.80	140	2.60	1.80	1.60	1.60	3.60	<1	<1	1.80	1.90	1.80	<1	<1
Jul-02	<1	<1	<1	<1	<1	<1	33	<1	<1	2.0	63	25	<1	<1	<1	<1	<1	34	48	<1	<1	<1	39	54
Jan-03	1.58	1.71	1.15	1.17	1.72	1.21	1.54	2.00	1.36	3.15	2.91	82.75	3.11	2.28	1.29	1.22	1.71	1.03	1.18	1.38	1.08	1.50	1.05	1.06
Jul-03	1.60	1.32	1.80	1.84	1.04	1.06	2.10	1.75	3.19	2.13	2.00	67.83	2.91	2.57	2.22	1.17	1.39	1.17	1.00	2.45	1.09	1.17	1.23	1.66

Note:

Wells in each area listed from North to South. Refer to Figure 4 for exact well locations.

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TABLE 3
TCE CONCENTRATIONS IN MW-24S, MW-33S, MW-34S and MW-29S

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Date	TCE Concentration (mg/L)			
	MW-24S	MW-33S	MW-34S	MW-29S
Jan. 1999	1.900	1.300	1.300	0.410
Jun. 1999	0.250	0.870	0.600	0.630
Feb. 2000	2.000	0.215	0.880	0.370
Aug. 2000	2.000	0.960	1.220	0.410
Jul. 2001	0.290	0.580	0.400	0.200
Jan. 2002	0.021	0.100	0.061	0.008
Jul. 2002	0.018	0.096	0.200	0.009
Jul. 2003	0.099	0.670	1.000	0.003

Notes:

Full-Scale Mulch Wall installed in July 2001.

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TABLE 4
PERFORMANCE DATA FOR NORTH SECTION OF MULCH WALL

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Mean % TCE Removal [1]	95.4%
Mean % Total Chlorinated Solvent Removal [2]	80.2%
Total Ethenes and Ethane Concentration Entering Wall [3]	2.287 uM
Total Ethenes and Ethane Concentration Exiting Wall [4]	0.554 uM
Mass Balance Closure [5]	24.2%

NOTES

1. Mean % TCE Removal was calculated by subtracting the mean TCE concentrations 15 ft downgradient from the mulch wall from the mean upgradient TCE concentrations over the course of the test, dividing by the mean upgradient TCE concentration, and multiplying by 100%. Mean upgradient concentrations were calculated by taking the geometric mean of molar TCE concentrations in wells MW-45S, MW-46S, MW-22S, and MW-27S for a given sampling event, and the straight mean over the 2-year monitoring period. Mean downgradient concentrations were determined in a similar fashion for MW-24S, MW-23S, MW-47S, and MW-48S.
2. Mean % Total Chlorinated Solvent Removal was calculated in the same manner as Mean % TCE Removal, but included TCE, cis-DCE, and VC.
3. This value was calculated by first taking the geometric mean concentration of total ethenes plus ethane for each sampling event and then taking an average over the 2-year monitoring period.
4. This value is determined in a similar manner to Total Ethenes and Ethane Concentration Entering Wall but uses concentrations in downgradient monitoring wells MW-24S, MW-23S, MW-47S, and MW-48S.
5. Mass Balance closure is calculated by dividing Total Ethenes and Ethane Concentrations Exiting Wall by Total Ethenes and Ethane Concentrations Entering Wall times 100%.

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TABLE 5
MULCH FILL SAMPLING RESULTS: JULY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

Location ID	B301-SB1	B301-SB2	B301-SB3
Field Sample ID	B301-01-SB-09	B301-02-SB-10	B301-03-SB-09
Date Collected	7/29/2003	7/29/2003	7/30/2003
Volatile Organic Compounds (ug/Kg)			
1,1-Dichloroethene	< 1	< 1	< 1
Tetrachloroethene	**0.67 JB**	**0.73 JB**	**0.98 JB**
Trichloroethene	< 1	**0.45**	< 1
cis-1,2-Dichloroethene	< 1	< 1	< 1
trans-1,2-Dichloroethene	< 1	**0.31 J**	**1.3**
Vinyl chloride	< 1	< 1	< 1
Organic Carbon (Walkley-Black)			
Fraction Organic Carbon (g/g)	**0.01880**	**0.02000**	**0.0164**
Total Organic Carbon (mg/kg)	**18800**	**20000**	**16400**

Notes:
J = Estimated
B = Blank Contamination

April 13, 2004

GROUNDWATER SERVICES, INC.

LIST OF FIGURES

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

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Offutt Air Force Base, Nebraska

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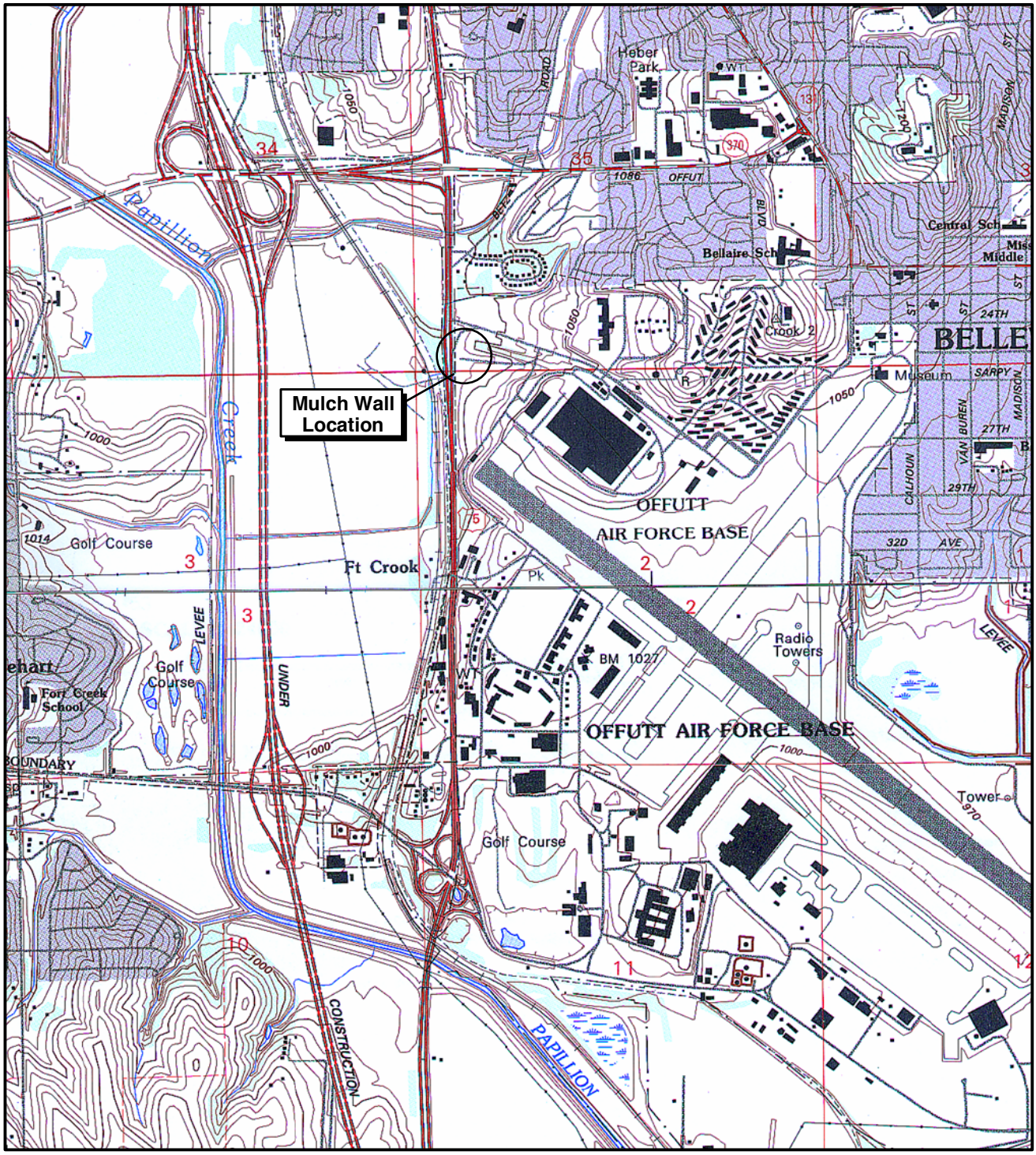
FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska



U.S. Geological Survey Map
Omaha, Nebr.-Iowa (1994)
Plattsmouth, Nebr.-Iowa (1994)
Quadrangle, 7.5 minute

SCALE (ft.)
0 1000 2000

GROUNDWATER SERVICES, INC.

SITE LOCATION MAP

Site B301
Offutt AFB, Nebraska

GSI Job No.:	G-2050	Scale:	As Shown	FIGURE 1
Drawn by:	CCJ	Approved by:	CEA	
Revised:	_____	Date:	4/13/04	

Proposed extent of off-base deed notifications

Established clear zone (3000 ft by 3000 ft)

Proposed extent of on-base groundwater and surface water restrictions

B301-MP5S *ND*
119 *ND*
118 *0.96*
117 *ND*
MW-10S *11*
B301-MP6S *1.2*
120 *ND*
121 *22*
130 *21*
129 *65*
128 *270*
122 *15*
TW-1 *210*
MW-20S *0.29*
SB7
A
SB9
MW-11S *1.6*
127 *ND*
MW-21S *120*
123 *0.48*
124 *ND*
B301-MP7S *49*
125 *ND*
MW-12S *8.7*
126 *ND*
MW-26S
MW-25S
MW-33S
MW-34S
MW-32S
MW-24S
MW-23S
MW-31S
MW-30S
MW-22S
MW-29S
MW-27S
MW-28S
MW-9S *350*
SB3
MW-19I *19*
MW-8I *190*
SB5
MW-17 *ND*
MW-14I *1300*
HP1
MW-18 *8700*
MW-7I *3600*
SB2
HP4
SB1
A'
Building 301

1
10
100
1000

N

LEGEND

- Existing monitoring well location with TCE concentration (µg/L)
- DPWS well location with TCE concentration (µg/L)
- Pilot-scale mulch wall monitoring well location
- Previously installed soil boring
- 10 — Revised estimated TCE concentration contour (µg/L) based on spring 2000 LTM and historical sample results
- *ND* Non detect
- Drainage ditch
- Existing pilot-scale mulch wall

SCALE (ft.)
0 150 300

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DISTRIBUTION OF TCE IN GROUNDWATER, SPRING 2000 LTM AND HISTORICAL SAMPLING RESULTS

Site 301B
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown	**FIGURE 2**	

WEST
A

EAST
A'

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

SOURCE AREA
GRANULAR IRON PRB

FILL

LOESS

UPPER GLACIAL OUTWASH UNIT

LOWER GLACIAL OUTWASH UNIT

ALLUVIAL CLAY AND SILT

ALLUVIAL SAND AND SILT

GLACIAL TILL

LIMESTONE

GS79 SB7 · GS98 · MW20S · GS84 · GS76 122 · TW1 · SB9 · ℄ OF RAILROAD · FORT CROOK ROAD · GS44 · BASE BOUNDARY · SB3 · MW9S.I · MW32S · MW31S · MW23S · BIOWALL · GRAVEL ROAD · GS29 · MW8I · SB5 · GS25 · GS19 · GS23 · SAC BLVD. ROAD · MW14 · HP1 · GS57 · SB1 · MW7S.I.D · HP5 · SB2 · HP4 · NORTHERN CORNER OF FACILITY 301 · GS53 · GS43

GRAPHICAL HYDROSTRATIGRAPHIC UNITS SYMBOLS

- FILL
- LOESS
- UPPER GLACIAL OUTWASH UNIT
- LOWER GLACIAL OUTWASH UNIT
- CLAY-RICH GLACIAL TILL
- ALLUVIAL CLAY AND SILT
- ALLUVIAL SAND AND SANDY SILT
- BEDROCK – WESTERN INTERIOR PLAINS CONFINING SYSTEMS

30 15 0 30
VERTICAL SCALE IN FEET

300 150 0 300
HORIZONTAL SCALE IN FEET

VERTICAL EXAGGERATION = 10x

- FULL-SCALE MULCH WALL
- ESTIMATED GROUNDWATER SURFACE
- 14 — MONITORING WELL SCREEN INTERVAL WITH TCE CONCENTRATION FROM SPRING 2000 LTM
- 1 — ESTIMATED TCE CONCENTRATION CONTOURS (µg/L) BASED ON SPRING 2000 LTM AND HISTORIC SAMPLE RESULTS
- 15 — DIRECT PUSH WATER SAMPLE LOCATION WITH TCE CONCENTRATION FROM SPRING 2000 LTM
- 4 — HISTORIC DIRECT PUSH WATER SAMPLE LOCATION WITH ADJUSTED TCE CONCENTRATION IF ABOVE 1 µg/L
- 2 — HISTORIC HYDROPUNCH WATER SAMPLE LOCATION WITH TCE CONCENTRATION (µg/L)
- ND — NON-DETECT AT SAMPLE LOCATION
- GRANULAR IRON PERMEABLE REACTIVE BARRIER

NOTES:

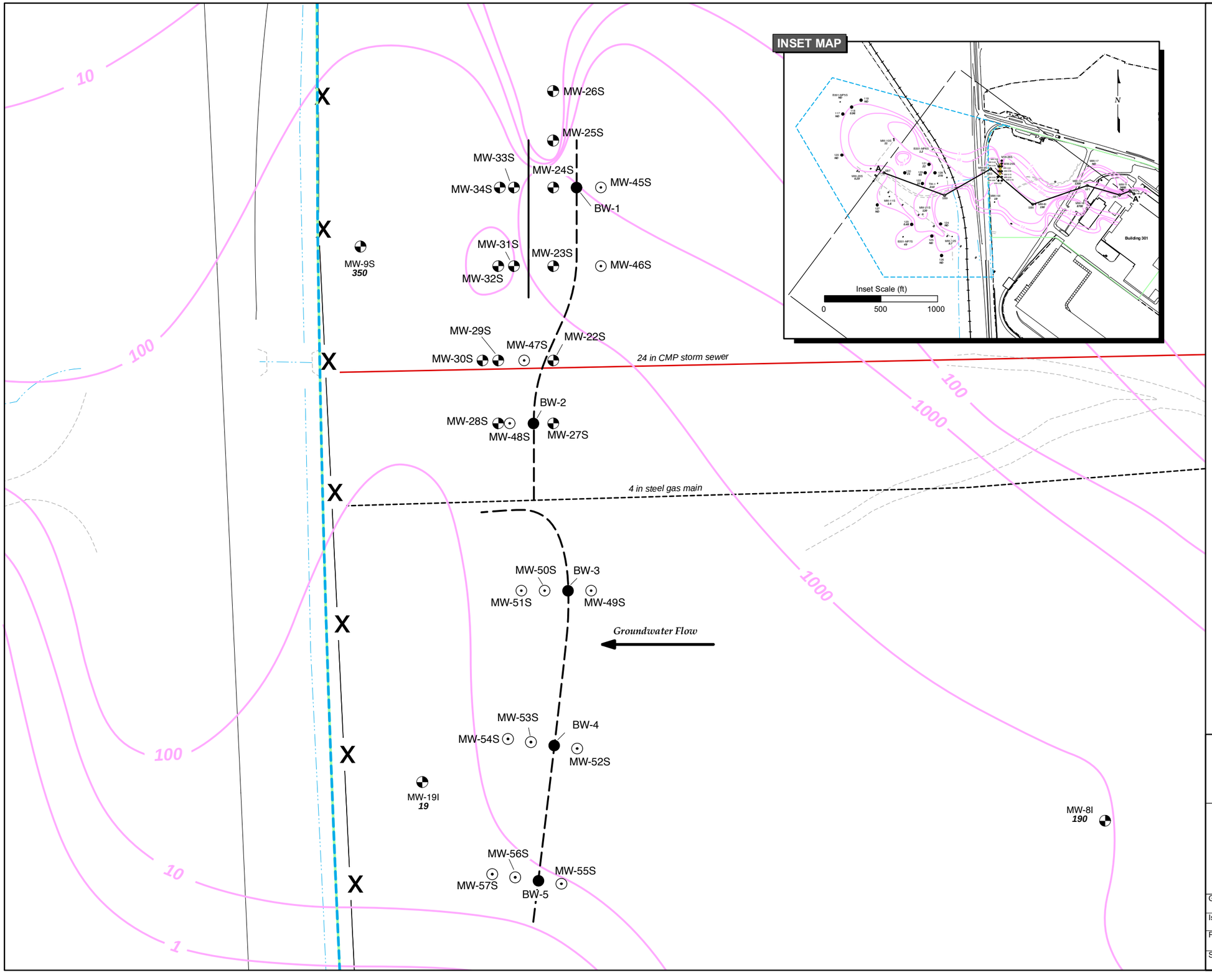
1) This figure represents a conceptual geologic model. The actual lithology between borings may vary from the shown interpretation.
2) Cross-section developed during the SFI/LTM (W-C 1998). See final SFI/LTM report for soil boring details.

GROUNDWATER SERVICES, INC.

VERTICAL DISTRIBUTION OF TCE IN GROUNDWATER ALONG HYDROGEOLOGIC PROFILE A-A'

Site B 301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	DLB
Issued:	4/13/04	Chk'd By:	MRS
Revised:	———	Appv'd By:	MRS
Scale:	As Shown		FIGURE 3



LEGEND

- Existing monitoring well location
- New monitoring well location
- New monitoring well location within mulch wall
- 10 – Revised estimated TCE concentration contour (µg/L) based on spring 2000 LTM and historical sample results
- Drainage ditch
- Pilot-scale mulch wall
- Full-scale mulch wall
- 24-in CMP storm sewer
- 4-in steel gas main

SCALE (ft.)

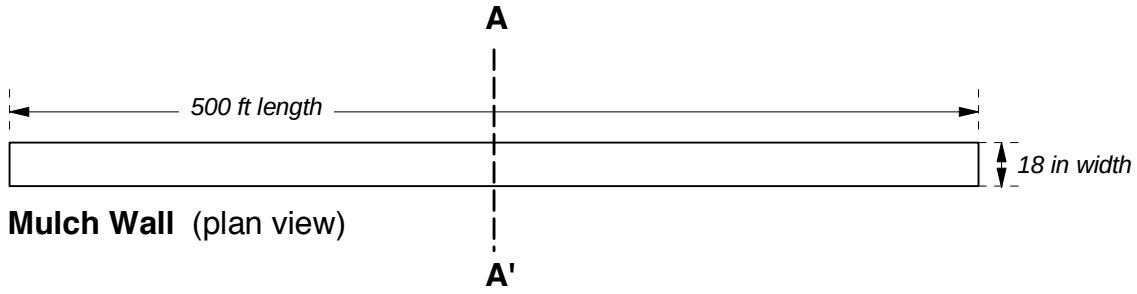
0 30 60

GROUNDWATER SERVICES, INC.

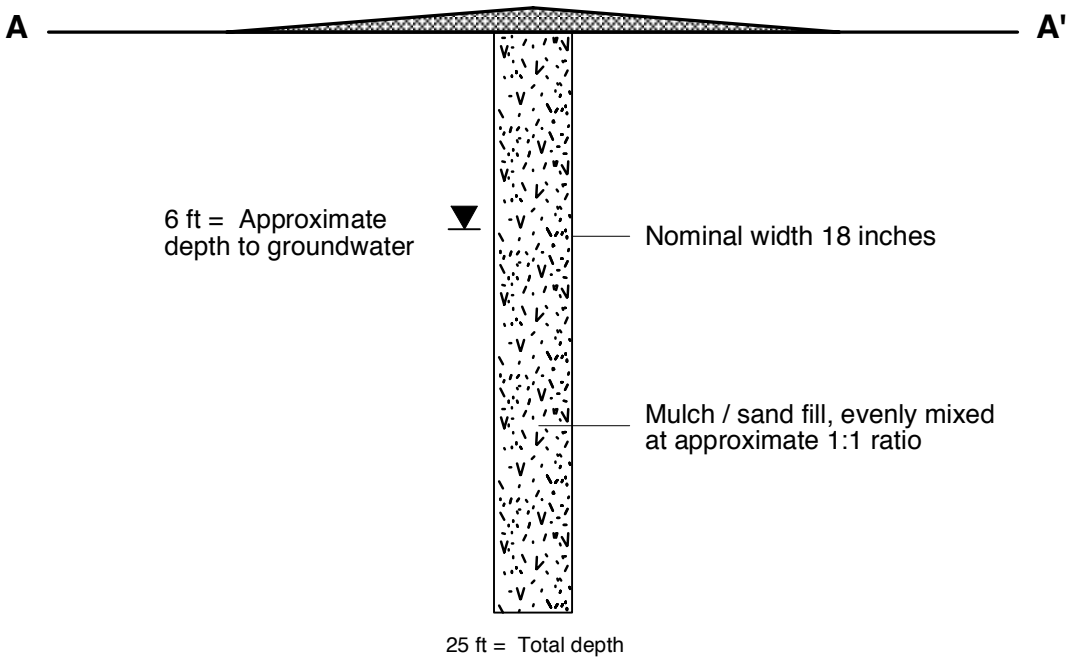
LOCATION OF FULL and PILOT SCALE MULCH WALLS and MONITORING WELLS

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	
Scale:	As Shown	**FIGURE 4**	



Mulch Wall (plan view)

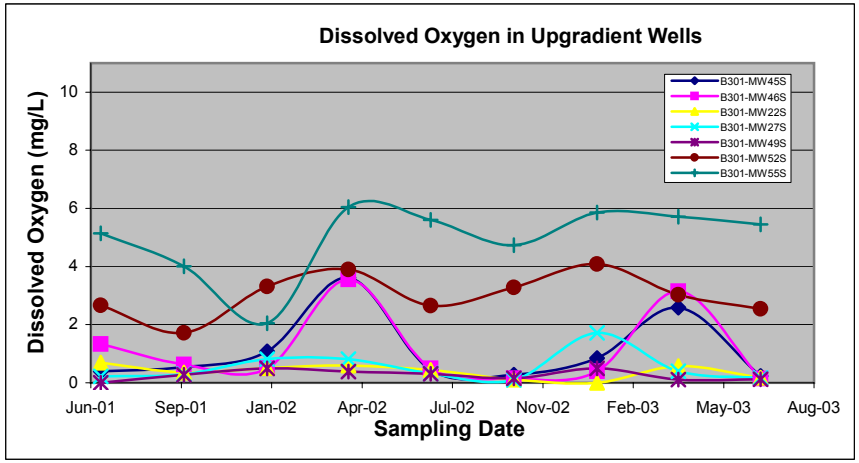


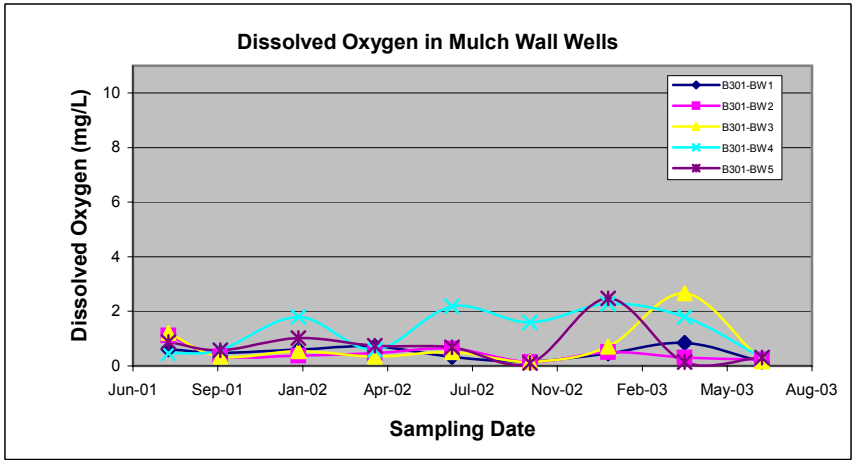
GROUNDWATER SERVICES, INC.	GSI Job No. G-2050	Drawn By: KVS	**SCHEMATIC CONSTRUCTION DIAGRAM FOR FULL-SCALE MULCH WALL**
	Issued: 4/13/04	Chk'd By: CEA	
	Revised: _____	Aprv'd By: CEA	Site B301 Offutt AFB, Nebraska
	Scale: Not to scale	**FIGURE 5**	

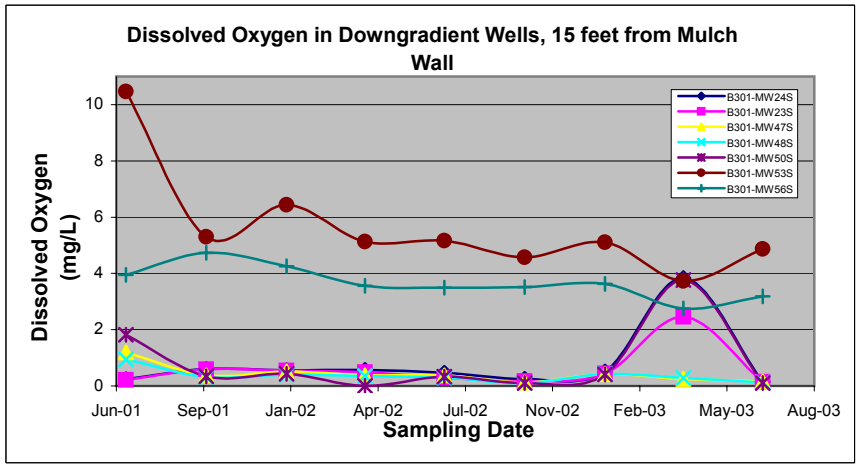
GROUNDWATER SERVICES, INC.

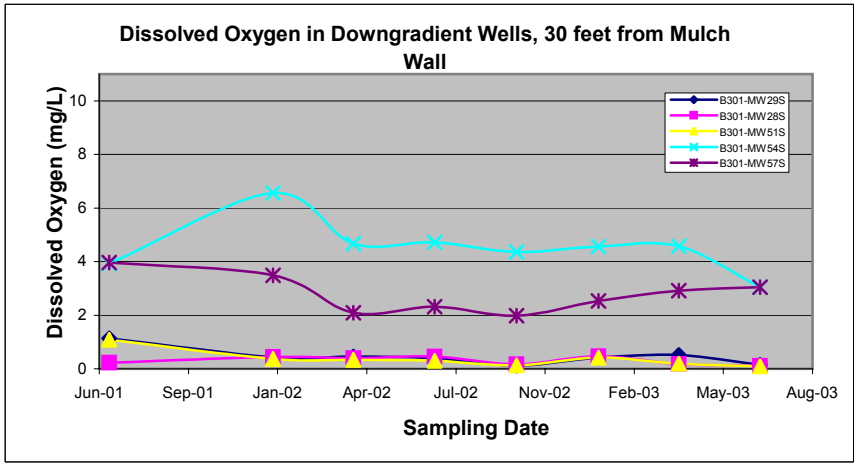
FIGURE 6
DISSOLVED OXYGEN IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas





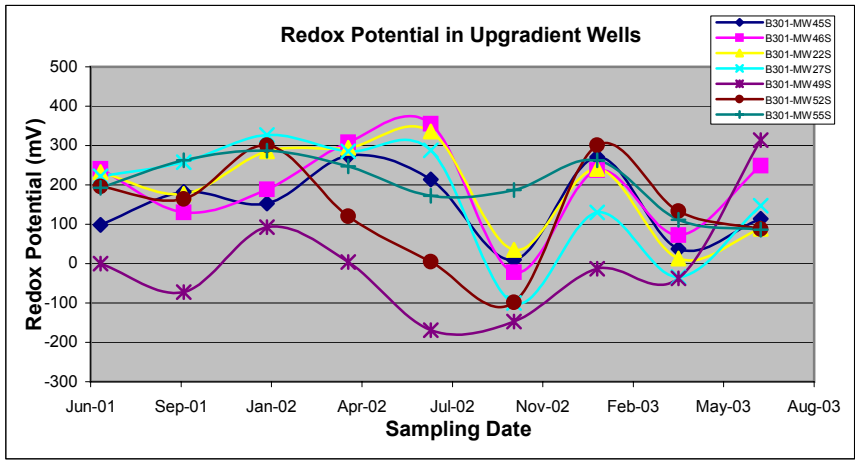


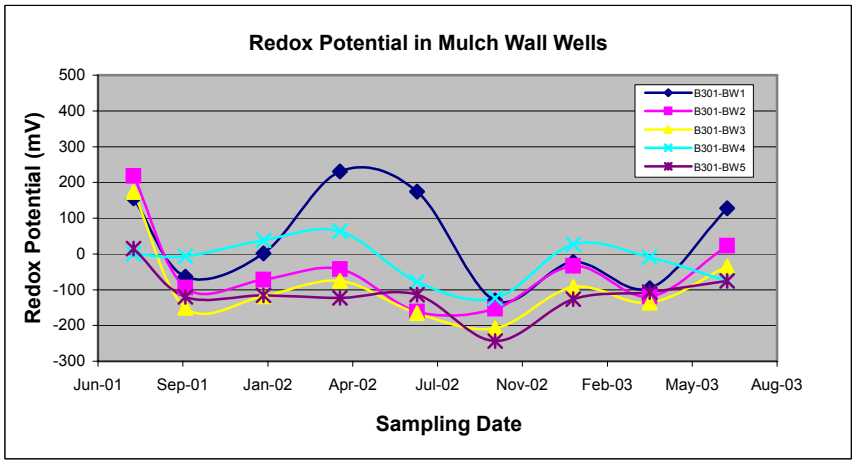


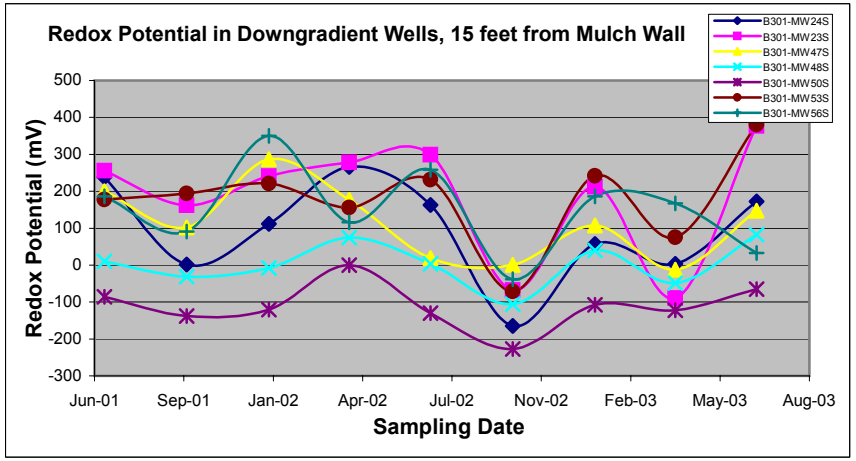
GROUNDWATER SERVICES, INC.

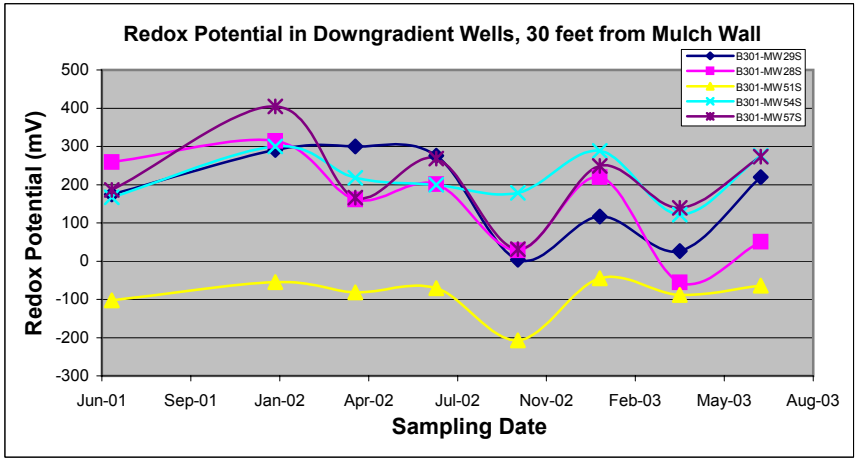
FIGURE 7
REDOX POTENTIAL IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas





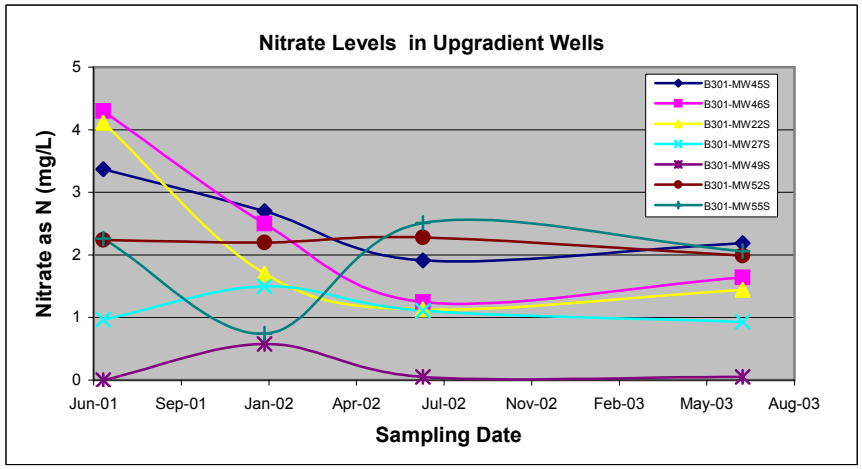


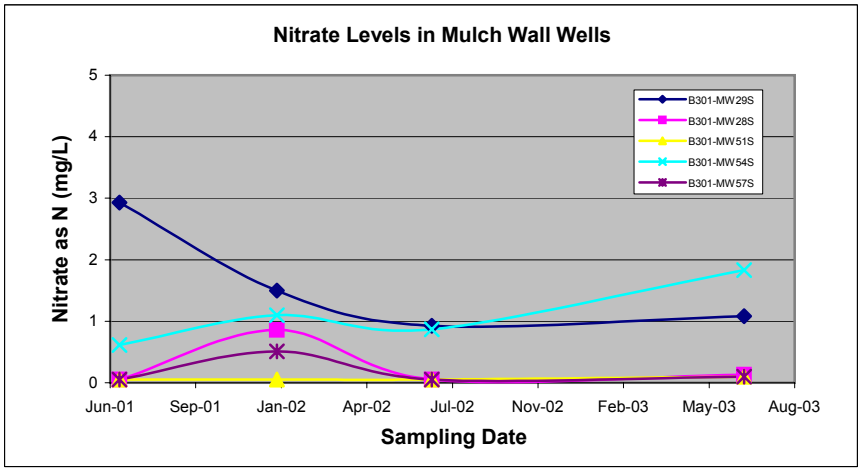


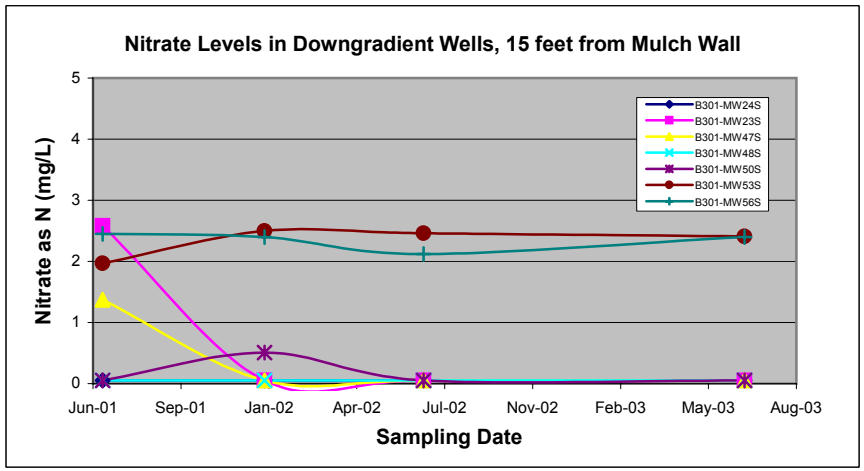
GROUNDWATER SERVICES, INC.

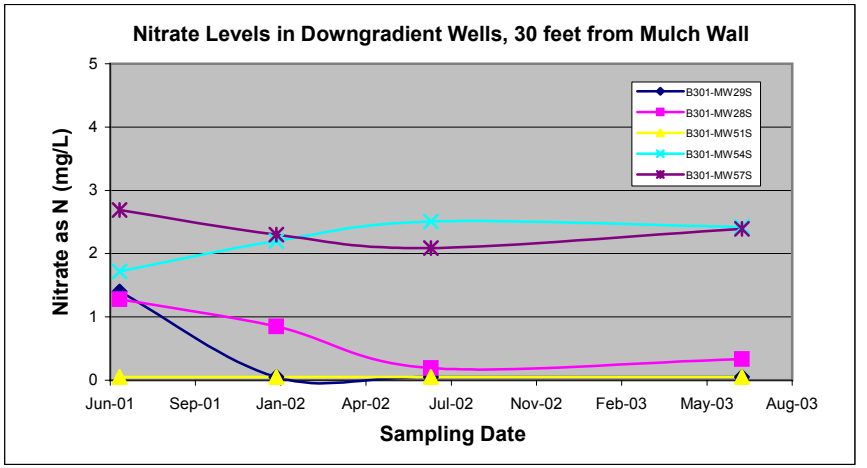
FIGURE 8
NITRATE IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas





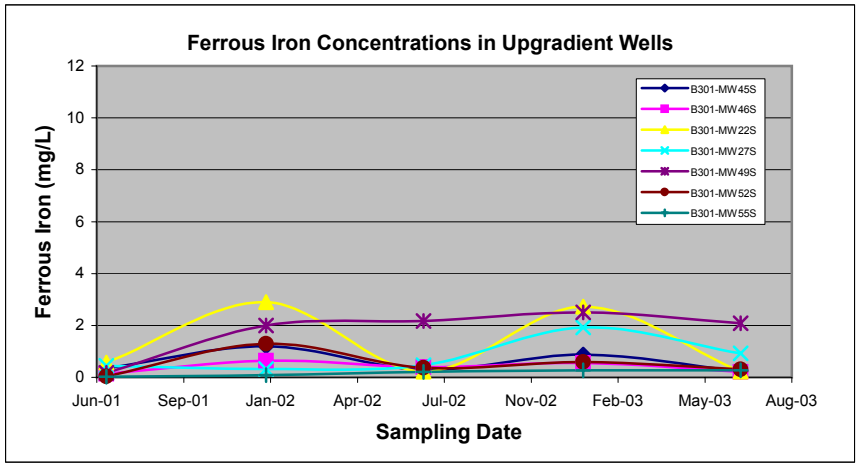


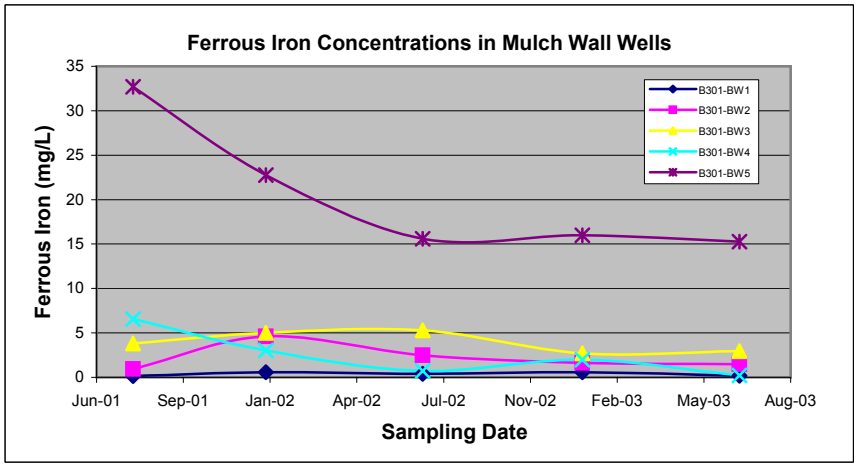


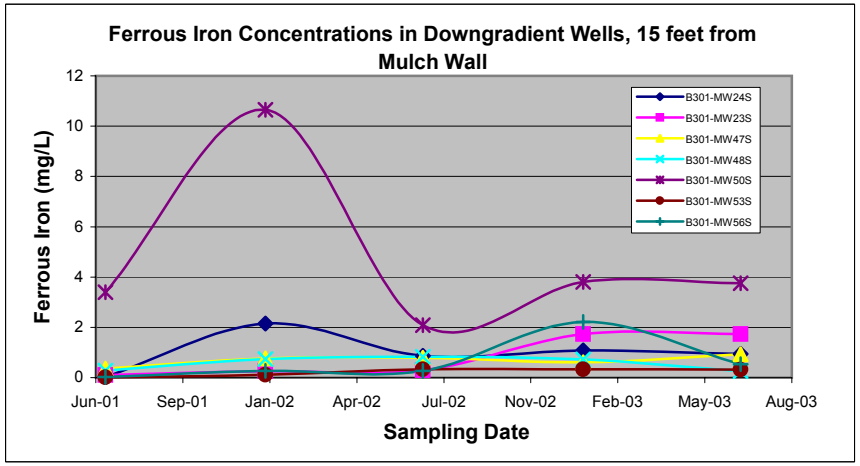
GROUNDWATER SERVICES, INC.

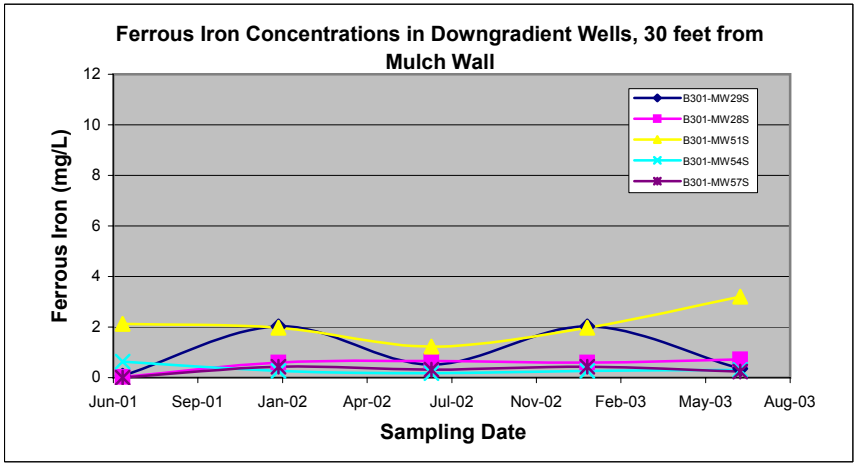
FIGURE 9
FERROUS IRON IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas





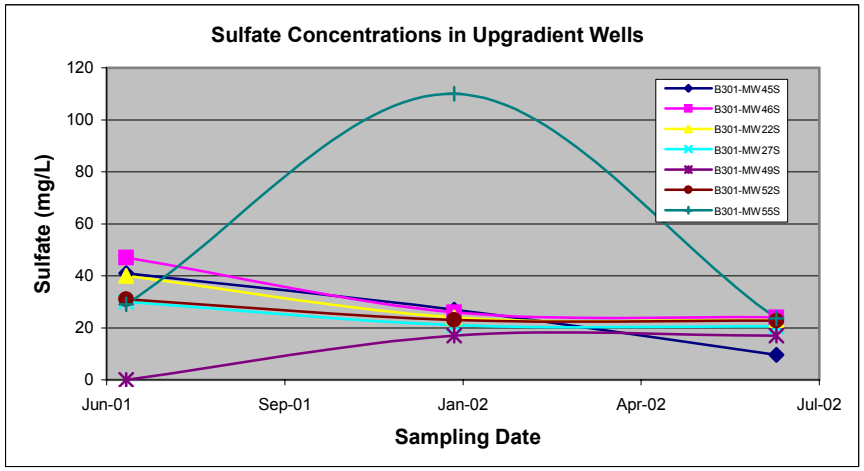


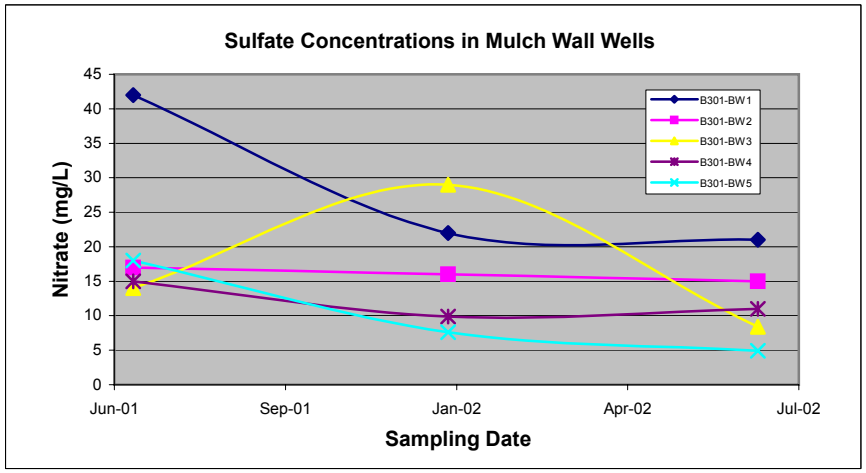


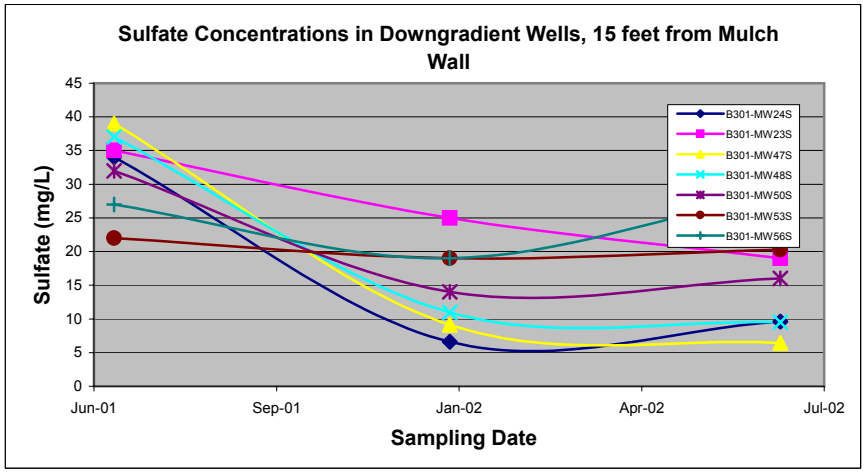
GROUNDWATER SERVICES, INC.

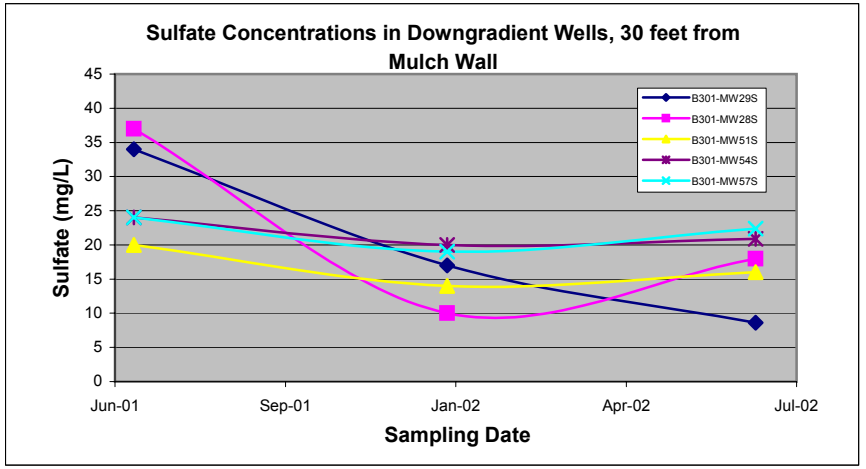
FIGURE 10
SULFATE IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas





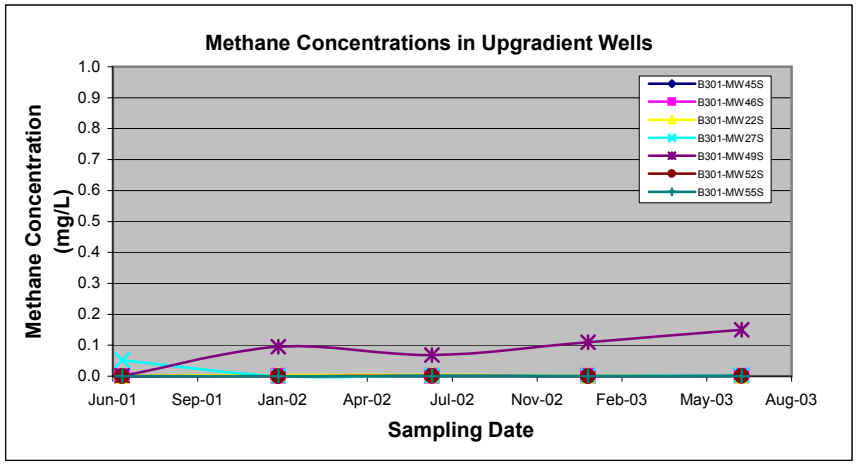


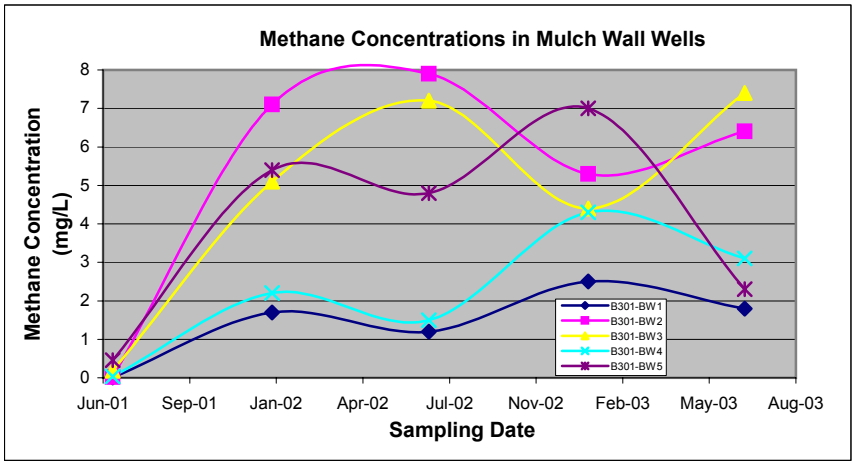


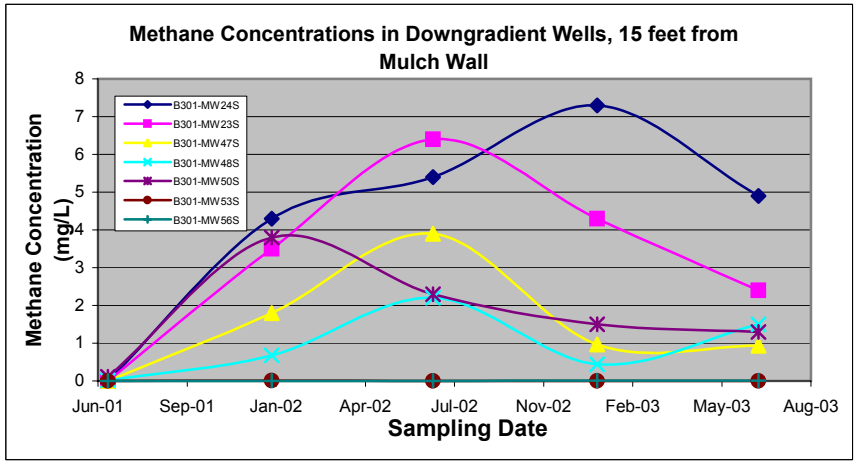
GROUNDWATER SERVICES, INC.

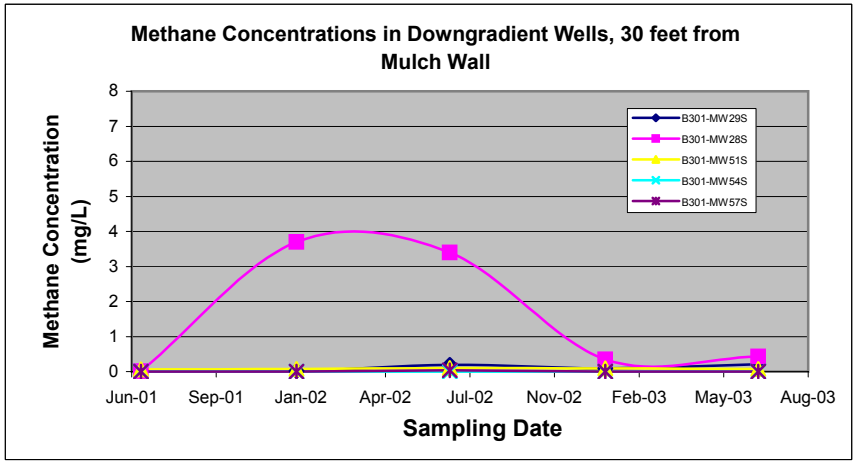
FIGURE 11
METHANE IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas





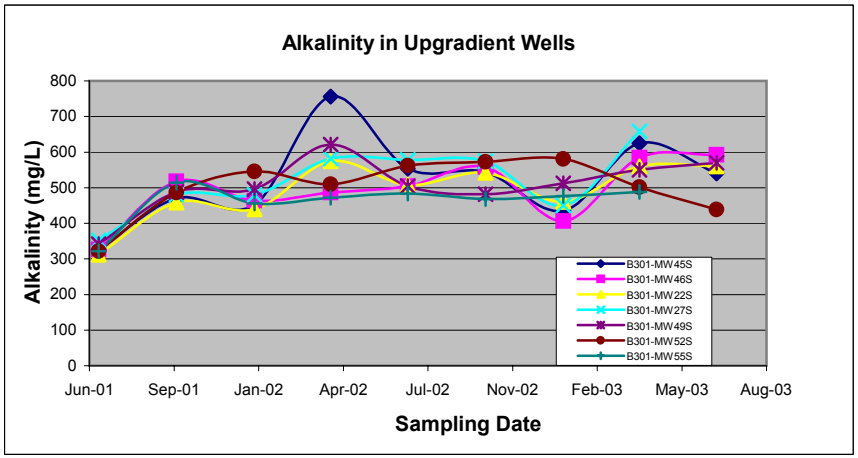


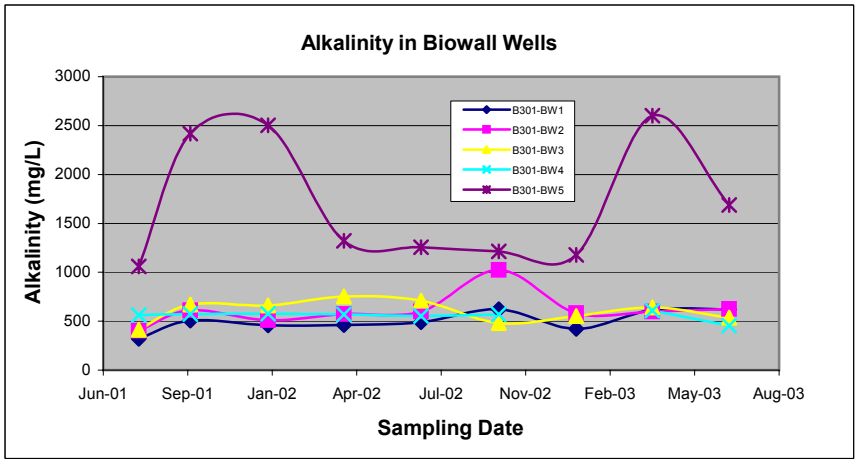


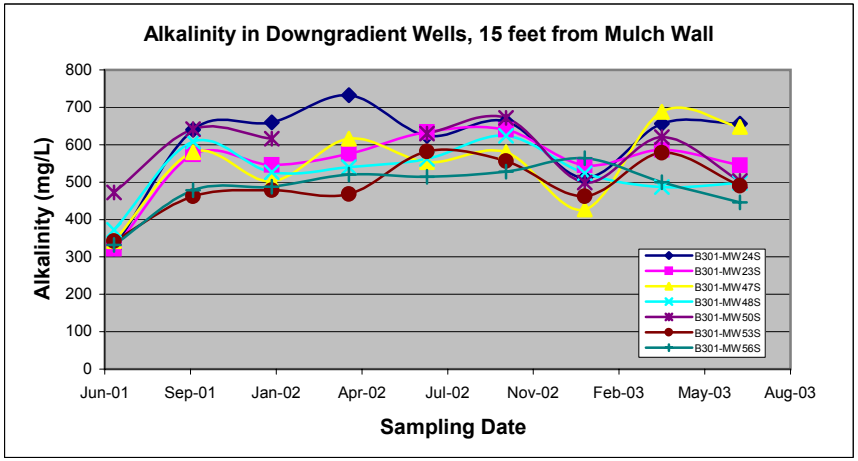
GROUNDWATER SERVICES, INC.

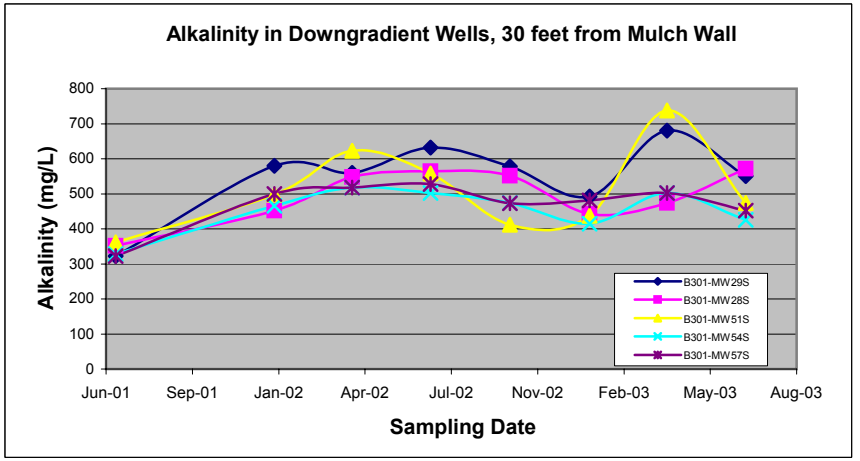
FIGURE 12
ALKALINITY IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

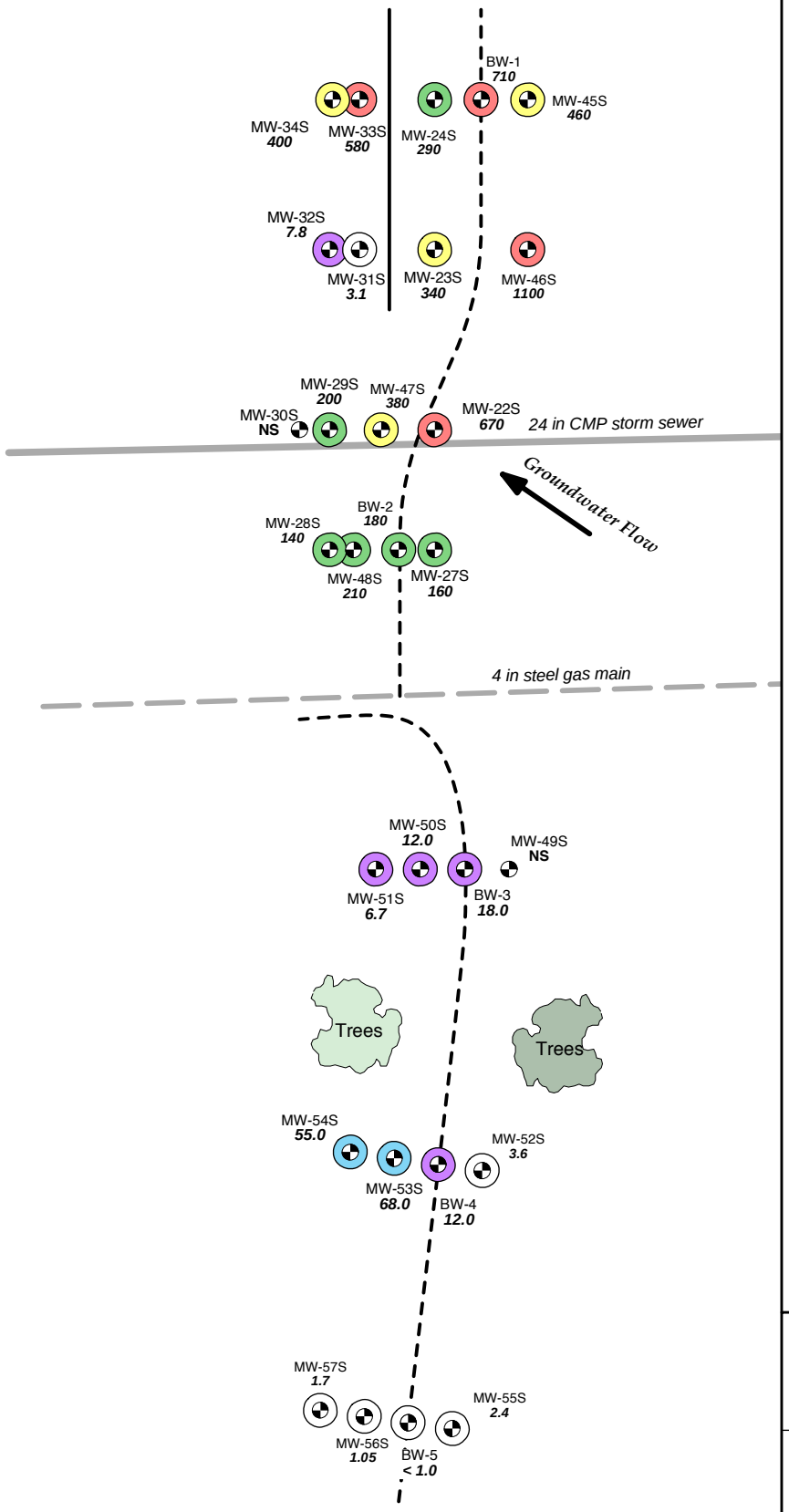
Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas











N

LEGEND

- Monitoring well location
- Pilot-scale mulch wall
- Full-scale mulch wall

Concentrations Levels of TCE (µg/L)

- <5
- 5-20
- >20-100
- >100-300
- >300-500
- >500

SCALE (ft)

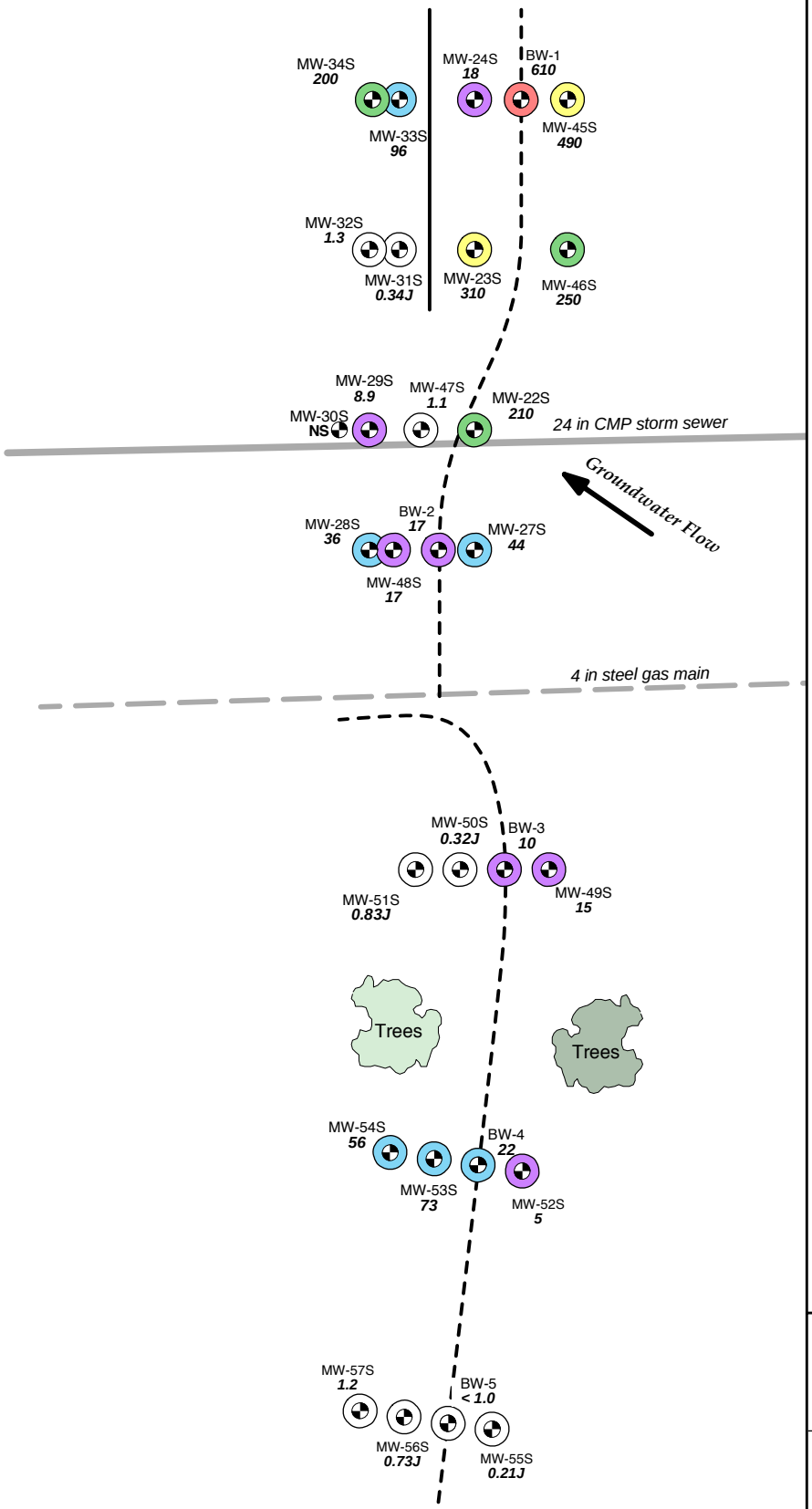
0 30 60

GROUNDWATER SERVICES, INC.

TCE CONCENTRATIONS IN GROUNDWATER, JULY 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 13**



N

LEGEND

- Monitoring well location
- Pilot-scale mulch wall
- Full-scale mulch wall

Concentrations Levels of TCE (µg/L)

- <5
- 5-20
- >20-100
- >100-300
- >300-500
- >500

SCALE (ft)

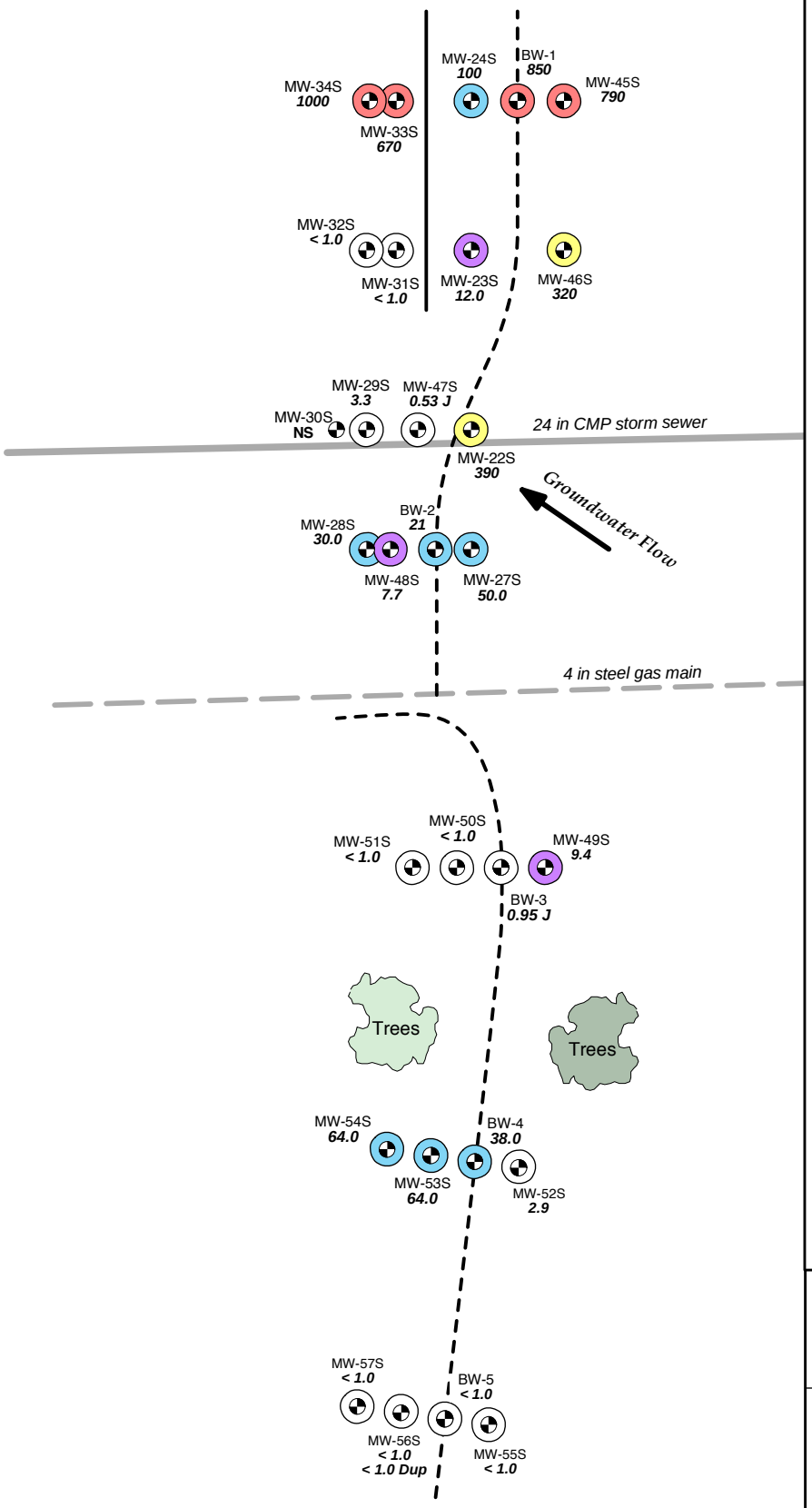
0 30 60

GROUNDWATER SERVICES, INC.

TCE CONCENTRATIONS IN GROUNDWATER, JULY 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	CCJ
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 14**



LEGEND

- Monitoring well location
- Pilot-scale mulch wall
- Full-scale mulch wall

Concentrations Levels of TCE (µg/L)

- <5
- 5-20
- >20-100
- >100-300
- >300-500
- >500

SCALE (ft)

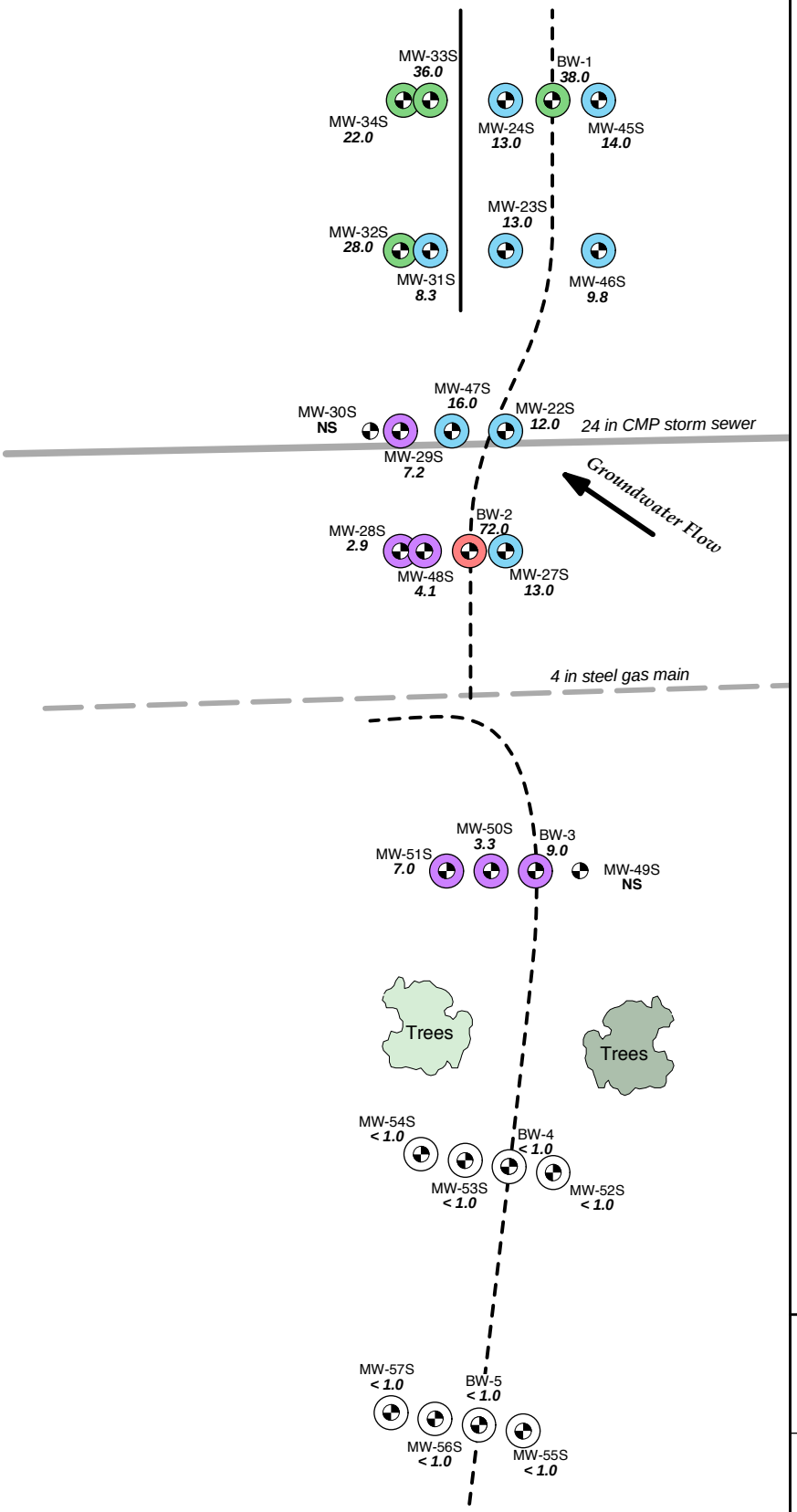
0 30 60

GROUNDWATER SERVICES, INC.

TCE CONCENTRATIONS IN GROUNDWATER, JULY 2003

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 15**



N

LEGEND

- Monitoring well location
- Pilot-scale mulch wall
- Full-scale mulch wall

Concentrations Levels of cis-DCE (µg/L)

- <1
- 1-10
- >10-20
- >20-70
- >70

SCALE (ft)

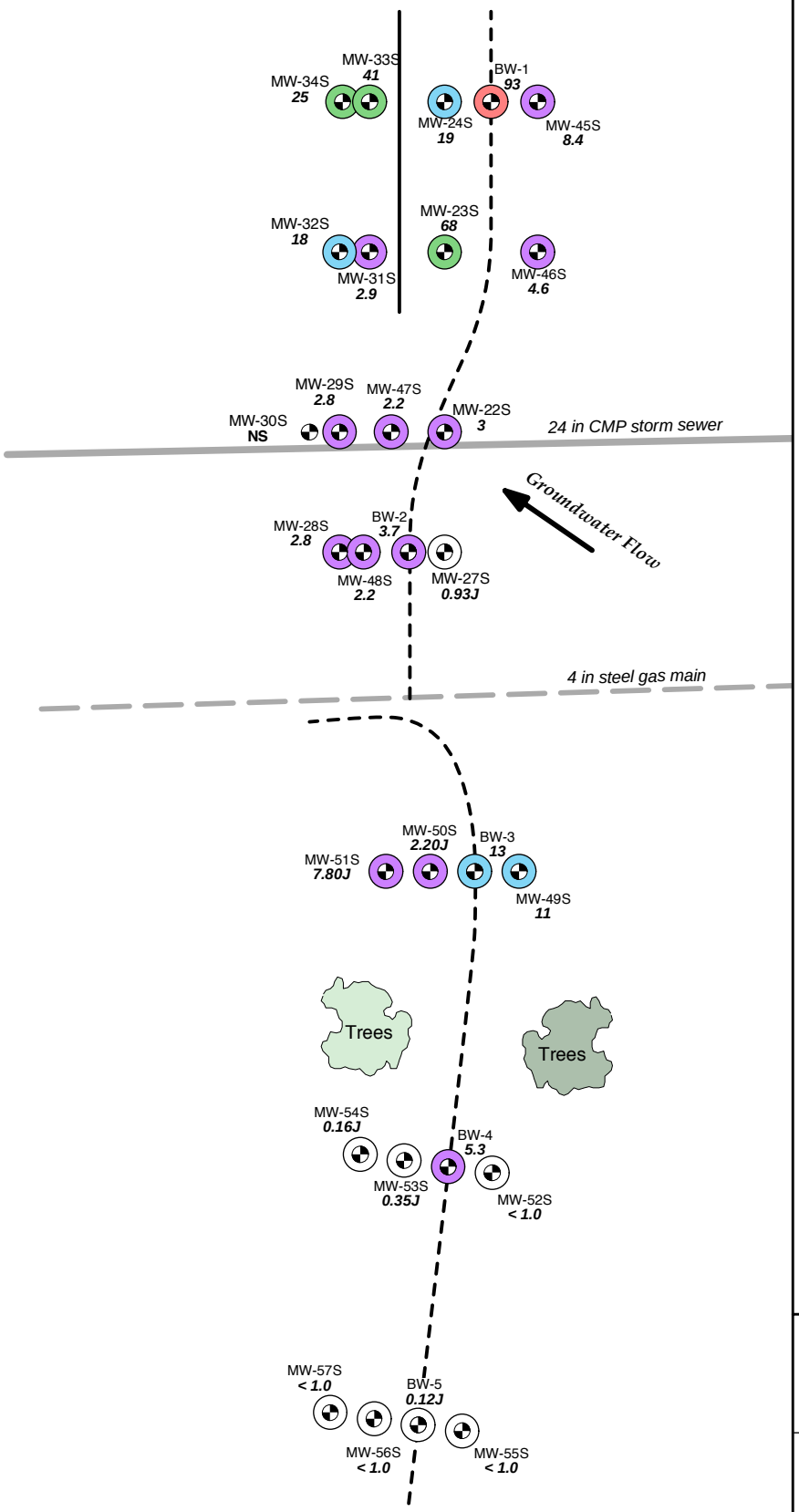
0 30 60

GROUNDWATER SERVICES, INC.

cis-DCE CONCENTRATIONS IN GROUNDWATER, JULY 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 16**



LEGEND

Monitoring well location

Pilot-scale mulch wall

Full-scale mulch wall

Concentrations Levels of cis-DCE (µg/L)

<1

1-10

>10-20

>20-70

>70

SCALE (ft)

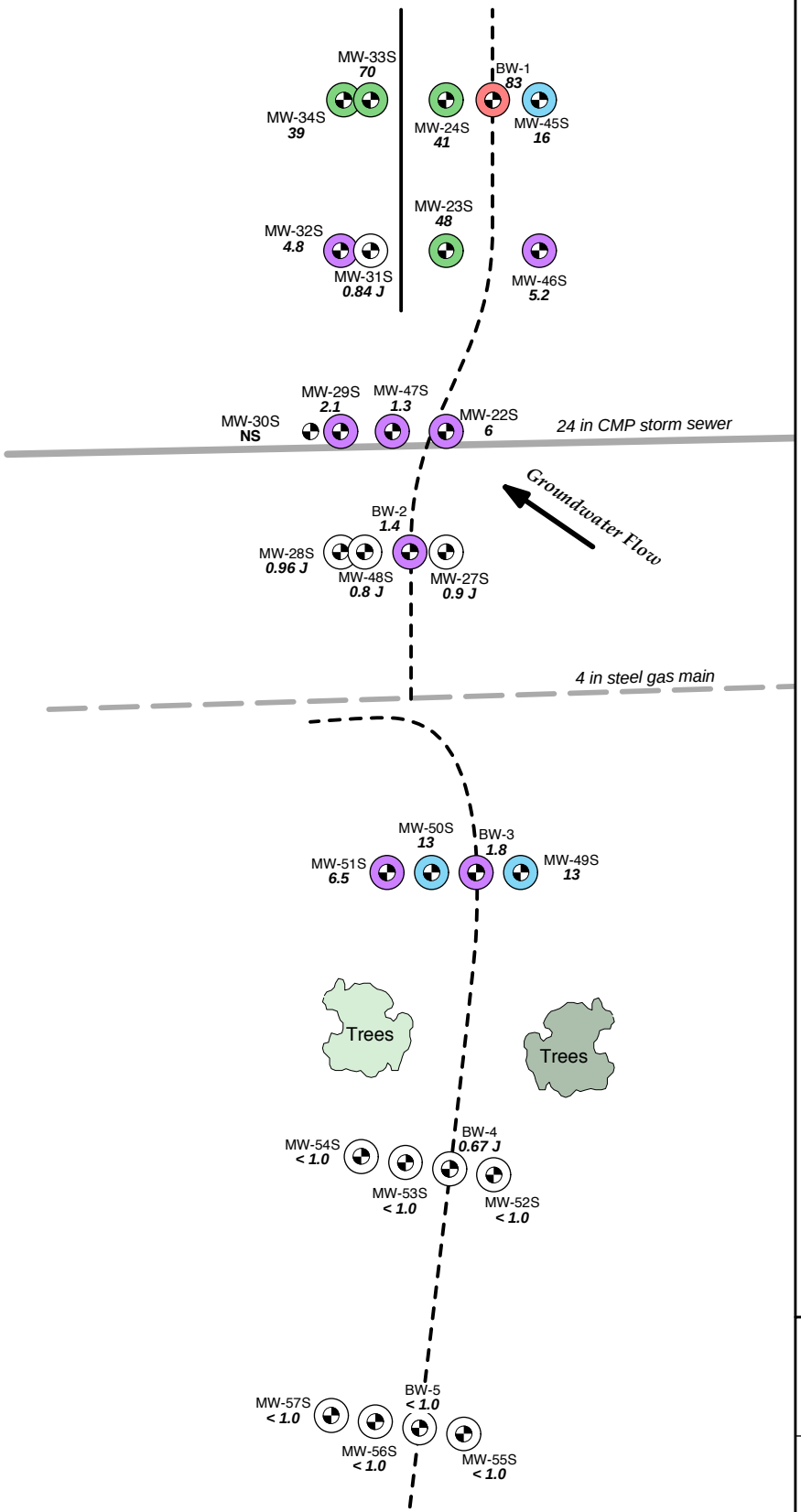
0 30 60

GROUNDWATER SERVICES, INC.

cis-DCE CONCENTRATIONS IN GROUNDWATER, JULY 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 17**



N

LEGEND

- Monitoring well location
- Pilot-scale mulch biowall
- Full-scale mulch biowall

Concentrations Levels of cis-DCE (µg/L)

- <1
- 1-10
- >10-20
- >20-70
- >70

SCALE (ft)

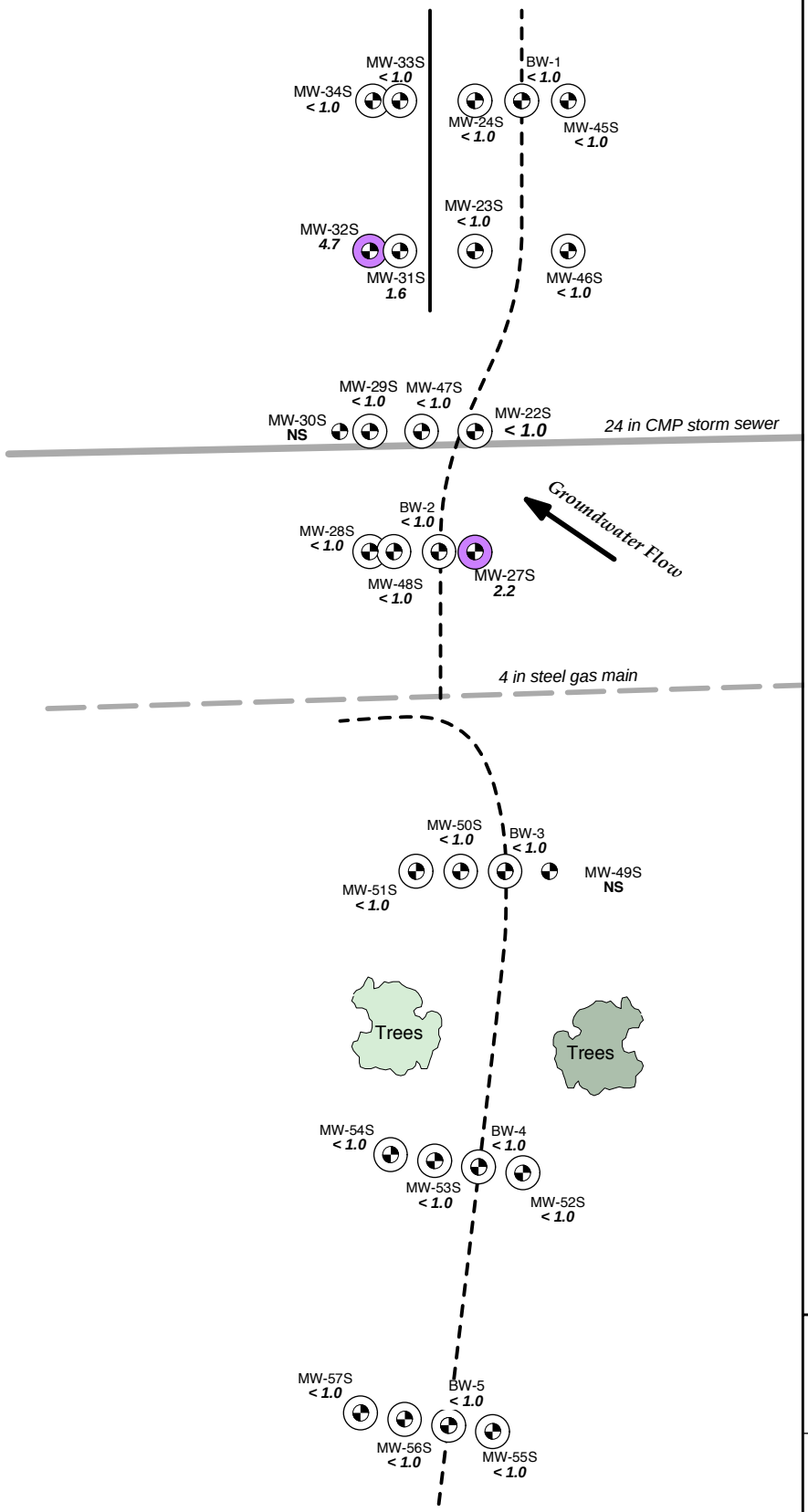
0 30 60

GROUNDWATER SERVICES, INC.

cis-DCE CONCENTRATIONS IN GROUNDWATER, JULY 2003

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 18**



N

LEGEND

- Monitoring well location
- Pilot-scale mulch biowall
- Full-scale mulch biowall

Concentrations Levels of vinyl chloride (µg/L)

- < 2
- 2-10
- >10-30

SCALE (ft)

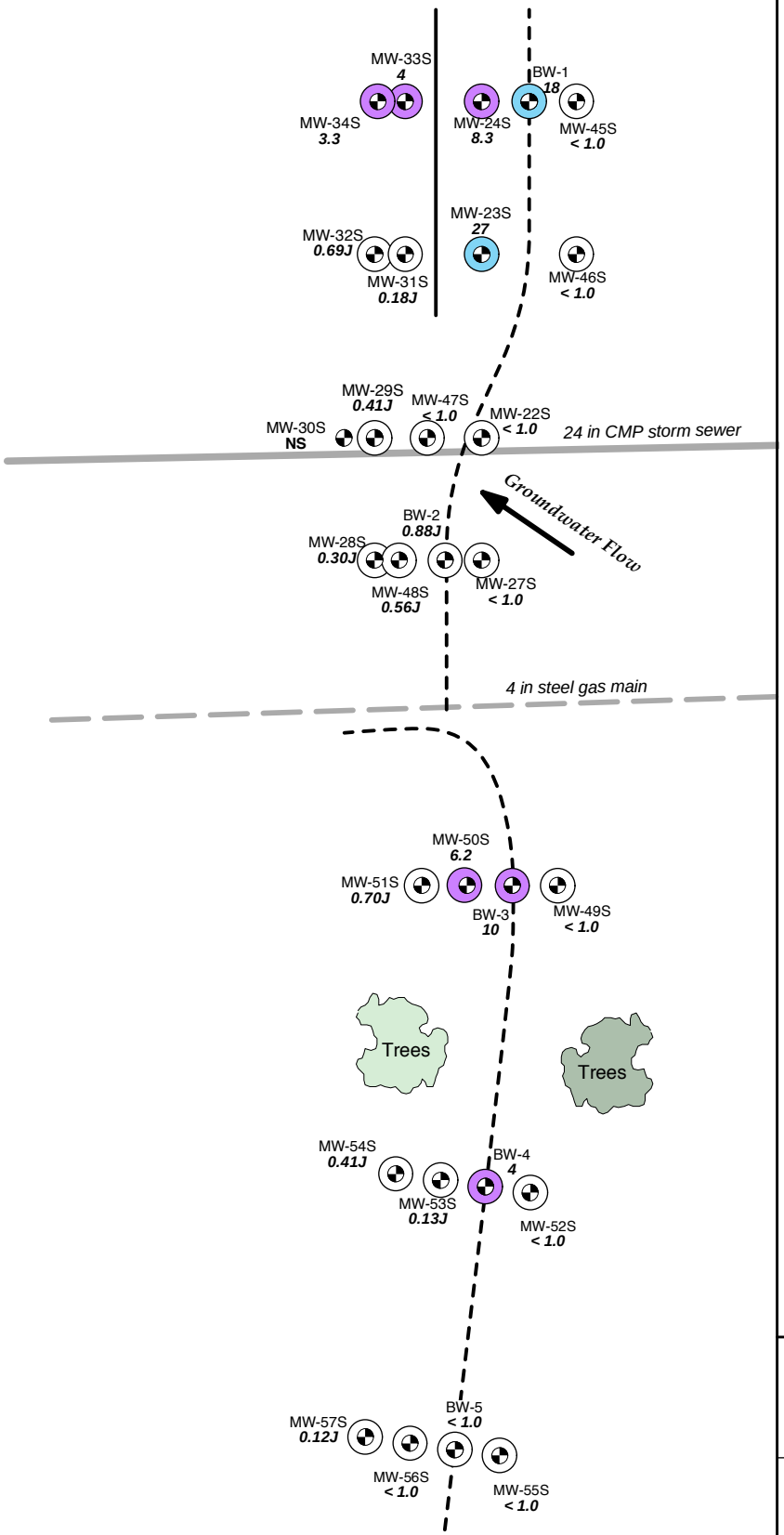
0 30 60

GROUNDWATER SERVICES, INC.

VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER: JULY 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 19**



N

LEGEND

- Monitoring well location
- Pilot-scale mulch biowall
- Full-scale mulch biowall

Concentrations Levels of vinyl chloride (µg/L)

- < 2
- 2-10
- >10-30

SCALE (ft)

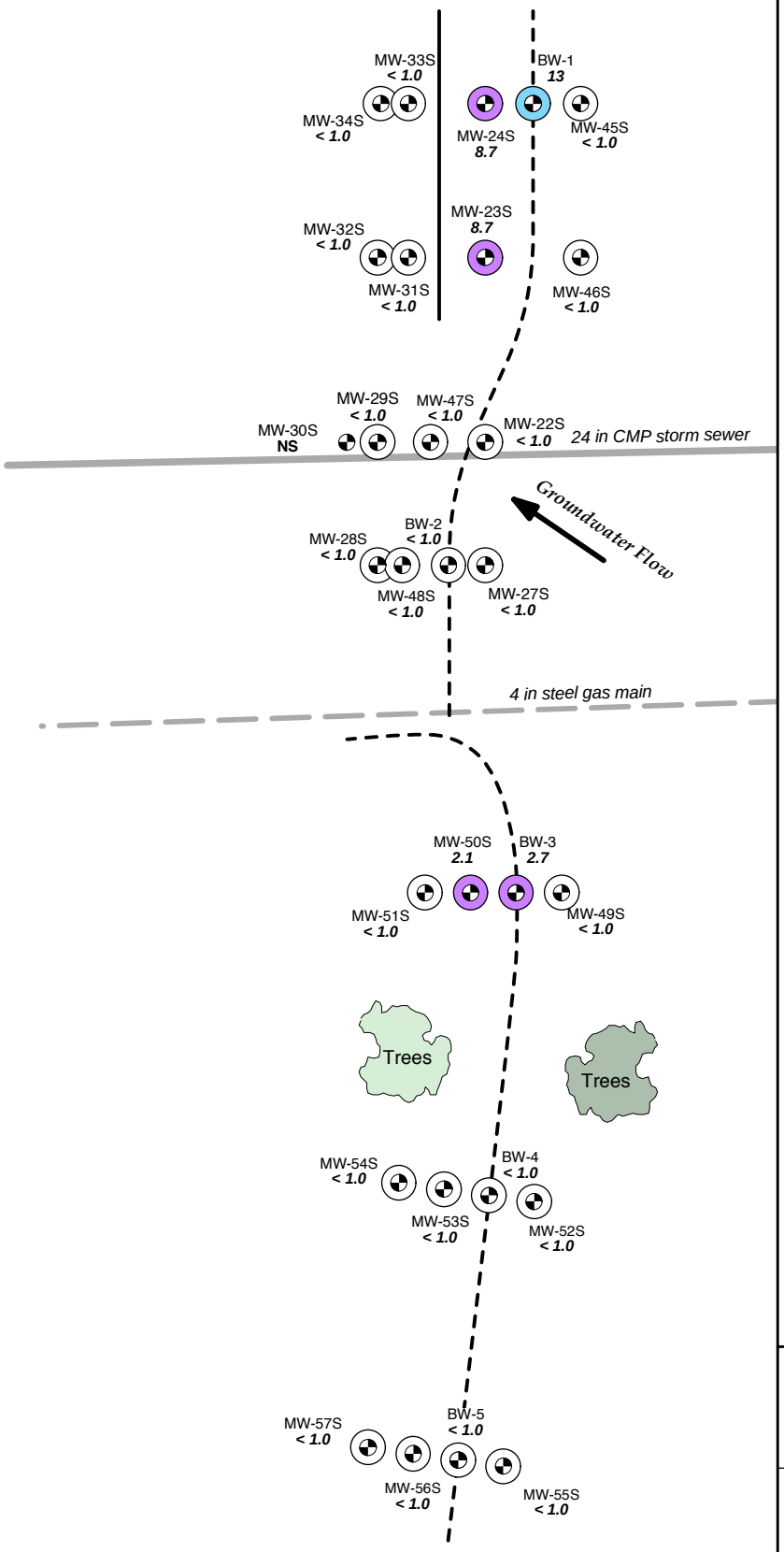
0 30 60

GROUNDWATER SERVICES, INC.

VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER: JULY 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	CCJ
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown	**FIGURE 20**	



N

LEGEND

- Monitoring well location
- Pilot-scale mulch biowall
- Full-scale mulch biowall

Concentrations Levels of vinyl chloride (µg/L)

- < 2
- 2-10
- >10-30

SCALE (ft)

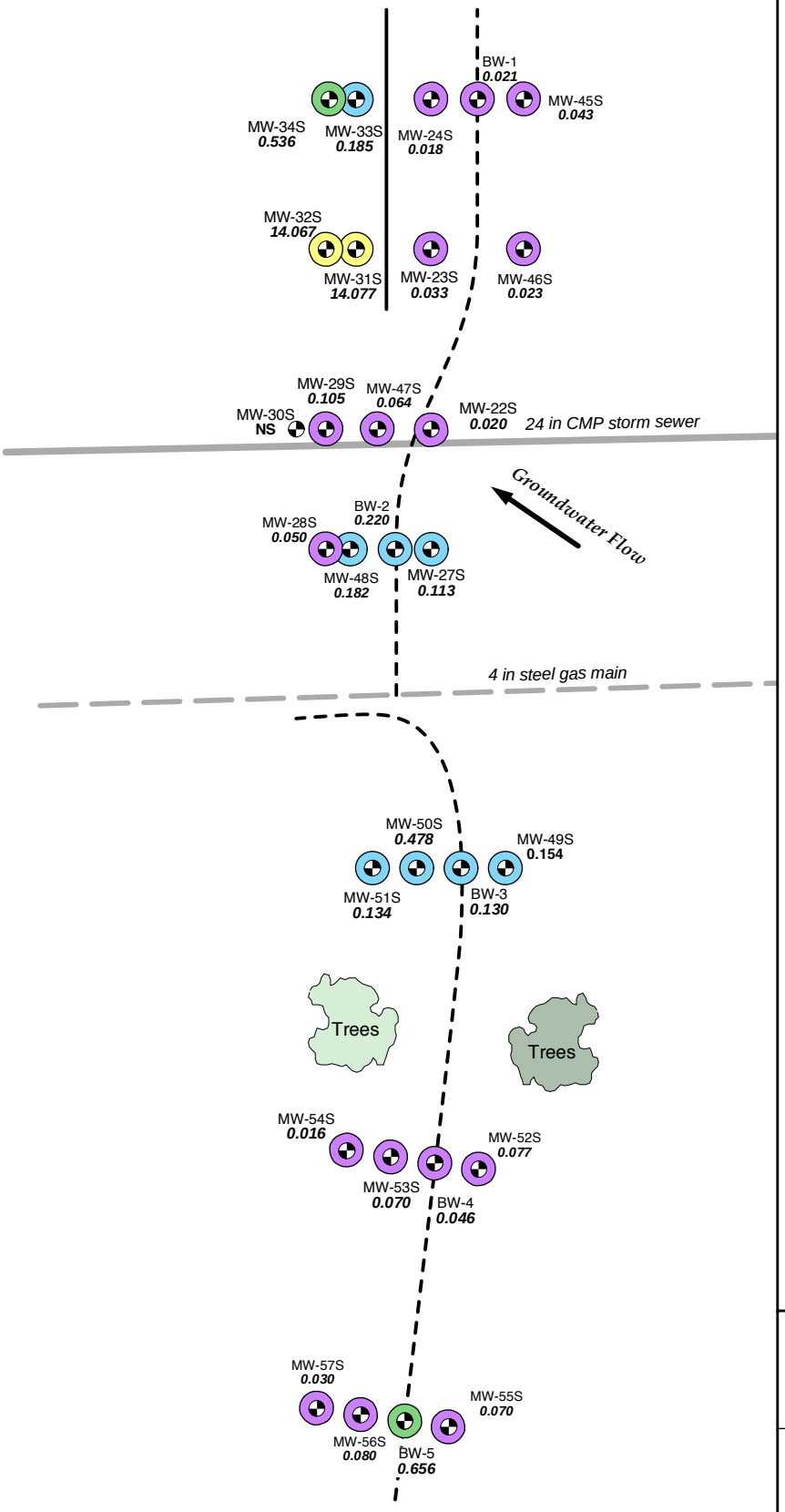
0 30 60

GROUNDWATER SERVICES, INC.

VINYL CHLORIDE CONCENTRATIONS IN GROUNDWATER: JULY 2003

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 21**



LEGEND

- Monitoring well location
- Pilot-scale mulch wall
- Full-scale mulch wall

Concentrations Levels of Ethene & Ethane (µg/L)

- < 0.1
- 0.1-0.5
- >0.5-1
- >1-30

SCALE (ft)

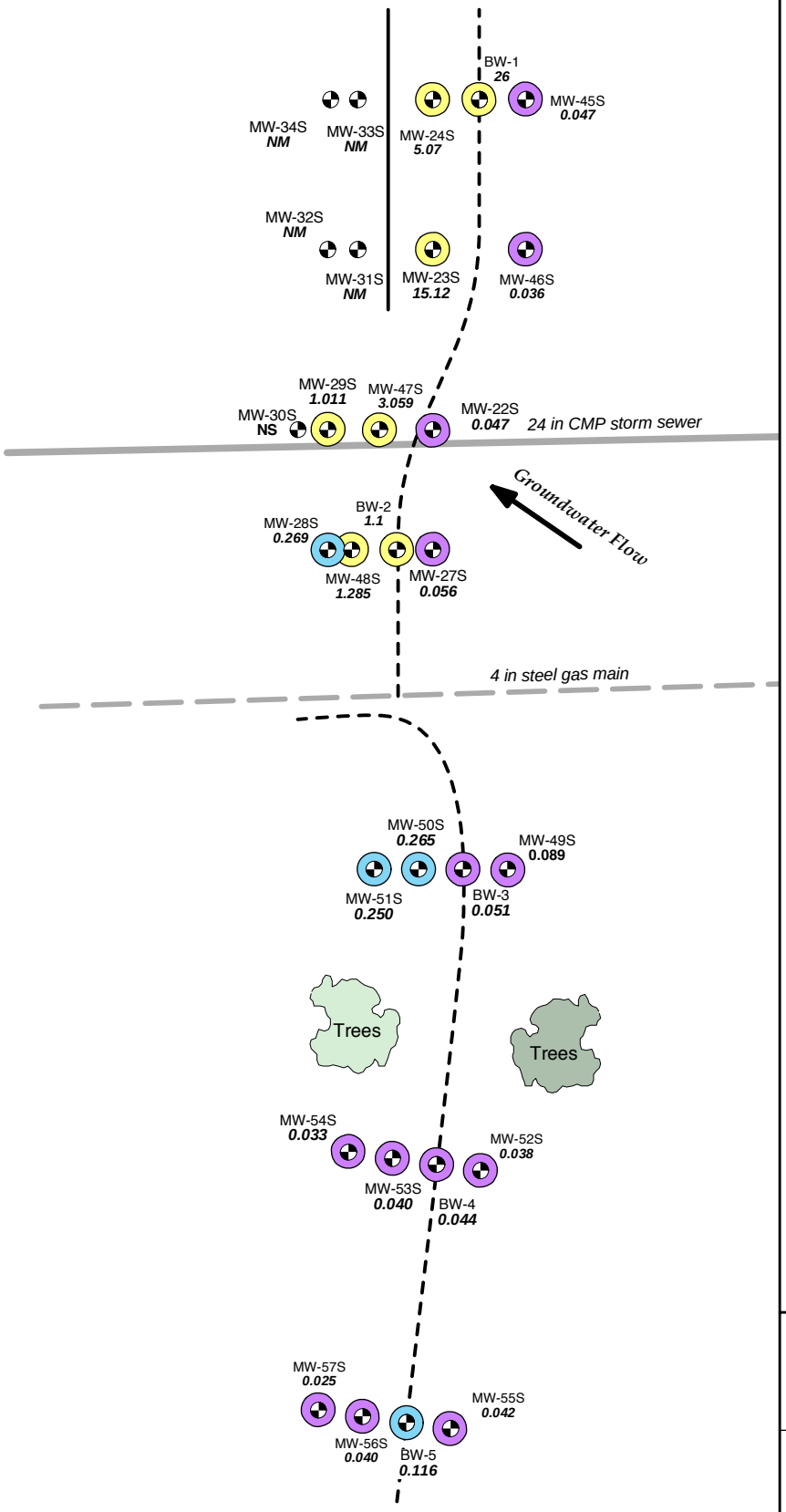
0 30 60

GROUNDWATER SERVICES, INC.

ETHENE & ETHANE CONCENTRATIONS IN GROUNDWATER: JULY 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 22**



LEGEND

- Monitoring well location
- Pilot-scale mulch wall
- Full-scale mulch wall

Concentrations Levels of Ethene & Ethane (µg/L)

- < 0.1
- 0.1-0.5
- >0.5-1
- >1-30

SCALE (ft)

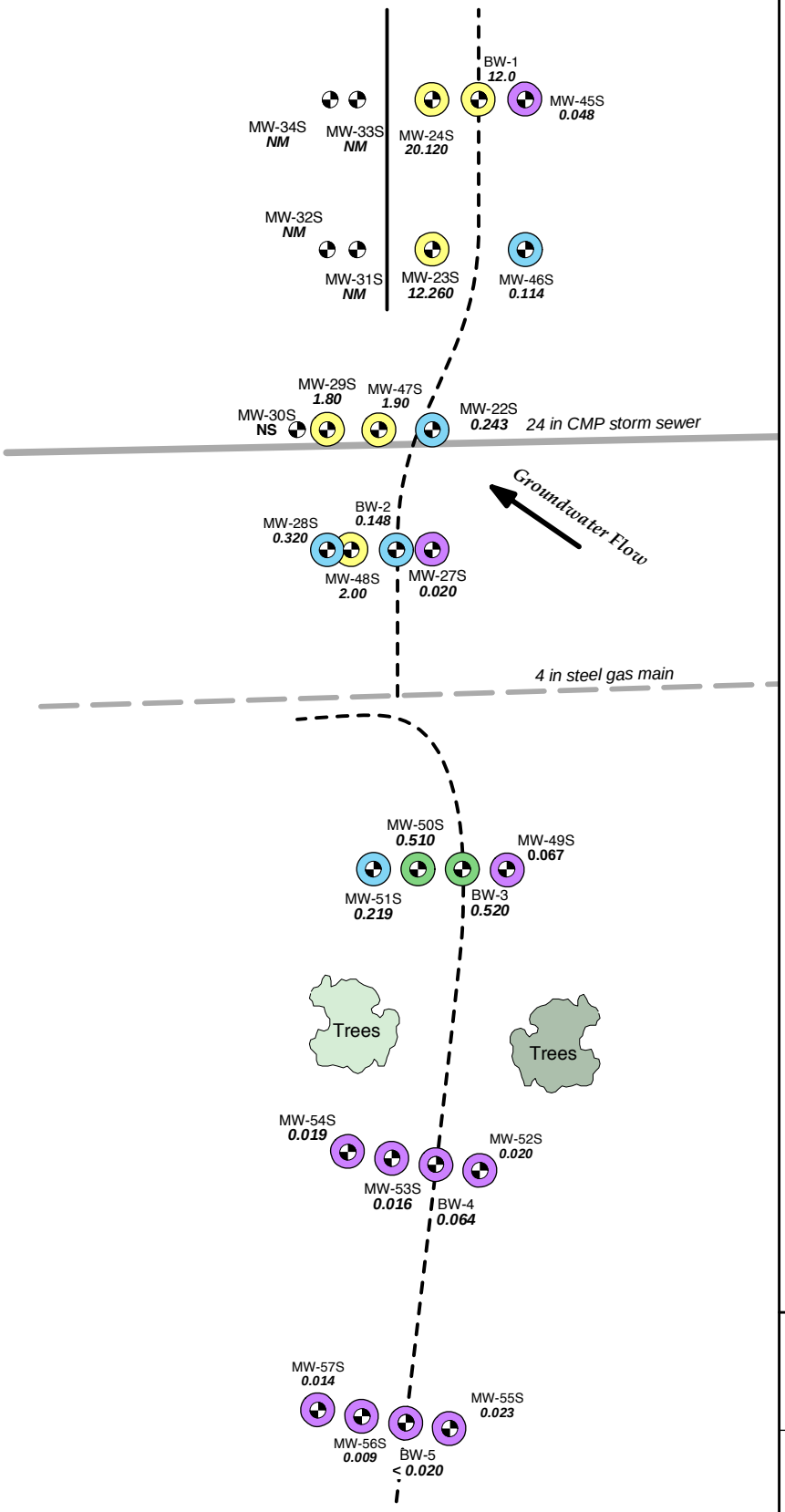
0 30 60

GROUNDWATER SERVICES, INC.

ETHENE & ETHANE CONCENTRATIONS IN GROUNDWATER: JULY 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 23**



LEGEND

- Monitoring well location
- Pilot-scale mulch wall
- Full-scale mulch wall

Concentrations Levels of Ethene & Ethane (µg/L)

- < 0.1
- 0.1-0.5
- >0.5-1
- >1-30

SCALE (ft)

0 30 60

GROUNDWATER SERVICES, INC.

ETHENE & ETHANE CONCENTRATIONS IN GROUNDWATER: JULY 2003

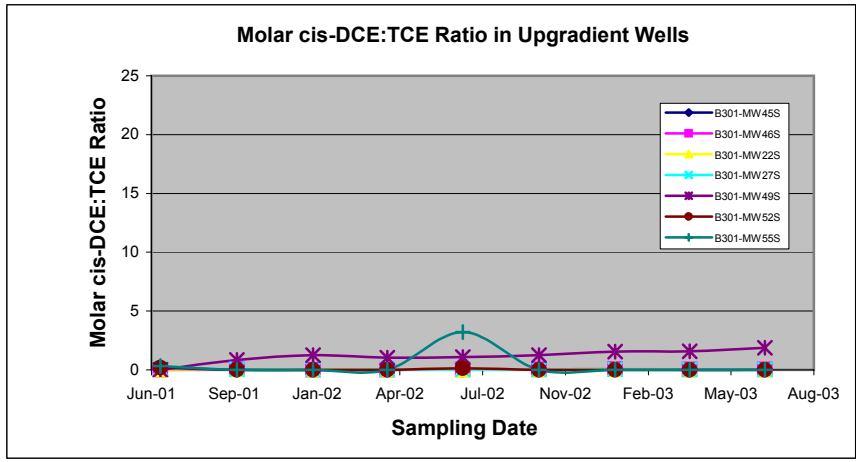
Site B301
Offutt AFB, Nebraska

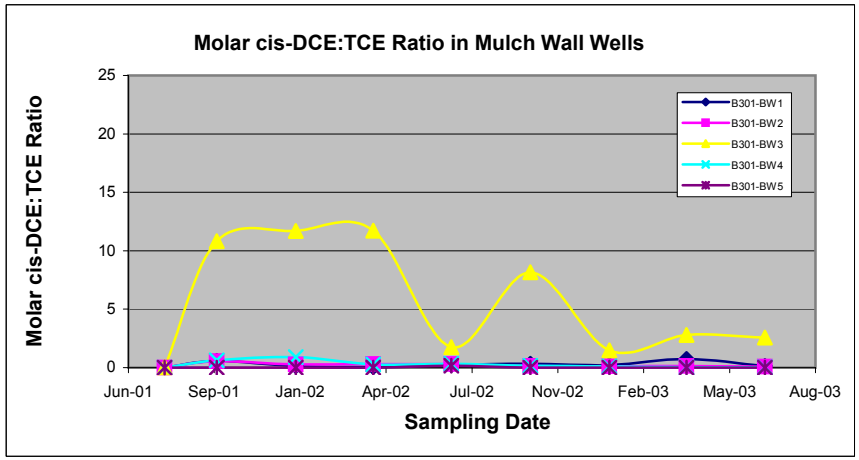
GSI Job No:	G-2050	Drawn By:	KVS
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE 24**

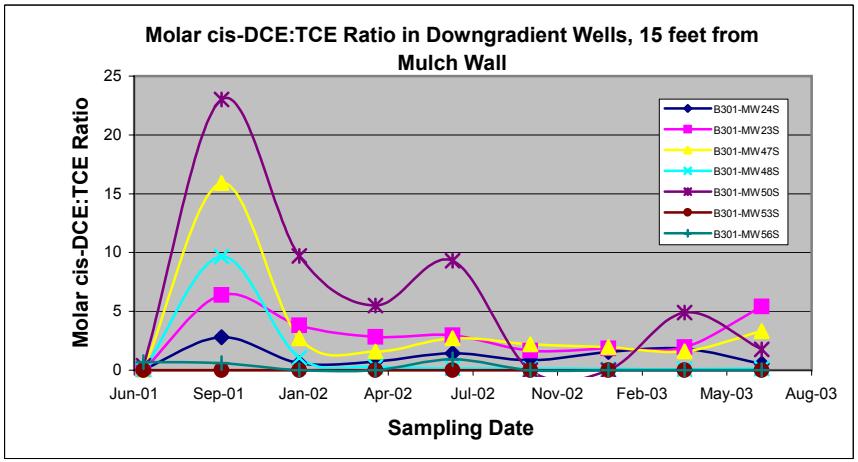
GROUNDWATER SERVICES, INC.

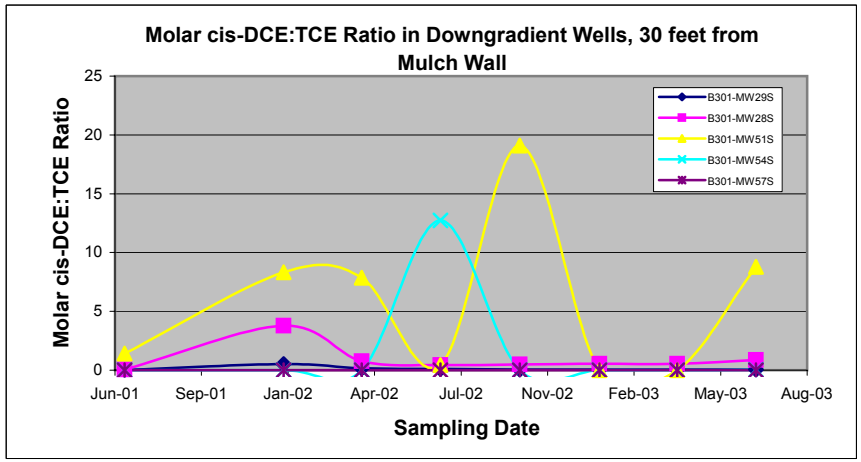
FIGURE 25
MOLAR cis-DCE/TCE RATIO IN UPGRADIENT, MULCH WALL, AND DOWNGRADIENT WELLS

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas





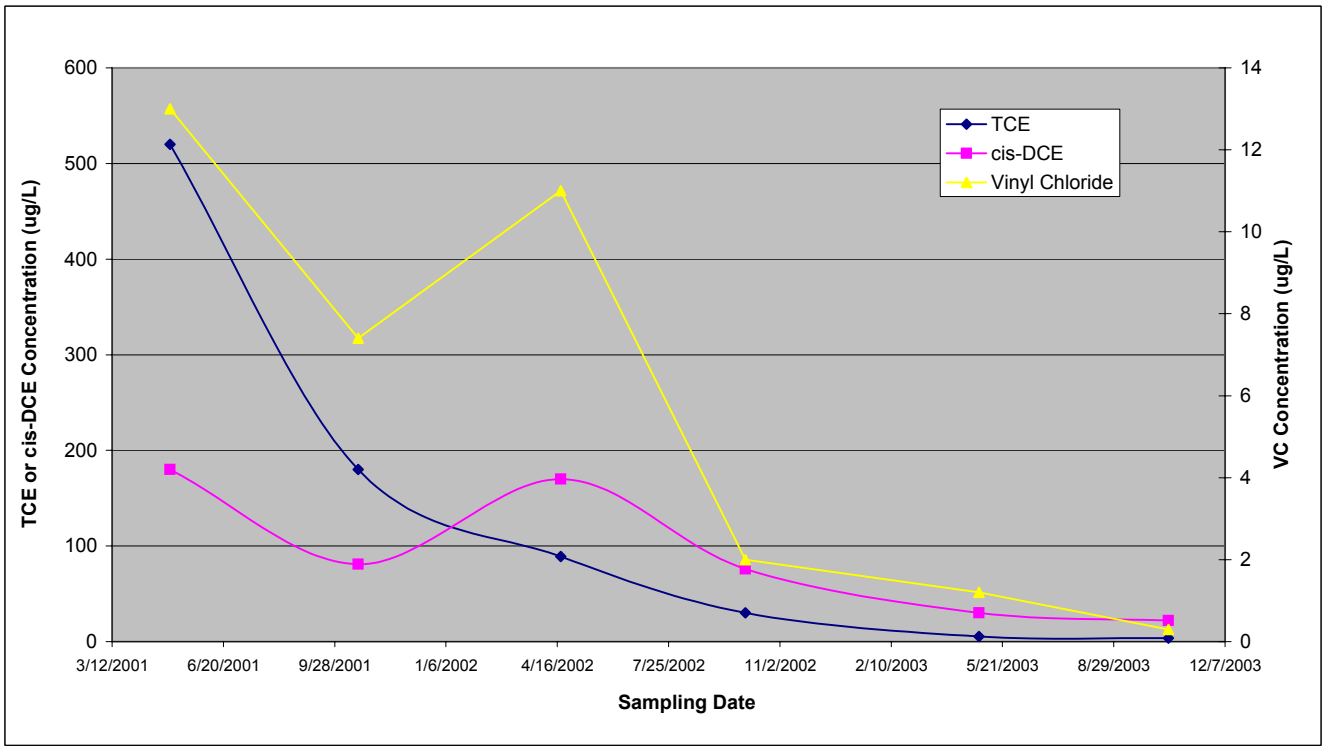




GROUNDWATER SERVICES, INC.

FIGURE 26
CHLORINATED CONSTITUENT CONCENTRATIONS IN GROUNDWATER IN MW-9S

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas



April 13, 2004

GROUNDWATER
SERVICES, INC.

APPENDICES

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

Appendix A	Representative Monitoring Well As-Built Diagrams and Logs and Well Specifications
Appendix B	Annual Potentiometric Surface Maps
Appendix C	Monitoring Data from All Sampling Events

April 13, 2004

GROUNDWATER
SERVICES, INC.

APPENDIX A

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

REPRESENTATIVE MONITORING WELL AS-BUILT DIAGRAMS AND LOGS AND WELL SPECIFICATIONS

GROUNDWATER SERVICES, INC

TABLE A-1
MONITORING WELL SPECIFICATIONS FOR MULCH WALL WELLS
Site B301

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Air Force Center for Environmental Excellence, Brooks AFB, TX

Well Specification	Well MW-45S	Well MW-46S	Well MW-47S	Well MW-48S	Well MW-49S	Well MW-50S	Well MW-51S	Well MW-52S	Well MW-53S
Upgradient/Downgradient/Within	up	up	down	down	up	down	down	up	down
Casing Diameter/Material:	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC
Screen Diameter/Material:	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC
Screen Slot Size (in):	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Top of Casing Elev. (ft MSL):	993	993.61	993.53	993.95	994.86	993.85	993.91	998.14	996.57
Well Depth (ft BGS):	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Screen Interval (ft BGS):	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0
Northing (ft)	554411.25	554360.55	554314.6	554276.89	554176.34	554178.63	554179.3	554073.29	554073.31
Easting (ft)	2984438.43	2984439.59	2984385.21	2984378.98	2984428.65	2984398.95	2984384.13	2984422.97	2984392.8

Notes:
1) Monitoring well locations are shown on Figure 4.
2) Well casing and screen diameters given above represent nominal pipe diameter dimensions.

GROUNDWATER SERVICES, INC

TABLE A-1
MONITORING WELL SPECIFICATIONS FOR MULCH WALL WELLS
Site B301

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater
Air Force Center for Environmental Excellence, Brooks AFB, TX

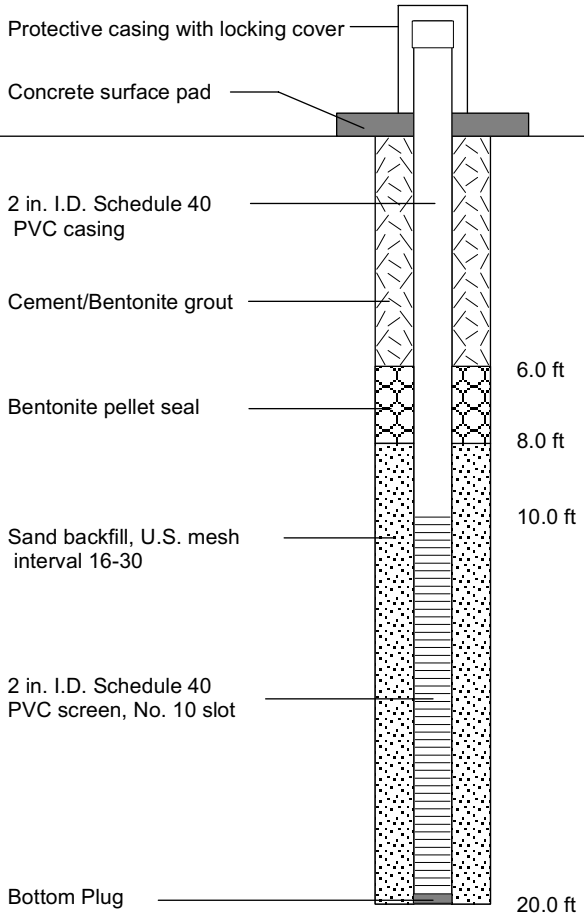
Well Specification	Well MW-54S	Well MW-55S	Well MW-56S	Well MW-57S	Well BW-1	Well BW-2	Well BW-3	Well BW-4	Well BW-5
Upgradient/Downgradient/Within	down	up	down	down	within	within	within	within	within
Casing Diameter/Material:	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC
Screen Diameter/Material:	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC	2"/PVC
Screen Slot Size (in):	0.010	0.010	----	----	0.020	0.020	0.020	0.020	0.020
Top of Casing Elev. (ft MSL):	996.13	999.86	998.47	998.16	993.13	993.44	994.1	997.62	999.57
Well Depth (ft BGS):	20.0	20.0	20.0	20.0	22.0	22.0	22.0	22.0	22.0
Screen Interval (ft BGS):	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0	10.0-20.0
Northing (ft)	554073.54	553989.78	553993.5	553995.81	554413.11	554275.4	554176.32	554071.15	553991.1
Easting (ft)	2984379.03	2984414.89	2984384.67	2984370.34	2984423.57	2984398.41	2984416.69	2984405.1	2984397.54

Notes:
1) Monitoring well locations are shown on Figure 4.
2) Well casing and screen diameters given above represent nominal pipe diameter dimensions.

GEOLOGIST: Mark Hampton
DRILLER: Professional Service Industries
DRILLING METHOD: Flight Auger
HOLE DIAMETER: 6.0-inches

COMPLETION DATE: November 12, 1998
TOP OF CASING ELEV: 993.18 ft MSL

SOIL DESCRIPTION	DEPTH IN FEET	WATER LEVEL	SAMPLE	BLOWS/FT	OVA (ppm)	WELL CONSTRUCTION
GROUND SURFACE	0					Protective casing with locking cover; Concrete surface pad
Grayish-brown clayey SILT (ML)	5	10/11/01				2 in. I.D. Schedule 40 PVC casing; Cement/Bentonite grout; 6.0 ft; Bentonite pellet seal; 8.0 ft; 10.0 ft; Sand backfill, U.S. mesh interval 16-30; 2 in. I.D. Schedule 40 PVC screen, No. 10 slot; Bottom Plug; 20.0 ft
Total Depth = 20.0 ft	10, 15, 20, 25, 30, 35					



Notes:
1. Groundwater seepage encountered at approximately 5 feet during drilling.
2. Water level elevations are approximate
3. Stratigraphy based on observation of drill cuttings

GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM
B301 - MW22S

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-1

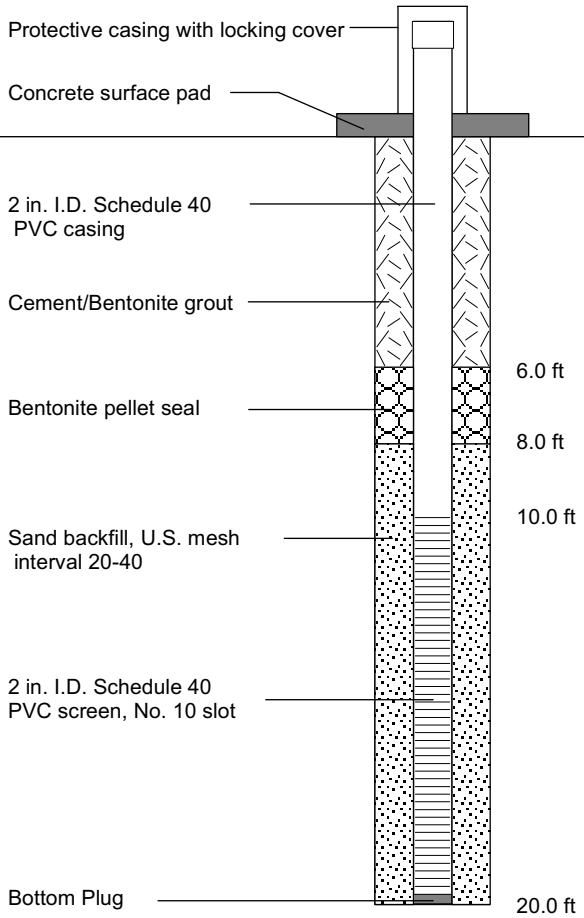
GEOLOGIST: Mark Hampton
DRILLER: Geotechnical Services, Inc.
DRILLING METHOD: Hollow-Stem Auger
HOLE DIAMETER: 8.25-inches

COMPLETION DATE: July 16, 2001
TOP OF CASING ELEV: 993.00 ft MSL

SOIL DESCRIPTION	DEPTH IN FEET	WATER LEVEL	SAMPLE	BLOWS/FT	OVA (ppm)
GROUND SURFACE	0				
Brown clayey, silty fine SAND (SM)					
	5	10/11/01 ▼			
Brown clayey SILT (ML)					
- becoming light brown below 9 ft.	10				
- gray below 17 ft.	15				
Total Depth = 20.0 ft	20				
	25				
	30				
	35				

Note:
Groundwater seepage encountered at approximately 8 feet during drilling.

WELL CONSTRUCTION



GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM
B301 - MW45S

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-2

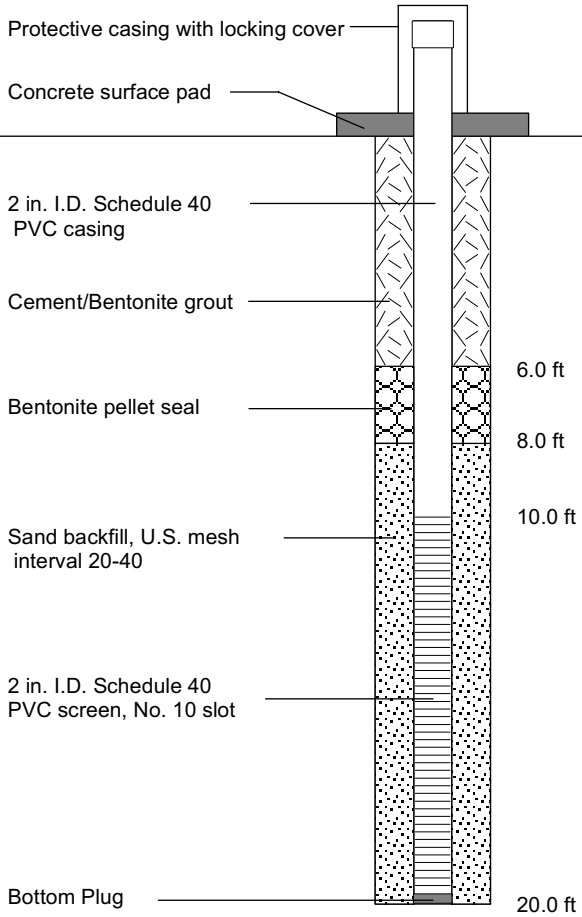
GEOLOGIST: Mark Hampton
DRILLER: Geotechnical Services, Inc.
DRILLING METHOD: Hollow-Stem Auger
HOLE DIAMETER: 8.25-inches

COMPLETION DATE: July 16, 2001
TOP OF CASING ELEV: 993.53 ft MSL

SOIL DESCRIPTION	DEPTH IN FEET	WATER LEVEL	SAMPLE	BLOWS/FT	OVA (ppm)
GROUND SURFACE	0				
Yellowish-orange clayey, silty fine SAND (SM)	5	10/11/01			
Dark gray clayey SILT (ML)	10				
- becoming light brown below 13 ft.	15				
Total Depth = 20.0 ft	20				
	25				
	30				
	35				

Note:
1. Groundwater seepage encountered at approximately 6 feet during drilling.

WELL CONSTRUCTION



GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM
B301 - MW47S

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-3

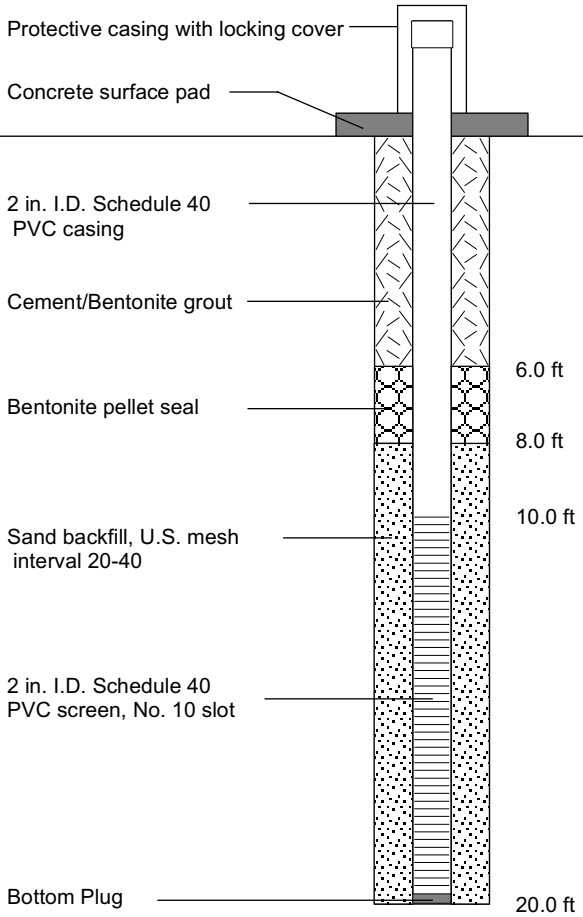
GEOLOGIST: Mark Hampton
DRILLER: Geotechnical Services, Inc.
DRILLING METHOD: Hollow-Stem Auger
HOLE DIAMETER: 8.25-inches

COMPLETION DATE: July 17, 2001
TOP OF CASING ELEV: 999.86 ft MSL

SOIL DESCRIPTION	DEPTH IN FEET	WATER LEVEL	SAMPLE	BLOWS/FT	OVA (ppm)
GROUND SURFACE	0				
Tan clayey, silty fine SAND (SM)					
	5	10/11/01			
- with less clay and coaser sand below 6 ft. - with clay seam at 7 ft.					
	10				
	15				
	20				
Total Depth = 20.0 ft					
	25				
	30				
	35				

Note:
Groundwater seepage encountered at approximately 6 feet during drilling.

WELL CONSTRUCTION



GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM
B301 - MW55S

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-4

GEOLOGIST: Mark Schipper
DRILLER: Geotechnical Services, Inc.
DRILLING METHOD: Flight Auger
HOLE DIAMETER: 6.0-inches

COMPLETION DATE: August 7, 2001
TOP OF CASING ELEV: 986.61 ft MSL

SOIL DESCRIPTION	DEPTH IN FEET	WATER LEVEL	SAMPLE	BLOWS/FT	OVA (ppm)	WELL CONSTRUCTION
GROUND SURFACE	0					Protective casing with locking cover; Concrete surface pad
Sand/mulch FILL	5	10/11/01				Cement/Bentonite grout; Bentonite pellet seal; 2 in. I.D. Schedule 40 PVC casing; Mulch/sand fill; 2 in. I.D. Schedule 40 PVC screen, No. 2 slot; Sump; Bottom Plug
	10					4.0 ft; 6.0 ft; 10.0 ft
	15					
	20					20.0 ft
Total Depth = 25.0 ft	25					
	30					
	35					

GROUNDWATER SERVICES, INC.

LOG & AS-BUILT DIAGRAM
MULCH WALL WELL BW-2

Site B301
Offutt Air Force Base, Nebraska

GSI Job No. G-2050
Page 1 of 1
Issued: 4/13/04

FIGURE A-5

April 13, 2004

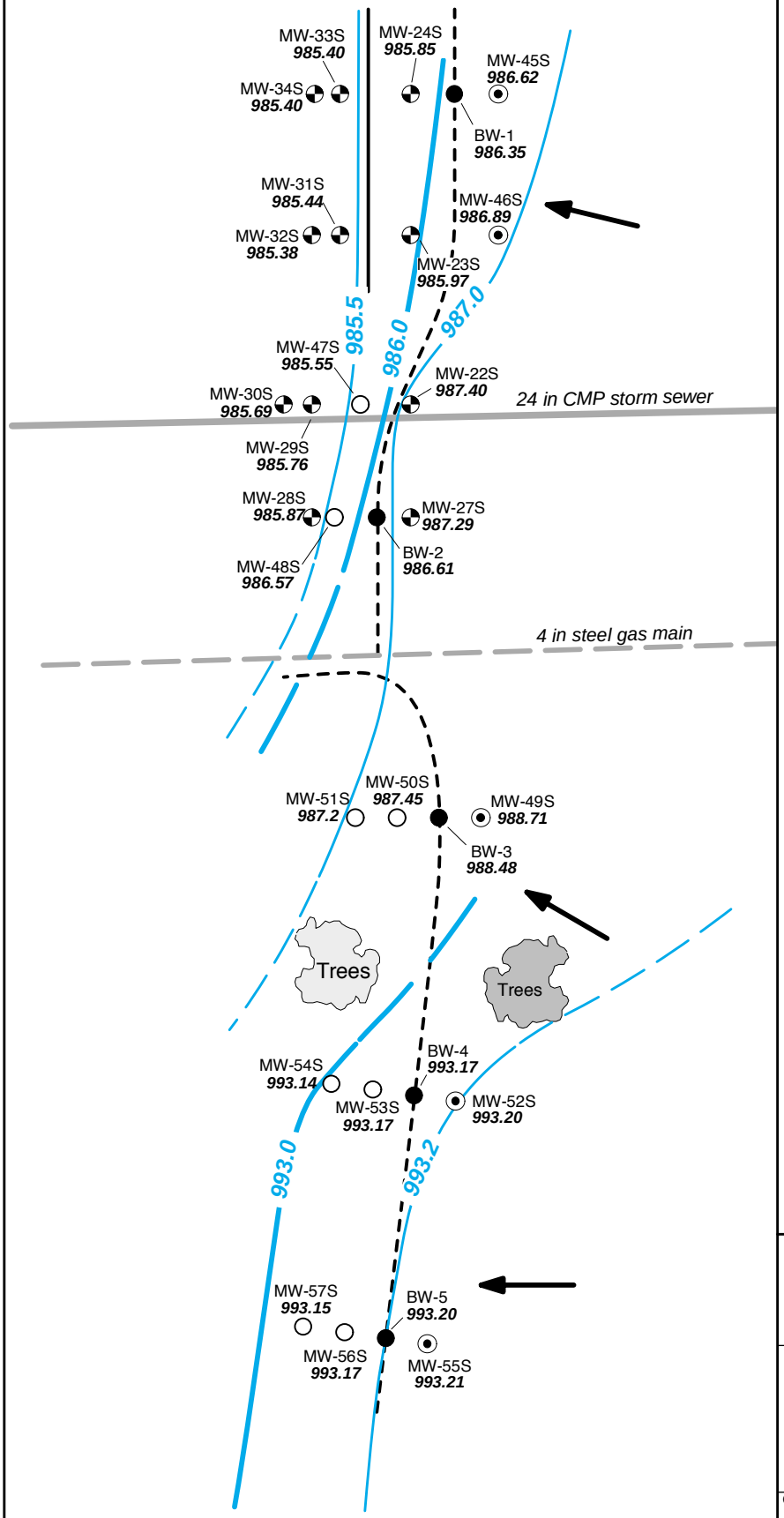
GROUNDWATER
SERVICES, INC.

APPENDIX B

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

ANNUAL POTENTIOMETRIC SURFACE MAPS



N

LEGEND

- Existing pilot scale-test monitoring well location
- New upgradient background monitoring well location
- New downgradient monitoring well location
- New mulch wall monitoring well location
- Existing pilot-scale mulch wall
- Full-scale mulch wall
- 995.0 — Potentiometric surface contour
- Inferred groundwater flow direction

SCALE (ft.)

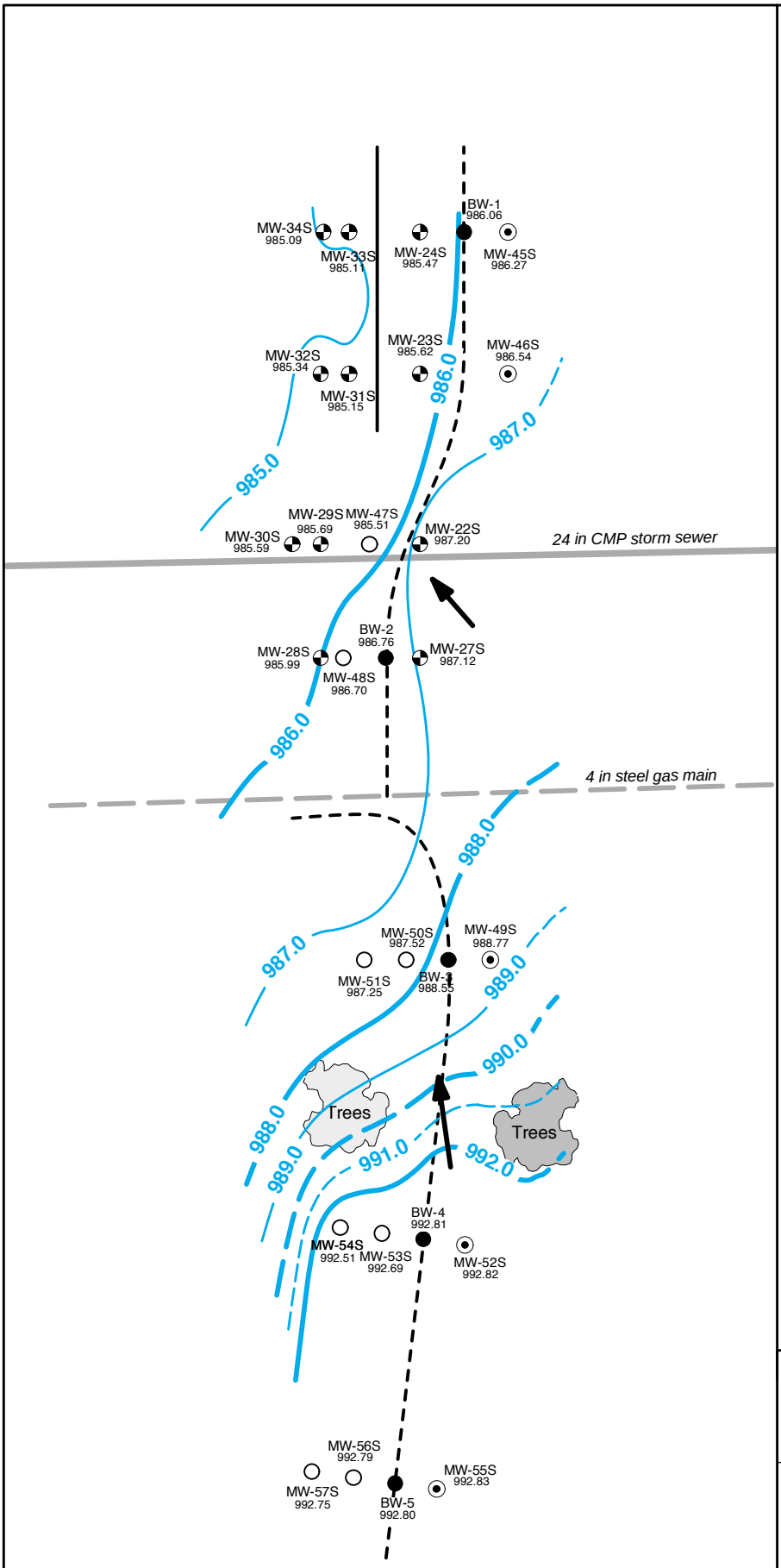
0 30 60

GROUNDWATER SERVICES, INC.

POTENTIOMETRIC SURFACE MAP for MULCH WALL: OCTOBER 11, 2001

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	DLB/CCJ
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE B-1**



N

LEGEND

- Existing pilot-scale test monitoring well location
- New upgradient background monitoring well location
- New downgradient monitoring well location
- New mulch wall monitoring well location
- Existing pilot-scale mulch wall
- Full-scale mulch wall
- 995.0 — Potentiometric surface contour
- Inferred groundwater flow direction

Contour Interval = 1.0 ft

SCALE (ft)

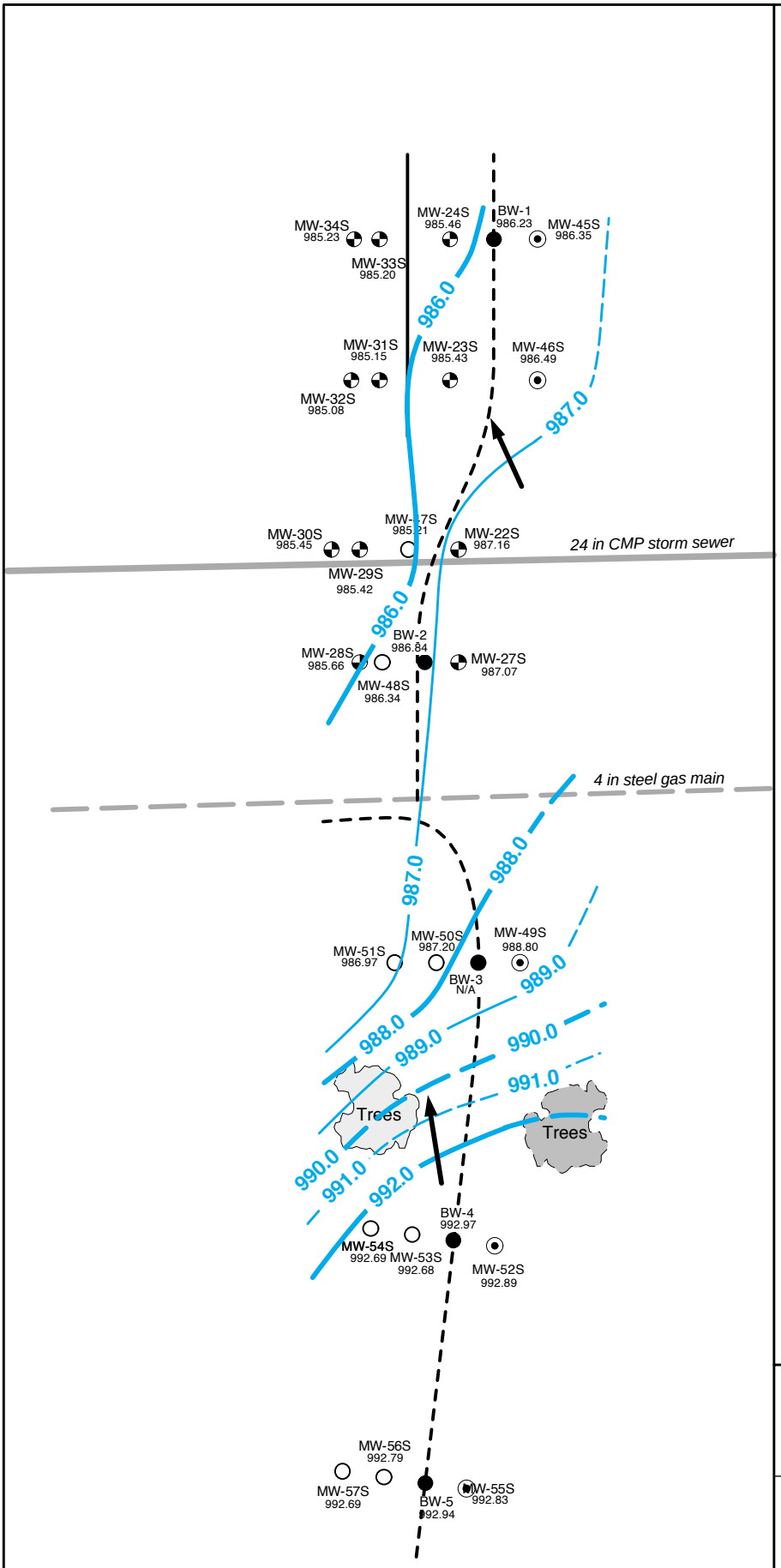
0 30 60

GROUNDWATER SERVICES, INC.

POTENTIOMETRIC SURFACE MAP FOR MULCH WALL: JULY 2, 2002

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS/DLB
Issued:	4/13/04	Chk'd By:	CEA
Revised:	———	Appv'd By:	CEA
Scale:	As Shown		**FIGURE B-2**



N

LEGEND

- Existing pilot-scale test monitoring well location
- New upgradient background monitoring well location
- New downgradient monitoring well location
- New mulch wall monitoring well location
- Existing pilot-scale mulch wall
- Full-scale mulch wall
- 995.0 — Potentiometric surface contour
- Inferred groundwater flow direction

Contour Interval = 1.0 ft

SCALE (ft)

0 30 60

GROUNDWATER SERVICES, INC.

POTENTIOMETRIC SURFACE MAP FOR MULCH WALL: JULY 31, 2003

Site B301
Offutt AFB, Nebraska

GSI Job No:	G-2050	Drawn By:	KVS/DLB
Issued:	4/13/04	Chk'd By:	CEA
Revised:	_____	Appv'd By:	CEA
Scale:	As Shown		**FIGURE B-3**

April 13, 2004

GROUNDWATER
SERVICES, INC.

APPENDIX C

FINAL REPORT FOR FULL-SCALE MULCH WALL TREATMENT OF CHLORINATED HYDROCARBON-IMPACTED GROUNDWATER

Building 301
Offutt Air Force Base, Nebraska

MONITORING DATA FROM ALL SAMPLING EVENTS

GROUNDWATER SERVICES, INC.

TABLE C-1
GROUNDWATER SAMPLING RESULTS: JULY 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS												
Date Sampled:		B301-MW22S 7/15/2001	B301-MW23S 7/15/2001	B301-MW24S 7/20/2001	B301-MW27S 7/20/2001	B301-MW28S 7/20/2001	B301-MW29S 7/20/2001	B301-MW31S 7/20/2001	B301-MW32S 7/20/2001	B301-MW33S 7/15/2001	B301-MW34S 7/14/2001	DUPLICATE B301-MW34SA 7/20/2001	B301-MW45S 7/20/2001	B301-MW46S 7/19/2001
Units														
Chlorinated Organics and Reduction By-Products														
PCE	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
TCE	mg/L	**0.67**	**0.34**	**0.29**	**0.16**	**0.14**	**0.2**	**0.0031**	**0.0078**	**0.58**	**0.4**	**0.4**	**0.46**	**1.1**
1,1-DCE	mg/L	**0.0025**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
cis-1,2-DCE	mg/L	**0.012**	**0.013**	**0.013**	**0.013**	**0.0029**	**0.0072**	**0.0083**	**0.028**	**0.036**	**0.023**	**0.021**	**0.014**	**0.0098**
trans-1,2-DCE	mg/L	**0.0028**	**0.0024**	**0.0019**	**0.011**	**0.0016**	**0.0021**	**0.004**	**0.0057**	**0.0019**	**0.002**	**0.0019**	<0.005	<0.005
Vinyl chloride	mg/L	<0.001	<0.001	<0.001	**0.0022**	<0.001	<0.001	**0.0016**	**0.0047**	<0.001	<0.001	<0.001	<0.005	<0.005
Ethene	ng/L	**13**	**27**	**18**	**79**	**25**	**36**	**77**	**67**	**25**	**36**	**38**	**31**	**17**
Ethane	ng/L	**7.0**	**6.0**	<5.0	**34**	**25**	**69**	**14000**	**14000**	**160**	**500**	**500**	**12**	**6.0**
cDCE/TCE ratio		**0.02**	**0.04**	**0.04**	**0.08**	**0.02**	**0.04**	**2.68**	**3.59**	**0.06**	**0.06**	**0.05**	**0.03**	**0.01**
Water Quality Parameters														
Temperature	°C	**14.3**	**14.7**	**14.7**	**14.9**	**14.8**	**14.2**	**13.6**	**14.5**	**13.8**	**13.4**	-	**15**	**15.6**
pH	pH units	**6.53**	**6.45**	**6.46**	**6.71**	**6.68**	**6.64**	**6.40**	**6.39**	**6.55**	**6.5**	**-**	**6.54**	**6.54**
Specific conductance	mS/cm	**0.599**	**0.600**	**0.603**	**0.604**	**0.598**	**0.583**	**0.022**	**0.631**	**0.584**	**0.582**	-	**0.619**	**0.616**
Total organic carbon	mg/L	**1.28**	**6.16**	**11.8**	<1	**2.31**	<1	**1.27**	<1	<1	<1	<1	<1	**1.49**
Chloride	mg/L	**14**	**19**	**20**	**7.7**	**8**	**8.3**	**22**	**22**	**21**	**20**	**21**	**17**	**13**
Natural Attenuation Parameters														
Dissolved oxygen	mg/L	**0.69**	**0.22**	**0.24**	**0.22**	**0.23**	**1.13**	**0.42**	**0.49**	**0.75**	**1.08**	-	**0.40**	**1.33**
Redox potential	mV	**232.3**	**255.3**	**238.6**	**221.9**	**259.3**	**174.5**	**84.3**	**110.8**	**266.4**	**313.8**	-	**98.5**	**240.4**
Sulfate	mg/L	**40**	**35**	**34**	**30**	**34**	**37**	**20**	**21**	**31**	**28**	**29**	**41**	**47**
Nitrate	mg/L	**4.11**	**2.58**	<0.1	**0.966**	**1.28**	**1.4**	<0.1	**1.04**	**2.35**	**1.96**	**2.07**	**3.37**	**4.3**
Ferrous Iron	mg/L	**0.573**	**0.104**	**0.0255**	**0.446**	**0.0316**	**0.0778**	**0.218**	**0.448**	<0.02	<0.02	<0.02	**0.34**	**0.133**
Methane	ug/L	**0.58**	**1.1**	**1.6**	**52**	**14**	**9.8**	**1600**	**670**	**41**	**130**	**140**	**0.48**	**0.11**
Alkalinity	mg/L	**312**	**322**	**322**	**352**	**352**	**322**	**352**	**372**	**312**	**332**	**312**	**326**	**326**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-1
GROUNDWATER SAMPLING RESULTS: JULY 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS											
										DUPLICATE		DUPLICATE	
Date Sampled:		B301-MW47S 7/20/2001	B301-MW48S 7/20/2001	B301-MW50S 7/20/2001	B301-MW51S 7/20/2001	B301-MW52S 7/20/2001	B301-MW53S 7/20/2001	B301-MW54S 7/20/2001	B301-MW55S 7/20/2001	B301-MW55SA 7/20/2001	B301-MW56S 7/20/2001	B-301-MW56SA 7/20/2001	B301-MW57S 7/20/2001
Units													
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	<0.005	**0.001**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TCE	mg/L	**0.38**	**0.21**	**0.012**	**0.0067**	**0.0036**	**0.068**	**0.055**	**0.0021**	**0.0027**	**0.001**	**0.0011**	**0.0017**
1,1-DCE	mg/L	<0.005	**0.007**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.016**	**0.0041**	**0.0033**	**0.007**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,2-DCE	mg/L	<0.005	**0.0023**	**0.0067**	**0.015**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	**46**	**140**	**430**	**92**	**110**	**36**	**16**	**62**	**56**	**66**	**76**	**30.0**
Ethane	ng/L	**18**	**42**	**48**	**42**	**44**	**34**	<5.0	**15**	**14**	**14**	**14**	<5.0
cDCE/TCE ratio		**0.04**	**0.02**	**0.28**	**1.04**	**0.14**	**0.01**	**0.01**	**0.24**	**0.19**	**0.50**	**0.45**	**0.29**
Water Quality Parameters													
Temperature	°C	**15.0**	**17.4**	**19.2**	**18.4**	**15.3**	**16.8**	**17.4**	**14.8**	-	**14.8**	-	**15.7**
pH	pH units	**6.66**	**6.67**	**6.51**	**6.69**	**6.78**	**6.81**	**6.83**	**6.78**	-	**6.82**	-	**6.77**
Specific conductance	mS/cm	**0.611**	**0.663**	**0.739**	**0.592**	**0.569**	**0.571**	**0.579**	**0.592**	-	**0.584**	-	**0.577**
Total organic carbon	mg/L	**4.73**	**7.7**	**94.9**	**1.61**	**1.66**	<1	**1.18**	**1.67**	**1.38**	**1.2**	**1.14**	<1
Chloride	mg/L	**16**	**10**	**12**	**7.7**	**13**	**9.3**	**10**	**23**	**22**	**15**	**15**	**13**
Natural Attenuation Parameters													
Dissolved oxygen	mg/L	**1.20**	**0.94**	**1.82**	**1.09**	**2.67**	**10.47**	**3.93**	**5.14**	-	**3.95**	-	**3.97**
Redox potential	mV	**199.9**	**10.1**	**-86.0**	**-102.2**	**195.8**	**177.8**	**166.9**	**193.0**	-	**186.5**	-	**186.2**
Sulfate	mg/L	**39**	**37**	**32**	**20**	**31**	**22**	**24**	**29**	**28**	**27**	**25**	**24**
Nitrate	mg/L	**1.37**	<0.1	<0.1	<0.1	**1.57**	**1.97**	**1.72**	**2.24**	**2.26**	**2.45**	**2.48**	**2.69**
Ferrous Iron	mg/L	**0.362**	**0.286**	**3.4**	**2.13**	**0.172**	<0.02	**0.635**	**0.0349**	**0.0226**	**0.031**	**0.036**	**0.201**
Methane	ug/L	**2.0**	**17**	**110**	**62**	**0.96**	**2.1**	**0.75**	**0.38**	**0.38**	**0.35**	**0.35**	**0.18**
Alkalinity	mg/L	**342**	**372**	**472**	**362**	**342**	**342**	**328**	**322**	**322**	**332**	**328**	**322**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-1
GROUNDWATER SAMPLING RESULTS: JULY 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		MULCH WALL MONITORING WELLS					
Date Sampled:		B301-BW1 8/10/2001	B301-BW2 8/10/2001	B301-BW3 8/10/2001	B301-BW4 8/10/2001	B301-BW5 8/10/2001	DUPLICATE B301-BW5A 8/10/2001
Units							
Chlorinated Organics and Reduction By-Products							
PCE	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TCE	mg/L	**0.71**	**0.18**	**0.018**	**0.012**	<0.001	<0.001
1,1-DCE	mg/L	**0.0027**	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.038**	**0.072**	**0.009**	<0.001	<0.001	<0.001
trans-1,2-DCE	mg/L	**0.0031**	**0.0011**	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	**21**	**220**	**130**	**46**	**630**	**460**
Ethane	ng/L	<5.0	<5.0	<5.0	<5.0	**26**	**16**
cDCE/TCE ratio		**0.001**	**0.003**	**0.03**	**0.04**	-	-
Water Quality Parameters							
Temperature	°C	**17.7**	**20.1**	**22.8**	**18.1**	**20**	-
pH	pH units	**6.18**	**6.43**	**6.4**	**5.76**	**5.34**	-
Specific conductance	mS/cm	**0.447**	**0.449**	**0.474**	**0.645**	**1.87**	-
Total organic carbon	mg/L	**2.84**	**6.29**	**37.9**	**266**	**1130**	**1130**
Chloride	mg/L	**13**	**6.3**	**6.6**	**9.8**	**35**	**34**
Natural Attenuation Parameters							
Dissolved oxygen	mg/L	**0.61**	**1.11**	**1.21**	**0.46**	**0.88**	-
Redox potential	mV	**155.4**	**218.1**	**173.8**	**0.1**	**15.4**	-
Sulfate	mg/L	**42**	**17**	**14**	**15**	**18**	**14**
Nitrate	mg/L	**2.93**	<0.1	<0.1	**0.616**	<0.1	<0.1
Ferrous Iron	mg/L	**0.133**	**0.933**	**3.82**	**6.57**	**32.7**	**29.8**
Methane	ug/L	**4.2**	**20**	**180**	**34**	**460**	**350**
Alkalinity	mg/L	**322**	**402**	**412**	**563**	**1060**	**1050**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-2
GROUNDWATER SAMPLING RESULTS: OCTOBER 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS										
						DUPLICATE						
Date Sampled:		B301-MW22S 10/31/2001	B301-MW23S 10/30/2001	B301-MW24S 10/30/2001	B301-MW27S 10/31/2001	B301-MW27S 10/31/2001	B301-MW45S 10/30/2001	B301-MW46S 10/30/2001	B301-MW47S 10/31/2001	B301-MW48S 10/31/2001	B301-MW49S 10/31/2001	B301-MW50S 10/31/2001
Units												
Chlorinated Organics and Reduction By-Products												
PCE	mg/L	**0.011 J**	**0.0003 J**	**0.002 J**	**0.002 J**	**0.004 J**	**0.011 J**	**0.011 J**	**0.001 J**	**0.002 J**	**0.0003 J**	<0.001
TCE	mg/L	**0.58**	**0.074**	**0.058**	**0.12**	**0.12**	**0.77**	**0.79**	**0.017**	**0.014**	**0.021**	**0.001**
1,1-DCE	mg/L	**0.017 J**	**0.004 J**	**0.004 J**	**0.0006 J**	**0.0006 J**	**0.018 J**	**0.019 J**	**0.0008 J**	**0.0006 J**	**0.0003 J**	<0.001
cis-1,2-DCE	mg/L	**0.018 J**	**0.35**	**0.12**	**0.004 J**	**0.007 J**	**0.022 J**	**0.033 J**	**0.2**	**0.1**	**0.013**	**0.017**
trans-1,2-DCE	mg/L	**0.016 J**	**0.008**	**0.009**	**0.003 J**	**0.006 J**	**0.001**	**0.001**	**0.003 J**	**0.004 J**	**0.012**	**0.007**
Vinyl chloride	mg/L	<0.001	**0.034**	**0.031**	**0.0003 J**	**0.0003 J**	<0.001	**0.016 J**	**0.013**	**0.015**	**0.0003 J**	**0.006**
cDCE/TCE ratio		**0.03**	**4.73**	**2.07**	**0.03**	**0.06**	**0.03**	**0.04**	**11.76**	**7.14**	**0.62**	**17.00**
Water Quality Parameters												
Temperature	°C	**16.22**	**15.34**	**16.70**	**16.57**	-	**16.23**	**17.09**	**16.28**	**17.30**	**15.20**	**15.60**
pH	pH units	**6.80**	**6.55**	**6.44**	**6.94**	-	**6.67**	**6.73**	**6.82**	**6.88**	**6.95**	**6.85**
Specific conductance	mS/cm	**0.59**	**0.71**	**0.77**	**0.60**	-	**0.63**	**0.61**	**0.66**	**0.71**	**0.58**	**0.84**
Natural Attenuation Parameters												
Alkalinity	mg/L	**458**	**574**	**640**	**480**	-	**470**	**518**	**580**	**608**	**488**	**642**
Dissolved oxygen	mg/L	**0.35**	**0.59**	**0.60**	**0.30**	-	**0.54**	**0.63**	**0.37**	**0.32**	**0.27**	**0.34**
Ferrous Iron	mg/L	**0.16**	**0.15**	**0.34**	**0.16**	-	**0.11**	**0.09**	**0.08**	**0.42**	**2.41**	**2.55**
Redox potential	mV	**177**	**162**	**2**	**258**	-	**182**	**130**	**102**	**-31**	**-72**	**-138**
Turbidity	NTU	**9**	**4**	**8**	**10**	-	**9**	**7**	**10**	**7**	**4**	**7**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-2
GROUNDWATER SAMPLING RESULTS: OCTOBER 2001

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS					MULCH WALL MONITORING WELLS				
		DUPLICATE									
		B301-MW50S	B301-MW52S	B301-MW53S	B301-MW55S	B301-MW56S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
Date Sampled:		10/31/2001	11/1/2001	11/1/2001	11/1/2001	11/1/2001	10/30/2001	10/31/2001	10/31/2001	11/1/2001	11/1/2001
Units											
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	<0.001	<0.001	**0.002**	<0.001	<0.001	**0.002**	**0.0004 J**	**0.0002 J**	**0.0004 J**	<0.02
TCE	mg/L	**0.001 J**	**0.002**	**0.076**	**0.0003 J**	**0.0009 J**	**0.49**	**0.085**	**0.003**	**0.019**	<0.02
1,1-DCE	mg/L	**0.0003 J**	<0.001	**0.0005 J**	<0.001	<0.001	**0.004 J**	**0.0004 J**	<0.001	**0.0004 J**	<0.02
cis-1,2-DCE	mg/L	**0.017**	<0.001	**0.0003 J**	<0.001	**0.0004 J**	**0.21**	**0.035**	**0.024**	**0.009**	<0.02
trans-1,2-DCE	mg/L	**0.006**	<0.001	<0.001	<0.001	**0.0003 J**	**0.004 J**	**0.0008 J**	**0.001**	<0.001	<0.02
Vinyl chloride	mg/L	**0.005**	<0.001	<0.001	<0.001	<0.001	**0.013**	**0.003**	**0.003**	<0.001	<0.02
cDCE/TCE ratio		**17.00**	-	-	-	**0.44**	**0.43**	**0.41**	**8.00**	**0.47**	-
Water Quality Parameters											
Temperature	°C	-	**16.40**	**15.15**	**16.24**	**15.54**	**16.05**	**18.75**	**15.25**	**16.28**	**16.73**
pH	pH units	-	**7.09**	**7.06**	**7.09**	**7.09**	**6.53**	**6.78**	**6.58**	**6.66**	**6.49**
Specific conductance	mS/cm	-	**0.60**	**0.59**	**0.72**	**0.60**	**0.65**	**0.64**	**0.95**	**0.70**	**3.01**
Natural Attenuation Parameters											
Alkalinity	mg/L	-	**486**	**462**	**514**	**478**	**506**	**612**	**672**	**574**	**2418**
Dissolved oxygen	mg/L	-	**1.72**	**5.30**	**4.01**	**4.73**	**0.48**	**0.35**	**0.34**	**0.59**	**0.57**
Ferrous Iron	mg/L	-	**0.13**	**0.13**	**0.05**	**0.10**	**0.98**	**6.15**	**5.00**	**3.18**	**30.75**
Redox potential	mV	-	**164**	**194**	**263**	**91**	**-64**	**-95**	**-151**	**-7**	**-120**
Turbidity	NTU	-	**5**	**7**	**5**	**7**	**9**	**8**	**7**	**3**	**23**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-3
GROUNDWATER SAMPLING RESULTS: JANUARY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS											
Date Sampled:		B301-MW22S 1/23/2002	B301-MW23S 1/23/2002	B301-MW24S 1/23/2002	B301-MW27S 1/24/2002	B301-MW28S 1/25/2002	B301-MW29S 1/24/2002	B301-MW31S 1/29/2002	B301-MW32S 1/29/2002	B301-MW33S 1/29/2002	B301-MW34S 1/29/2002	B301-MW45S 1/23/2002	B301-MW46S 1/23/2002
Units													
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	**0.00075 J**	<0.001	**0.00013 J**	<0.001	<0.001	<0.001	**0.00036 J**	**0.00011 J**	**0.00035 J**	**0.00098 J**	**0.0015**	**0.0018**
TCE	mg/L	**0.25**	**0.026**	**0.021**	**0.043**	**0.029**	**0.0075**	**0.00027 J**	**0.0084**	**0.1**	**0.061**	**0.54**	**0.64**
1,1-DCE	mg/L	**0.00089 J**	**0.00036 J**	<0.001	<0.001	<0.001	<0.001	<0.001	**0.00045 J**	**0.00056 J**	**0.00061 J**	**0.0053**	**0.0046**
cis-1,2-DCE	mg/L	**0.0034**	**0.073**	**0.0094**	<0.001	**0.011**	**0.021**	**0.0024**	**0.11**	**0.11**	**0.072**	**0.005**	**0.0039**
trans-1,2-DCE	mg/L	**0.00073 J**	**0.0055**	**0.006**	<0.001	<0.001	**0.0011**	**0.0045**	**0.0036**	**0.0059**	**0.0058**	**0.0011**	**0.00098 J**
Vinyl chloride	mg/L	<0.001	**0.0096**	**0.0028**	<0.001	**0.0017**	**0.0022**	**0.00028 J**	**0.006**	**0.0048**	**0.0036**	<0.001	<0.001
Ethene	ng/L	**14**	**79**	**1300**	**6.9**	**120.00 J**	**6.9**	-	-	-	-	**9.5**	**13**
Ethane	ng/L	**12**	**2600**	**15000**	<5	<5	**400**	-	-	-	-	**22**	**9**
cDCE/TCE ratio		**0.01**	**2.81**	**0.45**	-	**0.38**	**2.80**	**8.89**	**13.10**	**1.10**	**1.18**	**0.01**	**0.01**
Water Quality Parameters													
Temperature	°C	**13.35**	**13.02**	**12.40**	**10.72**	**10.60**	**13.12**	**11.52**	**11.66**	**11.69**	**11.03**	**12.70**	**13.16**
pH	pH units	**6.53**	**6.33**	**6.27**	**6.66**	**6.63**	**6.53**	**6.32**	**6.38**	**6.35**	**6.31**	**6.49**	**6.5**
Specific conductance	mS/cm	**0.467**	**0.550**	**0.593**	**0.478**	**0.487**	**0.554**	**0.648**	**0.597**	**0.608**	**0.592**	**0.478**	**0.486**
Total organic carbon	mg/L	**2.8**	**1.8**	**2.6**	**1.5**	**1.9**	**1.8**	-	-	-	-	**1.6**	**2.6**
Chloride	mg/L	**7.3**	**9.6**	**11**	**6.1**	**6.1**	**6.5**	-	-	-	-	**9**	**8.9**
Natural Attenuation Parameters													
Alkalinity	mg/L	**440**	**546**	**660**	**480**	**452**	**580**	**746**	**602**	**660**	**642**	**452**	**464**
Dissolved oxygen	mg/L	**0.51**	**0.55**	**0.56**	**0.81**	**0.44**	**0.43**	**0.77**	**0.59**	**0.55**	**0.51**	**1.08**	**0.50**
Ferrous Iron	mg/L	**2.90**	**0.25**	**2.15**	**0.32**	**1.23**	**0.79**	**0.62**	**0.42**	**0.33**	**0.35**	**1.20**	**0.64**
Nitrate	mg/L	**1.7**	<0.1	<0.1	**1.5**	**0.85**	<0.1	-	-	-	-	**2.7**	**2.5**
Sulfate	mg/L	**24**	**25**	**6.6**	**21**	**17**	**10**	-	-	-	-	**27**	**26**
Redox potential	mV	**285**	**241**	**112**	**327**	**314**	**291**	**319**	**302**	**327**	**322**	**153**	**189**
Turbidity	NTU	**7**	**9**	**7**	**3**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**7**
Hydrogen	nM	**1.2**	**1.2**	**1.1**	**0.9**	**1**	**1.3**	-	-	-	-	**1.5**	**1.1**
Methane	ug/L	**3.7**	**3500**	**4300**	**0.46**	**22**	**3700**	-	-	-	-	**2.1**	**0.66**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-3
GROUNDWATER SAMPLING RESULTS: JANUARY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS											
					DUPLICATE		DUPLICATE						
Date Sampled:		B301-MW47S 1/24/2002	B301-MW48S 1/24/2002	B301-MW49S 1/25/2002	B301-MW49S 1/25/2002	B301-MW50S 1/25/2002	B301-MW50S 1/25/2002	B301-MW51S 1/25/2002	B301-MW52S 1/26/2002	B301-MW53S 1/26/2002	B301-MW54S 1/26/2002	B301-MW55S 1/26/2002	B301-MW56S 1/29/2002
Units													
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	<0.001	<0.001	**0.00016 J**	**0.00037 J**	<0.001	<0.001	<0.001	<0.001	**0.0022**	**0.0015**	**0.00019 J**	**0.00028 J**
TCE	mg/L	**0.0022**	**0.014**	**0.012**	**0.017**	**0.00039 J**	**0.00054 J**	**0.0013**	**0.0057**	**0.09**	**0.081**	<0.001	**0.001**
1,1-DCE	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.0007 J**	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.0044**	**0.011**	**0.011**	**0.011**	**0.0028**	**0.0031**	**0.008**	<0.001	<0.001	**0.00013 J**	<0.001	<0.001
trans-1,2-DCE	mg/L	<0.001	<0.001	**0.0091**	**0.0091**	**0.0063**	**0.0062**	**0.016**	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	**0.0037**	<0.001	<0.001	**0.0096**	**0.013**	**0.00092 J**	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	<5	**100**	**10**	**11**	**53**	**46**	**66**	**18**	**21**	**13**	**18**	-
Ethane	ng/L	**260**	**18**	<5	<5	<5	<5	**120**	<5	<5	<5	<5	-
cDCE/TCE ratio		**2.00**	**0.79**	**0.92**	**0.65**	**7.18**	**5.74**	**6.15**	-	-	**0.00**	-	-
Water Quality Parameters													
Temperature	°C	**12.24**	**10.24**	**11.63**	-	**11.69**	-	**11.29**	**11.93**	**13.57**	**12.97**	**13.09**	**11.27**
pH	pH units	**6.56**	**6.58**	**6.62**	-	**6.54**	-	**6.67**	**6.79**	**6.75**	**6.77**	**6.76**	**6.79**
Specific conductance	mS/cm	**0.489**	**0.499**	**0.464**	-	**0.623**	-	**0.475**	**0.495**	**0.482**	**0.476**	**0.668**	**0.493**
Total organic carbon	mg/L	**1.6**	**1.6**	**1.8**	**2**	**3.5**	**3.7**	**1.8**	<1	<1	<1	<1	<1
Chloride	mg/L	**6.3**	**6.3**	**5.8**	**5.9**	**6.7**	-	**6.9**	**8.9**	**8**	**8.8**	**32**	**13**
Natural Attenuation Parameters													
Alkalinity	mg/L	**502**	**526**	**496**	-	**616**	-	**498**	**546**	**478**	**466**	**456**	**488**
Dissolved oxygen	mg/L	**0.51**	**0.40**	**0.50**	-	**0.43**	-	**0.37**	**3.31**	**6.44**	**6.56**	**2.05**	**4.25**
Ferrous Iron	mg/L	**0.76**	**0.74**	**2.00**	-	**10.65**	-	**2.90**	**1.30**	**0.12**	**0.81**	**0.09**	**0.27**
Nitrate	mg/L	<0.1	<0.1	**0.58**	**0.57**	**0.51**	-	<0.1	**2.2**	**2.5**	**2.2**	**0.74**	**2.4**
Sulfate	mg/L	**9.1**	**11**	**17**	**17**	**14**	-	**14**	**23**	**19**	**20**	**110**	**19**
Redox potential	mV	**287**	**-8**	**93**	-	**-121**	-	**-55**	**301**	**221**	**300**	**287**	**350**
Turbidity	NTU	**3**	**3**	**3**	-	**3**	-	**3**	**3**	**3**	**4**	**4**	**3**
Hydrogen	nM	**0.92**	**0.73**	**3.5**	**2.4**	**0.86**	**0.83**	**0.75**	**0.92**	**0.98**	**1**	**1**	-
Methane	ug/L	**1800**	**680**	**95**	**99**	**3800**	**3800**	**76**	**0.07**	**12**	**0.47**	**0.17**	-

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-3
GROUNDWATER SAMPLING RESULTS: JANUARY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

			MULCH WALL MONITORING WELLS				
Date Sampled:		B301-MW57S 1/29/2002	B301-BW1 1/23/2002	B301-BW2 1/24/2002	B301-BW3 1/25/2002	B301-BW4 1/26/2002	B301-BW5 1/26/2002
Units							
Chlorinated Organics and Reduction By-Products							
PCE	mg/L	**0.0003 J**	**0.0013**	<0.001	**0.0002 J**	**0.00082 J**	<0.001
TCE	mg/L	**0.0013**	**0.48**	**0.028**	**0.0011**	**0.027**	<0.001
1,1-DCE	mg/L	<0.001	**0.0041**	<0.001	**0.0014**	**0.0026**	<0.001
cis-1,2-DCE	mg/L	<0.001	**0.051**	**0.0055**	**0.0095**	**0.018**	<0.001
trans-1,2-DCE	mg/L	<0.001	**0.0021**	<0.001	**0.00031 J**	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	**0.0079**	**0.001**	**0.0046**	**0.00047 J**	**0.00087 J**
Ethene	ng/L	-	**5200**	**890**	**53**	<5	**6.9**
Ethane	ng/L	-	**610**	**250**	<5	<5	<5
cDCE/TCE ratio		-	**0.11**	**0.20**	**8.64**	**0.67**	-
Water Quality Parameters							
Temperature	°C	**11.03**	**13.31**	**10.69**	**9.16**	**12.43**	**12.56**
pH	pH units	**6.77**	**6.38**	**6.42**	**6.24**	**6.32**	**6.33**
Specific conductance	mS/cm	**0.483**	**0.491**	**0.506**	**0.608**	**0.525**	**2.390**
Total organic carbon	mg/L	<1	**3.3**	**2.7**	**4.5**	**3.8**	**140**
Chloride	mg/L	**9.8**	**9.4**	**6.4**	**7.5**	**8.4**	**27**
Natural Attenuation Parameters							
Alkalinity	mg/L	**500**	**458**	**510**	**662**	**576**	**2502**
Dissolved oxygen	mg/L	**3.49**	**0.60**	**0.38**	**0.54**	**1.79**	**1.02**
Ferrous Iron	mg/L	**0.37**	**0.57**	**4.60**	**5.00**	**3.02**	**22.75**
Nitrate	mg/L	**2.3**	**1.5**	**0.86**	<0.1	**1.1**	**0.51**
Sulfate	mg/L	**19**	**22**	**16**	**29**	**9.9**	**7.6**
Redox potential	mV	**405**	**2**	**-72**	**-118**	**38**	**-116**
Turbidity	NTU	**3**	**3**	**10**	**3**	**3**	**21**
Hydrogen	nM	-	**0.83**	**1.3**	**1.4**	**1.2**	**1.2**
Methane	ug/L	-	**1700**	**7100**	**5100**	**2200**	**5400**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-4
GROUNDWATER SAMPLING RESULTS: APRIL 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS									
Date Sampled:		B301-MW22S 4/22/2002	B301-MW23S 4/22/2002	B301-MW24S 4/22/2002	B301-MW27S 4/22/2002	B301-MW28S 4/22/2002	B301-MW29S 4/22/2002	B301-MW45S 4/22/2002	B301-MW46S 4/22/2002	B301-MW47S 4/22/2002	B301-MW48S 4/22/2002
Units											
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.0012**	**0.00058 J**	< 0.001	**0.00083 J**	**0.00076 J**	**0.0002 J**	**0.0013**	**0.0016**	< 0.001	**0.00042 J**
TCE	mg/L	**0.320**	**0.045**	**0.029**	**0.044**	**0.034**	**0.009**	**1.000**	**0.530**	**0.0023**	**0.020**
1,1-DCE	mg/L	**0.0029**	**0.0011**	< 0.001	**0.00044 J**	< 0.001	< 0.001	**0.0036**	**0.0052**	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.0046**	**0.094**	**0.016**	**0.00066 J**	**0.0041**	**0.005**	**0.0087**	**0.0051**	**0.0027**	**0.0045**
trans-1,2-DCE	mg/L	**0.0013**	**0.0059**	**0.0056**	**0.00045 J**	**0.00021 J**	**0.00093 J**	**0.0027**	**0.0018**	**0.00053 J**	**0.00022 J**
Vinyl chloride	mg/L	**0.0015**	**0.025**	**0.0033**	< 0.001	**0.002**	**0.001**	< 0.001	**0.000098 J**	**0.00042 J**	**0.0023**
cDCE/TCE ratio		**0.01**	**2.09**	**0.55**	**0.02**	**0.12**	**0.56**	**0.01**	**0.01**	**1.17**	**0.23**
Water Quality Parameters											
Temperature	°C	**11.96**	**11.27**	**10.13**	**12.10**	**10.05**	**10.59**	**10.62**	**10.97**	**10.89**	**10.60**
pH	pH units	**6.87**	**6.68**	**6.63**	**6.96**	**6.86**	**6.83**	**6.81**	**6.84**	**6.85**	**6.85**
Specific conductance	mS/cm	**0.662**	**0.725**	**0.758**	**0.669**	**0.671**	**0.740**	**0.665**	**0.653**	**0.694**	**0.675**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.59**	**0.49**	**0.57**	**0.81**	**0.39**	**0.45**	**3.61**	**3.56**	**0.37**	**0.35**
Redox potential	mV	**294**	**278**	**266**	**285**	**161**	**300**	**274**	**308**	**177**	**74**
Ferrous Iron	mg/L	**0.45**	**0.56**	**0.66**	**0.49**	**0.52**	**0.94**	**0.26**	**1.12**	**1.18**	**0.97**
Turbidity	ntu	**5**	**3**	**2**	**70**	**5**	**17**	**10**	**50**	**12**	**21**
Alkalinity	mg/L	**574**	**576**	**732**	**582**	**548**	**560**	**756**	**486**	**616**	**540**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-4
GROUNDWATER SAMPLING RESULTS: APRIL 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS									
				DUPLICATE							
Date Sampled:		B301-MW49S 4/23/2002	B301-MW50S 4/23/2002	B301-MW50SA 4/23/2002	B301-MW51S 4/23/2002	B301-MW52S 4/23/2002	B301-MW53S 4/23/2002	B301-MW54S 4/23/2002	B301-MW55S 4/23/2002	B301-MW56S 4/23/2002	B301-MW57S 4/23/2002
Units											
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.00038 J**	< 0.001	< 0.001	< 0.001	< 0.001	**0.0016**	**0.0021**	< 0.001	< 0.001	< 0.001
TCE	mg/L	**0.017**	**0.00081 J**	**0.00074 J**	**0.0015**	**0.011**	**0.060**	**0.073**	**0.0001 J**	**0.0011**	**0.0013**
1,1-DCE	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.0002**	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.013**	**0.004**	**0.003**	**0.0087**	< 0.001	**0.00033 J**	< 0.001	< 0.001	< 0.001	< 0.001
trans-1,2-DCE	mg/L	**0.011**	**0.0095**	**0.0093**	**0.016**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Vinyl chloride	mg/L	< 0.001	**0.0071**	**0.0075**	**0.0012**	**0.000098**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cDCE/TCE ratio		**0.76**	**4.94**	**4.05**	**5.80**	**-**	**0.01**	**-**	**-**	**-**	**-**
Water Quality Parameters											
Temperature	°C	**12.86**	**11.07**	**-**	**10.48**	**11.52**	**13.40**	**14.71**	**11.78**	**13.92**	**13.18**
pH	pH units	**6.95**	**6.90**	**-**	**6.98**	**7.02**	**7**	**6.95**	**7.01**	**6.95**	**6.79**
Specific conductance	mS/cm	**0.643**	**0.780**	**-**	**0.666**	**0.675**	**0.655**	**0.659**	**0.734**	**0.674**	**0.667**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.39**	**0.35**	**-**	**0.34**	**3.90**	**5.13**	**4.67**	**6.05**	**3.56**	**2.09**
Redox potential	mV	**4**	**-111**	-	**-82**	**120**	**156**	**218**	**247**	**116**	**166**
Ferrous Iron	mg/L	**2.41**	**3.15**	**-**	**2.17**	**0.38**	**0.55**	**0.28**	**0.57**	**0.39**	**0.46**
Turbidity	ntu	**6**	**4**	**-**	**2**	**3**	**7**	**3**	**7**	**3**	**2**
Alkalinity	mg/L	**621**	**616**	**-**	**623**	**510**	**468**	**518**	**472**	**520**	**518**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-4
GROUNDWATER SAMPLING RESULTS: APRIL 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		MULCH WALL MONITORING WELLS				
Date Sampled:		B301-BW1 4/22/2002	B301-BW2 4/22/2002	B301-BW3 4/23/2002	B301-BW4 4/23/2002	B301-BW5 4/23/2002
Units						
Chlorinated Organics and Reduction By-Products						
PCE	mg/L	**0.0015**	**0.00028 J**	**0.00016 J**	**0.0008 J**	**0.00064 J**
TCE	mg/L	**0.49**	**0.017**	**0.0015**	**0.028**	**0.00011 J**
1,1-DCE	mg/L	**0.0044**	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.023**	**0.0039**	**0.013**	**0.0059**	< 0.001
trans-1,2-DCE	mg/L	**0.0026**	**0.00045 J**	**0.00061 J**	< 0.001	< 0.001
Vinyl chloride	mg/L	**0.0022**	**0.0011**	**0.00085 J**	**0.001**	< 0.001
cDCE/TCE ratio		**0.047**	**0.229**	**8.67**	**0.21**	**-**
Water Quality Parameters						
Temperature	°C	**11.23**	**12.38**	**12.15**	**12.89**	**12.99**
pH	pH units	**6.74**	**6.62**	**6.51**	**6.72**	**6.48**
Specific conductance	mS/cm	**0.654**	**0.711**	**0.792**	**0.687**	**3.337**
Natural Attenuation Parameters						
Dissolved oxygen	mg/L	**0.72**	**0.47**	**0.34**	**0.59**	**0.74**
Redox potential	mV	**231**	**-42**	**-75**	**63**	**-123**
Ferrous Iron	mg/L	**0.58**	**3.17**	**4.21**	**2.8**	**20.00**
Turbidity	ntu	**3**	**50**	**10**	**7**	**40**
Alkalinity	mg/L	**462**	**572**	**752**	**568**	**1321**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-5
GROUNDWATER SAMPLING RESULTS: JULY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS											
								DUPLICATE					
Date Sampled:		B301-MW22S 7/19/2002	B301-MW23S 7/19/2002	B301-MW24S 7/18/2002	B301-MW27S 7/22/2002	B301-MW28S 7/23/2002	B301-MW29S 7/22/2002	B301-MW29S 7/22/2002	B301-MW31S 7/25/2002	B301-MW32S 7/25/2002	B301-MW33S 7/25/2002	B301-MW34S 7/25/2002	B301-MW45S 7/18/2002
Units													
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	**0.00086 J**	**<0.001**	**<0.001**	**0.00097 J**	**<0.001**	<0.001	<0.001	<0.001	<0.001	<0.001	**0.00010 J**	**0.00096 J**
TCE	mg/L	**0.21**	**0.031**	**0.018**	**0.044**	**0.036**	**0.0089**	**0.009**	**0.00034 J**	**0.0013**	**0.096**	**0.200**	**0.49**
1,1-DCE	mg/L	**0.00099 J**	**0.00055 J**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.00027 J**	**0.00073 J**	**0.0029**
cis-1,2-DCE	mg/L	**0.003**	**0.068**	**0.019**	**0.00093 J**	**0.0028**	**0.0028**	**0.0027**	**0.0029**	**0.018**	**0.041**	**0.025**	**0.0084**
trans-1,2-DCE	mg/L	**0.00090 J**	**0.0085**	**0.0073**	**0.00039 J**	**0.00017 J**	**0.00069 J**	**0.00066 J**	**0.0058**	**0.0029**	**0.0056**	**0.0037**	**0.002**
Vinyl chloride	mg/L	<0.001	**0.027**	**0.0083**	<0.001	**0.00030 J**	**0.00041 J**	**0.00035 J**	**0.00018 J**	**0.00069 J**	**0.004**	**0.0033**	<0.001
Ethene	ng/L	**33**	**120**	**770**	**26**	**220**	**11**	**6**	-	-	-	**-**	**25**
Ethane	ng/L	**14**	**15000**	**43000**	**30**	**49**	**1000**	**1100**	-	-	-	**-**	**22**
cDCE/TCE ratio		**0.014**	**2.19**	**1.06**	**0.021**	**0.08**	**0.31**	**0.31**	**8.53**	**13.85**	**0.43**	**0.13**	**0.017**
Water Quality Parameters													
Temperature	°C	**18.23**	**14.16**	**16.06**	**16.90**	**17.07**	**14.52**	-	**14.11**	**14.80**	**13.77**	**14.05**	**14.71**
pH	pH units	**6.68**	**6.37**	**6.36**	**6.58**	**6.61**	**6.62**	-	**6.18**	**6.25**	**6.11**	**6.13**	**6.16**
Specific conductance	mS/cm	**0.620**	**0.690**	**0.660**	**0.630**	**0.620**	**0.710**	-	**0.770**	**0.750**	**0.680**	**0.660**	**0.600**
Total organic carbon	mg/L	<1	<1	<1	<1	<1	<1	<1	-	-	-	-	<1
Chloride	mg/L	**5.8**	**8.13**	**9.04**	**5.2**	**5**	**5.3**	**0.6**	-	-	-	-	**7.19**
Natural Attenuation Parameters													
Alkalinity	mg/L	**508**	**634**	**624**	**578**	**564**	**632**	-	**686**	**682**	**550**	**534**	**554**
Dissolved oxygen	mg/L	**0.44**	**0.30**	**0.47**	**0.32**	**0.45**	**0.39**	-	**0.35**	**0.35**	**0.32**	**0.33**	**0.44**
Ferrous Iron	mg/L	**0.22**	**0.29**	**0.86**	**0.47**	**0.66**	**0.52**	-	**2.74**	**2.30**	**0.31**	**0.28**	**0.29**
Nitrate	mg/L	**1.13**	<0.1	<0.1	**1.11**	**0.192**	<0.1	<0.1	-	-	-	-	**1.91**
Sulfate	mg/L	**23**	**19**	**9.6**	**20.5**	**18**	**8.6**	**8.7**	-	-	-	-	**9.6**
Redox potential	mV	**336**	**299**	**163**	**288**	**201**	**276**	-	**17**	**57**	**145**	**154**	**214**
Turbidity	NTU	**2**	**2**	**3**	**5**	**8**	**2**	-	**2**	**12**	**3**	**7**	**2**
Hydrogen	nM	**0.84**	**0.73**	**1**	**1.2**	**1**	**1.1**	-	-	-	-	**-**	**1.1**
Methane	ug/L	**4.6**	**6400**	**5400**	**2**	**190**	**3400**	-	-	-	-	-	**0.99**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-5
GROUNDWATER SAMPLING RESULTS: JULY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS											
						DUPLICATE							
Date Sampled:		B301-MW46S 7/18/2002	B301-MW47S 7/22/2002	B301-MW48S 7/22/2002	B301-MW49S 7/23/2002	B301-MW49S 7/23/2002	B301-MW50S 7/23/2002	B301-MW51S 7/23/2002	B301-MW52S 7/23/2002	B301-MW53S 7/24/2002	B301-MW54S 7/24/2002	B301-MW55S 7/24/2002	B301-MW56S 7/24/2002
Units													
Chlorinated Organics and Reduction By-Products													
PCE	mg/L	**0.00076 J**	<0.001	**0.00011 J**	**0.00063**	**0.0006**	**0.00016**	**0.00014**	**0.00025**	**0.0013**	**0.00079 J**	<0.001	<0.001
TCE	mg/L	**0.250**	**0.0011**	**0.017**	**0.015**	**0.015**	**0.00032 J**	**0.00083 J**	**0.005**	**0.073**	**0.056**	**0.00021 J**	**0.00073 J**
1,1-DCE	mg/L	**0.0012**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.0046**	**0.0022**	**0.0022**	**0.012**	**0.011**	**0.00220 J**	**0.00780 J**	<0.001	**0.00035 J**	**0.00016 J**	<0.001	<0.001
trans-1,2-DCE	mg/L	**0.0016**	**0.00040 J**	**0.00018 J**	**0.012**	**0.012**	**0.0088**	**0.016**	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	<0.001	**0.00056 J**	<0.001	<0.001	**0.0062**	**0.00070 J**	<0.001	**0.00013 J**	**0.00041 J**	<0.001	<0.001
Ethene	ng/L	**20**	**59**	**85**	**32**	**-**	**240**	**120**	**29**	**22**	**20**	**27**	**18**
Ethane	ng/L	**16**	**3000**	**1200**	**57**	**-**	**25**	**130**	**9**	**18**	**13**	**15**	**22**
cDCE/TCE ratio		**0.018**	**2.000**	**0.129**	**0.800**	**0.733**	**6.875**	**9.398**	**0.100**	**0.005**	**0.003**	**2.380**	**0.680**
Water Quality Parameters													
Temperature	°C	**15.15**	**15.84**	**16.83**	**15.56**	-	**16.48**	**15.92**	**18.37**	**20.78**	**15.00**	**18.10**	**15.10**
pH	pH units	**5.91**	**6.6**	**6.39**	**6.67**	**-**	**6.60**	**6.66**	**6.71**	**6.80**	**6.66**	**6.71**	**6.78**
Specific conductance	mS/cm	**0.61**	**0.660**	**0.640**	**0.600**	**-**	**0.730**	**0.620**	**0.610**	**0.610**	**0.610**	**0.650**	**0.640**
Total organic carbon	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	**34**	**39**	**33**	**48**
Chloride	mg/L	**5.94**	**5.4**	**5.3**	**4.7**	**-**	**0.7**	**5.8**	**7**	**8**	**8.5**	**13**	**11**
Natural Attenuation Parameters													
Alkalinity	mg/L	**504**	**554**	**562**	**504**	-	**630**	**558**	**562**	**582**	**502**	**484**	**514**
Dissolved oxygen	mg/L	**0.49**	**0.37**	**0.30**	**0.31**	**-**	**0.33**	**0.30**	**2.65**	**5.17**	**4.72**	**5.61**	**3.49**
Ferrous Iron	mg/L	**0.39**	**0.79**	**0.83**	**2.17**	**-**	**2.09**	**1.23**	**0.37**	**0.33**	**0.18**	**0.21**	**0.27**
Nitrate	mg/L	**1.25**	<0.1	<0.1	<0.1	**-**	<0.1	<0.1	**2.28**	**2.46**	**2.51**	**2.51**	**2.12**
Sulfate	mg/L	**24**	**6.4**	**9.5**	**17**	**-**	**16**	**16**	**22.8**	**20.3**	**20.9**	**23.6**	**28.8**
Redox potential	mV	**355**	**19**	**3**	**-169**	**-**	**-130**	**-71**	**5**	**231**	**200**	**172**	**258**
Turbidity	NTU	**2**	**2**	**2**	**7**	**-**	**3**	**8**	**3**	**3**	**7**	**2**	**4**
Hydrogen	nM	**1.1**	**1.3**	**1.5**	**1.7**	**-**	**1.6**	**1.5**	**1.5**	**1.6**	**1.3**	**2**	1.4
Methane	ug/L	**0.91**	**3900**	**2200**	**68**	**-**	**2300**	**96**	**0.76**	**0.06**	**0.2**	**0.3**	1

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-5
GROUNDWATER SAMPLING RESULTS: JULY 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

			MULCH WALL MONITORING WELLS					
							DUPLICATE	
		B301-MW57S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW4	B301-BW5
Date Sampled:		7/25/2002	7/18/2002	7/22/2002	7/23/2002	7/24/2002	7/24/2002	7/24/2002
Units								
Chlorinated Organics and Reduction By-Products								
PCE	mg/L	<0.001	**0.001**	**0.0017**	0.0100 J	<0.001	-	**0.00057 J**
TCE	mg/L	**0.0012**	**0.61**	**0.017**	**0.010**	**0.022**	-	<0.001
1,1-DCE	mg/L	<0.001	**0.0035**	**0.00088 J**	**0.010**	**0.002**	-	**0.0039**
cis-1,2-DCE	mg/L	<0.001	**0.093**	**0.0037**	**0.013**	**0.0053**	-	**0.00012 J**
trans-1,2-DCE	mg/L	<0.001	**0.004**	**0.00019 J**	**0.00150 J**	**0.00015 J**	-	**0.00032 J**
Vinyl chloride	mg/L	**0.00012 J**	**0.018**	**0.00088 J**	**0.010**	**0.004**	**-**	<0.001
Ethene	ng/L	**17**	**7000**	**470**	**36**	**39**	**43**	**29**
Ethane	ng/L	**8**	**1900**	**630**	**15**	5	5	**87**
cDCE/TCE ratio		**0.42**	**0.15**	**0.22**	**1.30**	**0.24**	**-**	**0.12**
Water Quality Parameters								
Temperature	°C	**15.90**	**15.13**	**24.80**	**19.51**	**16.30**	**-**	**16.94**
pH	pH units	**6.71**	**6.18**	**6.36**	**6.32**	**6.15**	**-**	**5.93**
Specific conductance	mS/cm	**0.660**	**0.610**	**0.710**	**0.690**	**0.690**	**-**	**2.780**
Total organic carbon	mg/L	**54**	<1	<1	**2**	**63**	**-**	**25**
Chloride	mg/L	**9.4**	**6.98**	**0.7**	**0.9**	**0.8**	**-**	**20.5**
Natural Attenuation Parameters								
Alkalinity	mg/L	**528**	**492**	**600**	**710**	**552**	**-**	**1256**
Dissolved oxygen	mg/L	**2.32**	**0.33**	**0.63**	**0.51**	**2.18**	**-**	**0.68**
Ferrous Iron	mg/L	**0.32**	**0.41**	**2.47**	**5.30**	**0.72**	**-**	**15.6**
Nitrate	mg/L	**2.09**	**0.928**	<0.1	<0.1	**0.868**	**-**	<0.1
Sulfate	mg/L	**22.4**	**21**	**15**	**8.4**	**11**	**-**	**4.9**
Redox potential	mV	**268**	**174**	**-161**	**-166**	**-78**	**-**	**-114**
Turbidity	NTU	**7**	**2**	**3**	**3**	**3**	**-**	**9**
Hydrogen	nM	**1.8**	**1**	**1.8**	**2.4**	**1.5**	**1.9**	**2**
Methane	ug/L	**37**	**1200**	**7900**	**7200**	**1500**	**1600**	**4800**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, methane, and hydrogen were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-6
GROUNDWATER SAMPLING RESULTS: OCTOBER 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS									
			DUPLICATE						DUPLICATE		
		B301-MW22S	B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW29S	B301-MW45S	B301-MW46S
Date Sampled:		10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002	10/16/2002
Units											
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.00099 J**	**0.001**	**0.00044 J**	<0.001	**0.0011**	**0.00082 J**	**0.0005 J**	**0.00054 J**	**0.0017**	**0.00081 J**
TCE	mg/L	**0.170**	**0.200**	**0.013**	**0.012**	**0.044**	**0.037**	**0.0072**	**0.0074**	**0.480**	**0.250**
1,1-DCE	mg/L	**0.00041 J**	**0.00048 J**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	**0.0028**	**0.00093 J**
cis-1,2-DCE	mg/L	**0.0027**	**0.0027**	**0.016**	**0.0075**	**0.00066 J**	**0.0016**	**0.0026**	**0.0026**	**0.012**	**0.0047**
trans-1,2-DCE	mg/L	**0.00049 J**	**0.00052 J**	**0.006**	**0.0053**	**0.00036 J**	<0.001	**0.00069 J**	**0.00076 J**	**0.0062**	**0.00078**
Vinyl chloride	mg/L	<0.001	<0.001	**0.0022**	**0.002**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cDCE/TCE ratio		**0.02**	**0.01**	**1.23**	**0.63**	**0.02**	**0.04**	**0.36**	**0.35**	**0.03**	**0.02**
Water Quality Parameters											
Temperature	°C	**15.82**	**-**	**16.69**	**15.39**	**15.98**	**16.95**	**16.58**	**-**	**15.70**	**16.01**
pH	pH units	**6.91**	**-**	**6.68**	**6.59**	**7.01**	**6.98**	**6.84**	**-**	**6.88**	**6.91**
Specific conductance	mS/cm	**0.73**	**-**	**0.76**	**0.81**	**0.74**	**0.73**	**0.87**	**-**	**0.74**	**0.74**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.11**	**-**	**0.17**	**0.25**	**0.10**	**0.17**	**0.12**	**-**	**0.28**	**0.15**
Redox potential	mV	**35**	**-**	**-68**	**-165**	**-100**	**28**	**4**	**-**	**10**	**-22**
Ferrous Iron	mg/L	**0.43**	**-**	**0.11**	**0.51**	**0.51**	**0.12**	**0.59**	**-**	**0.32**	**0.09**
Turbidity	ntu	**3**	**-**	**3**	**3**	**3**	**7**	**3**	**-**	**10**	**5**
Alkalinity	mg/L	**542**	**-**	**640**	**662**	**574**	**552**	**578**	**-**	**544**	**558**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-6
GROUNDWATER SAMPLING RESULTS: OCTOBER 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS									
Date Sampled:		B301-MW47S 10/16/2002	B301-MW48S 10/16/2002	B301-MW49S 10/17/2002	B301-MW50S 10/18/2002	B301-MW51S 10/19/2002	B301-MW52S 10/20/2002	B301-MW53S 10/21/2002	B301-MW54S 10/22/2002	B301-MW55S 10/23/2002	B301-MW56S 10/24/2002
Units											
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.00026 J**	**0.00042 J**	**0.00066 J**	<0.001	<0.001	<0.001	**0.0016**	**0.0017**	<0.001	<0.001
TCE	mg/L	**0.0016**	**0.018**	**0.013**	<0.001	**0.00056 J**	**0.012**	**0.063**	**0.063**	<0.001	**0.00068 J**
1,1-DCE	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.0026**	**0.0019**	**0.012**	**0.0024**	**0.0079**	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,2-DCE	mg/L	**0.00051 J**	<0.001	**0.014**	**0.0097**	**0.014**	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	<0.001	<0.001	**0.0031**	**0.00091 J**	<0.001	<0.001	<0.001	<0.001	<0.001
cDCE/TCE ratio		**1.63**	**0.11**	**0.92**		**14.11**					
Water Quality Parameters											
Temperature	°C	**16.46**	**16.95**	**15.02**	**16.17**	**16.25**	**16.82**	**15.82**	**15.17**	**16.85**	**16.10**
pH	pH units	**6.85**	**6.91**	**6.96**	**6.95**	**7.03**	**7.09**	**7.13**	**6.94**	**7.10**	**7.13**
Specific conductance	mS/cm	**0.79**	**0.75**	**0.71**	**0.86**	**0.73**	**0.73**	**0.71**	**0.72**	**0.81**	**0.74**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.13**	**0.10**	**0.15**	**0.10**	**0.13**	**3.28**	**4.57**	**4.36**	**4.74**	**3.52**
Redox potential	mV	**1**	**-106**	**-147**	**-227**	**-207**	**-98**	**-71**	**179**	**187**	**-38**
Ferrous Iron	mg/L	**0.31**	**0.42**	**2.25**	**2.51**	**1.98**	**0.42**	**0.39**	**0.10**	**0.30**	**0.17**
Turbidity	ntu	**7**	**3**	**3**	**3**	**3**	**4**	**3**	**3**	**5**	**5**
Alkalinity	mg/L	**580**	**624**	**482**	**672**	**412**	**573**	**556**	**474**	**468**	**528**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-6
GROUNDWATER SAMPLING RESULTS: OCTOBER 2002

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

			MULCH WALL MONITORING WELLS				
Date Sampled:		B301-MW57S 10/25/2002	B301-BW1 10/16/2002	B301-BW2 10/16/2002	B301-BW3 10/17/2002	B301-BW4 10/17/2002	B301-BW5 10/17/2002
Units							
Chlorinated Organics and Reduction By-Products							
PCE	mg/L	<0.001	**0.00075 J**	**0.00058 J**	<0.001	**0.00024 J**	<0.001
TCE	mg/L	**0.0014**	**0.24**	**0.023**	**0.00098 J**	**0.017**	<0.001
1,1-DCE	mg/L	<0.001	**0.00098 J**	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	<0.001	**0.06**	**0.0021**	**0.0059**	**0.0021**	<0.001
trans-1,2-DCE	mg/L	<0.001	**0.0018**	**0.00026 J**	**0.0015**	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	**0.0098**	**0.00072 J**	**0.0034**	**0.0018**	<0.001
cDCE/TCE ratio			**0.250**	**0.09**	**6.02**	**0.12**	
Water Quality Parameters							
Temperature	°C	**16.03**	**15.88**	**17.50**	**15.51**	**16.49**	**17.16**
pH	pH units	**7.08**	**6.71**	**6.73**	**6.64**	**6.52**	**6.60**
Specific conductance	mS/cm	**0.71**	**0.74**	**0.75**	**0.82**	**0.85**	**3.31**
Natural Attenuation Parameters							
Dissolved oxygen	mg/L	**1.98**	**0.17**	**0.14**	**0.15**	**1.59**	**0.10**
Redox potential	mV	**31**	**-130**	**-153**	**-208**	**-124**	**-244**
Ferrous Iron	mg/L	**0.24**	**1.24**	**1.98**	**4.9**	**3.1**	**16.25**
Turbidity	ntu	**12**	**5**	**7**	**3**	**5**	**12**
Alkalinity	mg/L	**473**	**620**	**1024**	**481**	**569**	**1215**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-7
GROUNDWATER SAMPLING RESULTS: JANUARY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS										
								DUPLICATE				
		B301-MW22S	B301-MW23S	B301-MW24S	B301-MW27S	B301-MW28S	B301-MW29S	B301-MW29S	B301-MW45S	B301-MW46S	B301-MW47S	B301-MW48S
Date Sampled:		1/28/2003	1/28/2003		1/27/2003	1/28/2003	1/28/2003	1/28/2003		1/28/2003	1/28/2003	1/27/2003
Units												
Chlorinated Organics and Reduction By-Products												
PCE	mg/L	**0.001 J**	**<0.001**	**<0.001**	**0.00170 J**	**0.0013**	**0.00097 J**	**0.00024**	**0.00190 J**	**0.0011**	**0.00018 J**	**0.0002 J**
TCE	mg/L	**0.13**	**0.016**	**0.0075**	**0.039**	**0.029**	**0.0064**	**0.006**	**0.41**	**0.21 E**	**0.0016**	**0.01**
1,1-DCE	mg/L	**0.00036 J**	**<0.001**	<0.001	**0.00028 J**	<0.001	<0.001	<0.001	**0.0044**	**0.0024**	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.0052**	**0.022**	**0.0086**	**0.00055 J**	**0.001**	**0.0026**	**0.0024**	**0.014**	**0.007**	**0.0023**	**0.00085 J**
trans-1,2-DCE	mg/L	**0.00081 J**	**0.01**	**0.0067**	**0.00041 J**	<0.001	**0.00046 J**	**0.00040 J**	**0.001**	**0.0011**	**0.00042 J**	**0.00025 J**
Vinyl chloride	mg/L	<0.001	**0.00086 J**	**0.0011**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	**17**	**32**	**30**	**8**	**36**	**21**	**22**	**12**	**12.000**	**16**	**38**
Ethane	ng/L	**10**	**7000**	**13000**	**6**	**60**	**1100**	**1000**	**13**	**13**	**940**	**620**
cDCE/TCE ratio		**0.040**	**1.375**	**1.147**	**0.014**	**0.034**	**0.406**	**0.375**	**0.034**	**0.033**	**1.438**	**0.085**
Water Quality Parameters												
Temperature	°C	**13.10**	**13.04**	**11.96**	**10.54**	**10.11**	**13.06**	-	**11.87**	**11.99**	**12.39**	**10.30**
pH	pH units	**6.96**	**6.68**	**6.62**	**7.05**	**7.06**	**6.9**	-	**6.93**	**6.94**		**6.98**
Specific conductance	mS/cm	**0.670**	**0.750**	**0.810**	**0.680**	**0.680**	**72.000**	-	**0.680**	**0.69**	**0.720**	**0.670**
Total organic carbon	mg/L	**1.15**	**2.28**	**3.11**	**1.17**	**1.08**	**1.35**	**1.41**	**1.58**	**1.71**	**1.29**	**1.22**
Natural Attenuation Parameters												
Alkalinity	mg/L	**460**	**545**	**511**	**450**	**443**	**492**	-	**435**	**406**	**427**	**524**
Dissolved oxygen	mg/L	**0..46**	**0.44**	**0.51**	**1.72**	**0.47**	**0.42**	-	**0.85**	**0.4**	**0.42**	**0.42**
Ferrous Iron	mg/L	**2.73**	**1.73**	**1.08**	**1.93**	**0.60**	**2.02**	-	**0.88**	**0.56**	**0.61**	**0.73**
Redox potential	mV	**241**	**212**	**57**	**130**	**220**	**117**	-	**271**	**237**	**107**	**40**
Turbidity	NTU	**5**	**7**	**8**	**9**	**7**	**3**	-	**12**	**10**	**6**	**12**
Methane	ug/L	**2.1**	**4300**	**7300**	**1**	**88**	**350**	**360**	**1.4**	**1**	**970**	**440**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-7
GROUNDWATER SAMPLING RESULTS: JANUARY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS								
	Date Sampled:	B301-MW49S	B301-MW50S 1/27/2003	B301-MW51S 1/27/2003	B301-MW52S 1/21/2003	B301-MW53S 1/21/2003	B301-MW54S 1/21/2003	B301-MW55S 1/20/2003	B301-MW56S 1/20/2003	B301-MW57S 1/20/2003
	Units									
Chlorinated Organics and Reduction By-Products										
PCE	mg/L	**0.00026 J**	<0.001	<0.001	<0.001	**0.0012**	**0.00078 J**	<0.001	<0.001	<0.001
TCE	mg/L	**0.0087**	<0.001	<0.001	**0.0081**	**0.060**	**0.050**	<0.001	<0.001	<0.001
1,1-DCE	mg/L	<0.001	<0.001	<0.001	<0.001	**0.00026 J**	<0.001	<0.001	<0.001	<0.001
cis-1,2-DCE	mg/L	**0.010**	**0.0027**	**0.0058**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,2-DCE	mg/L	**0.01**	**0.0074**	**0.011**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl chloride	mg/L	<0.001	**0.0018**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethene	ng/L	**14**	**120**	**59**	**13**	**20**	**14**	**10**	**10**	**12**
Ethane	ng/L	<0.001	**16**	**140**	**9**	**10**	**10**	**<0.001**	**9**	**7**
cDCE/TCE ratio		**1.149**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Water Quality Parameters										
Temperature	°C	**12.68**	**11.25**	**10.65**	**11.97**	**13.88**	**13.30**	**12.17**	**12.56**	**11.43**
pH	pH units	**6.8**	**7.04**	**7.06**	**7.14**	**7.11**	**7.08**	**7.09**	**7.13**	**7.06**
Specific conductance	mS/cm	**0.66**	**0.740**	**0.670**	**0.680**	**0.660**	**0.670**	**0.760**	**0.670**	**0.660**
Total organic carbon	mg/L	**1.72**	**1.71**	**1.5**	**1.21**	**1.03**	**1.05**	**1.54**	**1.18**	**1.06**
Natural Attenuation Parameters										
Alkalinity	mg/L	**512**	**499**	**437**	**581**	**462**	**415**	**476**	**564**	**481**
Dissolved oxygen	mg/L	**0.49**	**0.41**	**0.42**	**4.08**	**5.11**	**4.56**	**5.86**	**3.63**	**2.53**
Ferrous Iron	mg/L	**2.5**	**3.80**	**1.97**	**0.59**	**0.33**	**0.27**	**0.27**	**2.21**	**0.43**
Redox potential	mV	**-13**	**-108**	**-45**	**301**	**242**	**288**	**263**	**186**	**249**
Turbidity	NTU	**10**	**9**	**7**	**2**	**5**	**3**	**2**	**4**	**7**
Methane	ug/L	**110**	**1500**	**88**	**0.17**	**2.9**	**0.77**	**0.04**	**9**	**0.02**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-7
GROUNDWATER SAMPLING RESULTS: JANUARY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		MULCH WALL MONITORING WELLS				
Date Sampled:		B301-BW1	B301-BW2 1/27/2003	B301-BW3 1/27/2003	B301-BW4	B301-BW5 1/20/2003
Units						
Chlorinated Organics and Reduction By-Products						
PCE	mg/L	**0.0017**	**0.00034 J**	<0.001	**0.00046 J**	<0.001
TCE	mg/L	**0.2**	**0.014**	**0.002**	**0.022**	<0.001
1,1-DCE	mg/L	**0.0012**	**0.00026 J**	<0.001	**0.001**	<0.001
cis-1,2-DCE	mg/L	**0.033**	**0.0012**	**0.0026**	**0.002**	<0.001
trans-1,2-DCE	mg/L	**0.002**	**0.0003 J**	**0.0012**	**0.00025 J**	<0.001
Vinyl chloride	mg/L	**0.0065**	<0.001	**0.0018**	**0.001**	<0.001
Ethene	ng/L	**3100**	**100**	**510**	**160**	**<0.001**
Ethane	ng/L	**3300**	**280**	**10**	<0.001	**<0.001**
cDCE/TCE ratio		**0.165**	**0.086**	**1.083**	**0.091**	
Water Quality Parameters						
Temperature	°C	**12.53**	**10.45**	**11.30**	**12.79**	**12.14**
pH	pH units	**6.81**	**6.86**	**6.63**	**6.63**	**6.58**
Specific conductance	mS/cm	**0.680**	**0.690**	**0.760**	**0.720**	**2.480**
Total organic carbon	mg/L	**2**	**1.36**	**3.15**	**2.91**	**82.75**
Natural Attenuation Parameters						
Alkalinity	mg/L	**421**	**583**	**554**	**5110**	**1178**
Dissolved oxygen	mg/L	**0.46**	**0.51**	**0.7**	**2.27**	**2.48**
Ferrous Iron	mg/L	**0.56**	**1.61**	**2.71**	**1.99**	**16**
Redox potential	mV	**(23)**	**-33**	**-92**	**27**	**-126**
Turbidity	NTU	**8**	**11**	**11**	**10**	**11**
Methane	ug/L	**2500**	**5300**	**4400**	**4300**	**7000**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride, sulfate, and nitrate by Method 300; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-8
GROUNDWATER SAMPLING RESULTS: APRIL 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS									
Date Sampled:		B301-MW22S 4/29/2003	B301-MW23S 4/30/2003	B301-MW24S 4/30/2003	B301-MW27S 4/29/2003	B301-MW28S 4/29/2003	B301-MW29S 4/29/2003	B301-MW45S 4/30/2003	B301-MW46S 4/30/2003	B301-MW47S 4/29/2003	B301-MW48S 4/29/2003
Units											
Chlorinated Organics and Reduction By-Products											
PCE	mg/L	**0.00057 J**	< 0.001	< 0.001	**0.00054**	**0.00037 J**	< 0.001	**0.00076 J**	**0.00081 J**	< 0.001	< 0.001
TCE	mg/L	**0.28**	**0.033**	**0.0065**	**0.046**	**0.027**	**0.0049**	**1.5**	**0.73**	**0.0021**	**0.012**
1,1-DCE	mg/L	**0.0025**	**0.00032 J**	< 0.001	< 0.001	< 0.001	< 0.001	**0.0026**	**0.0039**	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.0066**	**0.048**	**0.0087**	< 0.001	**0.001**	**0.002**	**0.014**	**0.0098**	**0.0025**	**0.00084 J**
trans-1,2-DCE	mg/L	**0.0011**	**0.011**	**0.0051**	**0.00031**	**0.00022 J**	**0.00041 J**	**0.0027**	**0.0021**	**0.00039 J**	**0.00021 J**
Vinyl chloride	mg/L	< 0.001	**0.0047**	**0.0012**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cDCE/TCE ratio		**0.024**	**1.455**	**1.338**	**0.022**	**0.037**	**0.408**	**0.009**	**0.013**	**1.190**	**0.070**
Water Quality Parameters											
Temperature	°C	**11.64**	**12.01**	**10.08**	**11.68**	**11.01**	**11.19**	**11.85**	**11.16**	**11.46**	**11.23**
pH	pH units	**6.97**	**6.73**	**6.63**	**7.05**	**7.04**	**6.91**	**6.91**	**6.95**	**6.91**	**6.99**
Specific conductance	mS/cm	**0.553**	**0.631**	**0.714**	**0.592**	**0.627**	**0.647**	**0.601**	**0.599**	**0.66**	**0.615**
Natural Attenuation Parameters											
Dissolved oxygen	mg/L	**0.57**	**2.46**	**3.83**	**0.4**	**0.18**	**0.51**	**2.59**	**3.15**	**0.25**	**0.29**
Redox potential	mV	**13**	**-89**	**3**	**-34**	**-56**	**26**	**37**	**72**	**-12**	**-49**
Ferrous Iron	mg/L	**0.22**	**0.29**	**0.94**	**4.75**	**0.38**	**1.24**	**2.1**	**0.45**	**1.01**	**0.31**
Turbidity	ntu	**19**	**27**	**12**	**49**	**357**	**10**	**249**	**48**	**41**	**12**
Alkalinity	mg/L	**560**	**586**	**656**	**658**	**474**	**680**	**6.25**	**584**	**688**	**487**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-8
GROUNDWATER SAMPLING RESULTS: APRIL 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS								
Date Sampled:		B301-MW49S 4/29/2003	B301-MW50S 4/28/2003	B301-MW51S 4/28/2003	B301-MW52S 4/28/2003	B301-MW53S 4/28/2003	B301-MW54S 4/28/2003	B301-MW55S 4/28/2003	B301-MW56S 4/28/2003	B301-MW57S 4/28/2003
Units										
Chlorinated Organics and Reduction By-Products										
PCE	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	**0.00027 J**	**0.0012**	< 0.001	< 0.001	< 0.001
TCE	mg/L	**0.012**	**0.00072 J**	< 0.001	**0.0074**	**0.043**	**0.09**	< 0.001	**0.0071**	< 0.001
1,1-DCE	mg/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.014**	**0.0026**	**0.007**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
trans-1,2-DCE	mg/L	**0.015**	**0.0091**	**0.013**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Vinyl chloride	mg/L	< 0.001	**0.0016**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cDCE/TCE ratio		**1.167**	**3.611**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Water Quality Parameters										
Temperature	°C	**12.08**	**11.76**	**11.54**	**12.59**	**13.28**	**14**	**11.28**	**12.12**	**12.06**
pH	pH units	**7.01**	**7.06**	**7.07**	**7.15**	**7.12**	**7.13**	**7.19**	**7.13**	**7.08**
Specific conductance	mS/cm	**0.576**	**0.662**	**0.608**	**0.571**	**0.572**	**0.593**	**0.646**	**0.562**	**0.586**
Natural Attenuation Parameters										
Dissolved oxygen	mg/L	**0.11**	**3.77**	**0.19**	**3.03**	**3.73**	**4.57**	**5.71**	**2.75**	**2.92**
Redox potential	mV	**-37**	**-122**	**-88**	**133**	**75**	**122**	**111**	**167**	**139**
Ferrous Iron	mg/L	**1.56**	**3.17**	**2.25**	**0.39**	**0.38**	**0.46**	**0.36**	**0.38**	**0.56**
Turbidity	ntu	**10**	**12**	**10**	**8**	**11**	**21**	**10**	**17**	**148**
Alkalinity	mg/L	**550**	**620**	**738**	**502**	**578**	**502**	**488**	**500**	**502**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-8
GROUNDWATER SAMPLING RESULTS: APRIL 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		MULCH WALL MONITORING WELLS				
Date Sampled:		B301-BW1 4/30/2003	B301-BW2 4/29/2003	B301-BW3 4/29/2003	B301-BW4 4/28/2003	B301-BW5 4/28/2003
Units						
Chlorinated Organics and Reduction By-Products						
PCE	mg/L	< 0.001	**0.00017 J**	< 0.001	**0.00023 J**	< 0.001
TCE	mg/L	**0.085**	**0.019**	**0.0015**	**0.03**	< 0.001
1,1-DCE	mg/L	**0.00056 J**	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	**0.046**	**0.0019**	**0.0031**	**0.00071 J**	< 0.001
trans-1,2-DCE	mg/L	**0.0025**	**0.00038 J**	**0.0029**	< 0.001	< 0.001
Vinyl chloride	mg/L	**0.013**	< 0.001	**0.0026**	< 0.001	< 0.001
cDCE/TCE ratio		**0.541**	**0.100**	**2.067**	**0.024**	**-**
Water Quality Parameters						
Temperature	°C	**11.4**	**11.23**	**11.5**	**12.82**	**11.83**
pH	pH units	**6.65**	**6.87**	**6.73**	**6.84**	**6.61**
Specific conductance	mS/cm	**0.675**	**0.611**	**0.635**	**0.625**	**2.475**
Natural Attenuation Parameters						
Dissolved oxygen	mg/L	**0.84**	**0.3**	**2.66**	**1.8**	**0.14**
Redox potential	mV	**-96**	**-119**	**-136**	**-9**	**-107**
Ferrous Iron	mg/L	**1.7**	**1.5**	**2.15**	**2.1**	**16.25**
Turbidity	ntu	**31**	**21**	**41**	**18**	**53**
Alkalinity	mg/L	**614**	**600**	**640**	**610**	**2600**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; alkalinity and ferrous iron analyzed using Hach kits.
2) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-9
GROUNDWATER SAMPLING RESULTS: JULY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS												
			DUPLICATE			DUPLICATE					DUPLICATE			
Date Sampled:		B301-MW22S 7/29/2003	B301-MW22S 7/29/2003	B301-MW23S 7/29/2003	B301-MW24S 7/30/2003	B301-MW24S 7/30/2003	B301-MW25S 7/30/2003	B301-MW27S 7/29/2003	B301-MW28S 7/29/2003	B301-MW29S 7/29/2003	B301-MW29S 7/29/2003	B301-MW31S 7/29/2003	B301-MW32S 7/29/2003	B301-MW33S 7/30/2003
Units														
Chlorinated Organics and Reduction By-Products														
PCE	mg/L	**0.00055 J**	**0.00053 J**	< 0.001	< 0.001	< 0.001	< 0.001	**0.00092 J**	**0.0008 J**	< 0.001	< 0.001	< 0.001	< 0.001	**0.00026 J**
TCE	mg/L	**0.39**	**0.39**	**0.012**	**0.1**	**0.097**	**0.35**	**0.05**	**0.03**	**0.0033**	**0.0036**	< 0.001	< 0.001	**0.67**
1,1-DCE	mg/L	**0.0013**	**0.0012**	< 0.001	< 0.001	< 0.001	**0.0013**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.002**
cis-1,2-DCE	mg/L	**0.006**	**0.0059**	**0.048**	**0.041**	**0.041**	**0.29**	**0.0009 J**	**0.00096 J**	**0.0021**	**0.0023**	**0.00084 J**	**0.0048**	**0.07**
trans-1,2-DCE	mg/L	**0.00098 J**	**0.00076 J**	**0.011**	**0.006**	**0.0059**	**0.013**	**0.00043 J**	**0.00015 J**	**0.00051 J**	**0.00049 J**	**0.0057**	**0.0**	**0.0067**
Vinyl chloride	mg/L	< 0.001	< 0.001	**0.0087**	**0.0087**	**0.0083**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.0012**
Ethane	ng/L	**53**	--	**12000**	**20000**	--	--	< 5	**120**	**1800**	--	--	--	--
Ethene	ng/L	**190**	--	**260**	**120**	--	--	**20**	**200**	< 5	--	--	--	--
cDCE/TCE ratio		**0.015**	**0.015**	**4.000**	**0.410**	**0.423**	**0.829**	**0.018**	**0.032**	**0.636**	**0.639**	--	--	**0.104**
Water Quality Parameters														
Temperature	°C	**14.85**	**14.85**	**15.24**	**15.04**	**15.04**	--	**17.27**	**16.94**	**14.77**	--	**15.24**	**14.11**	**14.38**
pH	pH units	**6.86**	**6.86**	**6.51**	**6.53**	**6.53**	--	**6.93**	**6.89**	**6.77**	--	**6.59**	**6.57**	**6.55**
Specific conductance	mS/cm	**0.642**	**0.642**	**0.693**	**0.678**	**0.678**	--	**0.639**	**0.61**	**0.7**	--	**0.789**	**0.8111**	**0.658**
Total Organic Carbon	mg/L	**1.80**	--	**2.57**	**2.91**	--	--	**1.84**	**1.09**	**2.45**	--	--	--	--
Natural Attenuation Parameters														
Dissolved oxygen	mg/L	**0.18**	**0.18**	**0.15**	**0.15**	**0.15**	--	**0.17**	**0.11**	**0.14**	--	**0.15**	**0.16**	**0.16**
Redox potential	mV	**89**	**89**	**377**	**172**	**172**	--	**147**	**51**	**220**	--	**54**	**14**	**122**
Ferrous Iron	mg/L	**0.22**	**0.22**	**1.73**	**0.94**	**0.94**	**0.32**	**0.93**	**0.72**	**0.36**	--	**5.00**	**0.73**	**0.28**
Turbidity	ntu	**19**	**19**	**10**	**12**	**12**	--	**27**	**17**	**17**	--	**16**	**12**	**10**
Alkalinity	mg/L	**560**	**560**	**545**	**656**	**656**	**573**	**6.48**	**572**	**551**	--	**629**	**627**	**529**
Methane	ug/L	**2.4**	--	**2400**	**4900**	--	--	**3**	**210**	**430**	--	--	--	--
Nitrate-Nitrite	mg/L	**1.44**	--	< 0.1	< 0.1	--	--	**0.93**	**0.335**	< 0.1	--	--	--	--

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

GROUNDWATER SERVICES, INC.

TABLE C-9
GROUNDWATER SAMPLING RESULTS: JULY 2003

Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS												
								DUPLICATE						
Date Sampled:		B301-MW34S 7/30/2003	B301-MW45S 7/30/2003	B301-MW46S 7/29/2003	B301-MW47S 7/29/2003	B301-MW48S 7/28/2003	B301-MW49S 7/28/2003	B301-MW49S 7/29/2003	B301-MW50S 7/28/2003	B301-MW51S 7/28/2003	B301-MW52S 7/28/2003	B301-MW53S 7/25/2003	B301-MW54S 7/25/2003	B301-MW55S 7/25/2003
Units														
Chlorinated Organics and Reduction By-Products														
PCE	ug/L	**0.00071 J**	**0.00089 J**	**0.00044 J**	< 0.001	< 0.001	**0.00025 J**	**0.00025 J**	< 0.001	< 0.001	< 0.001	**0.00096 J**	**0.00084 J**	< 0.001
TCE	ug/L	**1**	**0.79**	**0.32**	**0.00053 J**	**0.0077**	**0.0094**	**0.0096**	< 0.001	< 0.001	**0.0029**	**0.064**	**0.064**	< 0.001
1,1-DCE	ug/L	**0.0026**	**0.0036**	**0.0013**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	ug/L	**0.039**	**0.016**	**0.0052**	**0.0013**	**0.0008 J**	**0.013**	**0.013**	**0.0013**	**0.0065**	< 0.001	< 0.001	< 0.001	< 0.001
trans-1,2-DCE	ug/L	**0.0033**	**0.0**	**0.00096 J**	**0.00076 J**	< 0.001	**0.014**	**0.014**	**0.008**	**0.012**	< 0.001	< 0.001	< 0.001	< 0.001
Vinyl chloride	ug/L	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	**0.0**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Ethane	ng/L	--	**15**	**19**	**1900**	**2000**	< 5	--	**10**	**130**	< 5	< 5	< 5	**7**
Ethene	ng/L	--	**33**	**85**	< 5	< 5	**67**	--	**500**	**89**	**20**	**16**	**19**	**16**
cDCE/TCE ratio		**0.039**	**0.020**	**0.016**	**2.453**	**0.104**	**1.383**	**1.354**	**1.300**	**6.500**	--	--	**0.016**	--
Water Quality Parameters														
Temperature	°C	**13.88**	**14.39**	**14.84**	**15.01**	**17.07**	**14.96**	--	**15.67**	**15.74**	**15.80**	**14.70**	**15.44**	**14.61**
pH	pH units	**6.62**	**6.89**	**6.78**	**6.85**	**6.84**	**6.84**	--	**6.91**	**6.90**	**7.07**	**6.84**	**6.92**	**7.12**
Specific conductance	mS/cm	**0.643**	**0.637**	**0.666**	**0.668**	**0.622**	**0.604**	--	**0.659**	**0.664**	**0.608**	**0.662**	**0.618**	**0.657**
Total Organic Carbon	mg/L	--	**1.60**	**1.32**	**2.22**	**1.17**	**1.04**	--	**1.39**	**1.17**	**1.06**	**1.17**	**1.23**	**2.10**
Natural Attenuation Parameters														
Dissolved oxygen	mg/L	**0.12**	**0.23**	**0.14**	**0.16**	**0.13**	**0.12**	--	**0.10**	**0.10**	**2.54**	**4.87**	**3.05**	**5.45**
Redox potential	mV	**254**	**114**	**249**	**147**	**82**	**314**	--	**-65**	**-64**	**88**	**380**	**276**	**86**
Ferrous Iron	mg/L	**0.28**	**0.23**	**0.21**	**0.93**	**0.25**	**2.09**	--	**3.75**	**3.20**	**0.31**	**0.32**	**0.30**	**0.27**
Turbidity	ntu	**198**	**12**	**42**	**27**	**36**	**5**	--	**12**	**15**	**51**	**7**	**21**	**10**
Alkalinity	mg/L	**548**	**540**	**592**	**648**	**498**	**570**	--	**503**	**474**	**439**	**490**	**426**	**4.8**
Methane	ug/L	--	**1**	**1**	**930**	**1500**	**150**	--	**1300**	**73**	**1.1**	**0.24**	**0.20**	**0.03**
Nitrate-Nitrite	mg/L	--	**2.19**	**1.64**	< 0.1	< 0.1	< 0.1	--	< 0.1	< 0.1	**1.99**	**2.41**	**2.42**	**2.06**

Notes:
1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
2) Ethene, ethane, and methane were analyzed by AM20GAX by Microseeps, Inc.
3) - = Not measured.

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Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater, Site B301, Offutt AFB, Nebraska
Air Force Center for Environmental Excellence, Brooks AFB, Texas

		PLUME AREA MONITORING WELLS			MULCH WALL MONITORING WELLS				
			DUPLICATE						
		B301-MW56S	B301-MW56S	B301-MW57S	B301-BW1	B301-BW2	B301-BW3	B301-BW4	B301-BW5
Date Sampled:		7/25/2003	7/26/2003	7/25/2003	7/30/2003	7/29/2003	7/28/2003	7/28/2003	7/25/2003
Units									
Chlorinated Organics and Reduction By-Products									
PCE	mg/L	< 0.001	< 0.001	< 0.001	**0.00079 J**	**0.00037 J**	< 0.001	**0.00047 J**	< 0.001
TCE	mg/L	< 0.001	< 0.001	< 0.001	**0.85**	**0.021**	**0.00095 J**	**0.038**	< 0.001
1,1-DCE	mg/L	< 0.001	< 0.001	< 0.001	**0.0031**	< 0.001	< 0.001	< 0.001	< 0.001
cis-1,2-DCE	mg/L	< 0.001	< 0.001	< 0.001	**0.083**	**0.0014**	**0.0018**	**0.00067 J**	< 0.001
trans-1,2-DCE	mg/L	< 0.001	< 0.001	< 0.001	**0.004**	**0.00021**	**0.0056**	< 0.001	< 0.001
Vinyl chloride	mg/L	< 0.001	< 0.001	< 0.001	**0.013**	< 0.001	**0.0027**	< 0.001	< 0.001
Ethane	ng/L	< 5	--	< 5	**6200**	**79**	< 5	< 5	< 10
Ethene	ng/L	**9**	--	**14**	**5800**	**69**	**520**	**64**	< 10
cDCE/TCE ratio		--	--	--	**0.098**	**0.067**	**1.895**	**0.018**	**--**
Water Quality Parameters									
Temperature	°C	**15.27**	--	**15.44**	**14.58**	**18.12**	**18.05**	**16.76**	**16.76**
pH	pH units	**7.01**	--	**6.92**	**6.76**	**6.81**	**6.74**	**6.46**	**6.46**
Specific conductance	mS/cm	**0.602**	--	**0.612**	**0.65**	**0.66**	**0.66**	**2.45**	**2.45**
Total Organic Carbon	mg/L	**< 1**	--	**1.66**	**1.75**	**3.19**	**2.13**	**2.00**	**67.83**
Natural Attenuation Parameters									
Dissolved oxygen	mg/L	**3.19**	--	**3.05**	**0.15**	**0.23**	**0.16**	**0.31**	**0.31**
Redox potential	mV	**33**	--	**273**	**128**	**23**	**-35**	**-75**	**-75**
Ferrous Iron	mg/L	**0.53**	--	**0.24**	**0.18**	**1.49**	**2.95**	**0.23**	**15.25**
Turbidity	ntu	**7**	--	**12**	**37**	**21**	--	**62**	**85**
Alkalinity	mg/L	**446**	--	**452**	**620**	**625**	**537**	**456**	**1688**
Methane	ug/L	**6.2**	--	**1.1**	**1800**	**6400**	**7400**	**3100**	**2300**
Nitrate-Nitrite	mg/L	**2.40**	--	**2.39**	**1.08**	**0.13**	< 0.1	**1.83**	**0.10**

Notes:

1) The following analyses were performed at Southern Petroleum Laboratories (SPL), Inc., Houston, Texas: Chlorinated organics analyzed by EPA Method 8021B; chloride and sulfate by Method 300; Nitrate by Method 353.2; TOC by Method 9060; alkalinity and ferrous iron analyzed using Hach kits.
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