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FINAL

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Project Report
Natural Attenuation Study
Ground Water, Surface Water, Soil and Sediment Investigation
Industri-Plex Superfund Site
Woburn, Massachusetts

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Notice

This document is intended for internal Agency use only. All research projects making conclusions or recommendations based on environmental data and funded by the U.S. Environmental Protection Agency are required to participate in the Agency Quality Assurance Program. This project was conducted under an approved Quality Assurance Project Plan. The procedures specified in this plan were used without exception. Information on the plan and documentation of the quality assurance activities and results are available from the Principal Investigator.

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1.0 Purpose of Study

This document provides an assessment of arsenic contamination within the Industri-Plex Superfund Site and GSIP Study Area. It fulfills the work objectives set forth in the Natural Attenuation Study Work Plan (NAS WP; Revision 2; September 14, 2000), which was developed from the proposal, 'Natural Attenuation of Arsenic in an Urban, Industrialized Watershed' (NAS Proposal), prepared by Dr. Robert Puls (EPA/ORD) for the Industri-Plex Superfund Site Remedial Project Manager, Joseph LeMay (EPA/Region 1). The purpose of this study was to 1) determine the migration mechanisms controlling arsenic transport at the Industri-Plex Superfund Site and the GSIP Study Area, 2) provide an evaluation of the potential role of natural attenuation processes in mitigating arsenic transport from the Industri-Plex Superfund Site and GSIP Study Area and 3) provide guidance for determination of reasonable, cost effective treatment technologies for a river/wetland in an urban watershed. USEPA Region I – New England agreed to partially fund the NAS WP in accordance with the August 18, 1999 memorandum entitled, 'Industri-Plex Superfund Site: Approval for ORD Arsenic Natural Attenuation Study.' The information derived from this report will be incorporated into the Industri-Plex Superfund Site, Operable Unit 2 (OU-2), Multiple Source Groundwater Response Plan (MSGRP), Remedial Investigation/Feasibility Study (RI/FS).

The primary role of EPA/ORD was to investigate the migration of arsenic from suspected source areas within the Industri-Plex Superfund Site into the Hall's Brook Holding Area (HBHA). Three goals were addressed as part of this investigation: 1) identification of the mobile form of arsenic in ground water, 2) identification of the processes controlling arsenic uptake onto HBHA sediments, and 3) evaluation of the stability of arsenic associated with HBHA sediments. This information serves as a basis for identifying the effectiveness of natural

attenuation within the HBHA to mitigate down gradient migration of arsenic into the Aberjona River and for evaluation of potential remedial alternatives.

1.1 Site Background

The Aberjona Watershed is an industrialized 65-km^2 watershed located in northeastern Massachusetts. The watershed boundary lies within the towns of Reading, Woburn, Winchester and Medford. The Aberjona Watershed extends to the Mystic Lakes, which drain into the Boston Harbor via the Mystic River. Historic industrial activities have resulted in contamination within the northern extent of the watershed. Specifically, activities at the Industri-Plex Superfund Site, a 245-acre industrial park located in Woburn, Massachusetts, resulted in the deposition of inorganic and organic contaminants in soils, sediments, and ground water. In response to public health concerns, a Record of Decision (ROD) for the Industri-Plex Superfund Site was signed in 1986, addressing on-site soil, sediment, and hot spot ground water contamination.

Contamination at the Industri-Plex Superfund Site was a result of historical industrial activity. From the mid - 1800s to the 1930s leather tanning was the dominant industry in Woburn, and the Aberjona and its tributaries served as the main conduits for tannery wastewater (Durant et al., 1990). During the same period, starting in the late 19th century, sulfuric acid and arsenical pesticide manufacturing took place near the headwaters of the watershed in an area now designated as the Industri-Plex Superfund Site (Aurilio, 1992). Estimates suggest that 270 metric tons of arsenic may still exist within the site boundaries (Aurilio, 1992). By-products from glue-manufacturing operations from 1934-1969 were disposed on site. It is hypothesized that leached degradation products from these materials has contributed to the mobilization of arsenic via the ground water from source areas to the HBHA (Davis et al., 1994).

The ground water beneath the Industri-Plex Superfund Site and HBHA in North Woburn has been designated as a non-drinking water source area by the state of Massachusetts. This designation may influence selection of remedial alternatives to address the contaminated soils, ground water, surface water and sediments. It is possible that most if not all ground water discharges to a wetland down gradient of the Industri-Plex Superfund Site. If true, this wetland area may sequester or retard down gradient transport of arsenic. However, there is uncertainty as to the forms of arsenic in the various environmental media, interactions between the surface water and ground water, and stability of arsenic-contaminated sediment in the HBHA. These uncertainties must be resolved prior to considering Monitored Natural Attenuation as a remedial action alternative for arsenic contamination at the Industri-Plex Superfund Site.

1.2 Summary of Field Activities

The field sampling activities and laboratory analyses performed under this study provide a current assessment of arsenic distribution in ground water, surface water, and sediments at the Industri-Plex Superfund Site and within the HBHA Pond. Site characterization was directed towards identifying the predominant chemical processes controlling arsenic migration to and sequestration within the HBHA. Field-based sampling was carried out over a period of 23 months to assess time-dependent trends in arsenic mobility within the Industri-Plex Superfund Site and GSIP Study Area. The data derived from this effort provides a means for 1) assessing the long-term assimilative capacity within the unconsolidated aquifer and the down gradient wetland, and 2) the potential for future mobilization of arsenic that is partitioned to soil/sediment solids.

Results from ground water, surface water, and sediment sampling and characterization are summarized and evaluated in the sections and appendices that follow. Collection of ground

water, surface water, and sediment samples was completed during the following dates: October 13-21, 1999; November 30 – December 3, 1999; March 27 – April 6, 2000; May 16-18, 2000; August 22-30, 2000; March 26 - April 14, 2001; May 11-17, 2001; and September 10-21, 2001. Descriptions of field activities during these dates are documented below:

October 13-21, 1999. Initiated collection of snap shot ground-water samples to provide a limited degree of plume characterization so that fixed ground-water monitoring points could be optimally located within the aquifer to monitor potential attenuation of arsenic within the Industri-Plex Superfund Site and GSIP Study Area.

November 30 – December 3, 1999. Completed collection of snap shot ground-water samples to provide a limited degree of plume characterization so that fixed ground-water monitoring points could be optimally located within the aquifer to monitor natural attenuation effects. Installed fixed ground-water monitoring points TW01, TW02, TW03, TW04 below HBHA Pond sediments, and TW06-1,2,3, TW07-1,2,3, and TW08-1,2 adjacent to HBHA Pond perimeter (see Appendix A for locations). Initiated monitoring of Hall's Brook Holding Area (HBHA) Pond water column to determine ground-water discharge derived from the Industri-Plex Superfund Site.

March 27 – April 6, 2000. Installed fixed ground-water monitoring points TW05 (below HBHA Pond sediments), TW08-3, and TW10-1,2,3 (see Appendix A for locations). Collected ground-water samples from fixed monitoring points within the Industri-Plex Superfund Site and GSIP Study Area, and surface water and sediment samples from the HBHA Pond. Sample collection was carried out to initiate long-term monitoring of arsenic discharge from site-derived ground water, establish the physical distribution of arsenic in HBHA Pond sediments, and to provide

data to build a conceptual model for the potential attenuation of arsenic within the Industri-Plex Superfund Site and GSIP Study Area.

May 16-18, 2000. Sampled from fixed ground-water monitoring points and collected sediment samples from north end of HBHA Pond at Atlantic Avenue Drainway discharge. Sampling effort supported long-term monitoring of arsenic attenuation within Industri-Plex Superfund Site and GSIP Study Area.

August 22-30, 2000. Sampled from fixed ground-water monitoring points to support long-term monitoring of arsenic attenuation within Industri-Plex Superfund Site and GSIP Study Area. Installed fixed ground-water monitoring points TW11, TW12, and TW13 adjacent to south bank of HBHA Pond.

March 26 – April 14, 2001. Sampled from fixed ground-water monitoring points and from HBHA Pond water column to support long-term monitoring of arsenic attenuation within Industri-Plex Superfund Site and GSIP Study Area. Collected additional sediments from HBHA Pond to assess potential time-dependent changes in arsenic distribution. Installed multi-level sampling station at north end of HBHA Pond (hereafter referred to as NML) to aid periodic monitoring of water column chemistry following the March high surface water flow event (see Appendix A for NML location).

May 11-17, 2001. Collected ground-water and surface water samples from north multi-level sampling station (NML) within the HBHA Pond for the purpose of establishing recovery of water column chemistry following the March high surface water flow event.

September 10-21, 2001. Collected ground water and surface water samples from fixed ground-water monitoring points and from the HBHA Pond. Completed monitoring of water column chemistry at the NML sampling station within the HBHA Pond for the purpose of establishing

recovery from the March high surface water flow event. Collected additional sediments from HBHA Pond to assess potential time-dependent changes in arsenic distribution. Data collection supported refinement of site conceptual model for attenuation of arsenic within the Industri-Plex Superfund Site and GSIP Study Area.

2.0 Site Monitoring Network

2.1 Snap-shot Ground-Water Locations

During development of the NAS Proposal, it was anticipated that the current extent of the arsenic ground water plume(s) would have been established by the Industri-Plex Site Remedial Trust (ISRT) prior to implementation of well installation and sampling under the NAS Work Plan. Unfortunately, ISRT had not implemented their Final Groundwater and Surface Water Response Plan (GSIP) to delineate the arsenic, toluene and benzene plumes on-site. Therefore, EPA/ORD conducted limited, snap-shot ground water sampling using Geoprobe direct push technology based on historical data in order to locate the current extent of the arsenic ground water plume before establishing fixed ground water monitoring locations for the NAS Work Plan. Landmarks referred to in the following discussion are illustrated in Figure A.1 (see Appendix A). The location of snap-shot monitoring points is illustrated in Figure A.2 (see Appendix A).

The concentrations of arsenic, benzene, and toluene detected at these monitoring locations are illustrated in Figure 1. In general, the concentrations of benzene and toluene were not elevated at snap-shot locations north of the Boston Edison Easement. The highest concentrations of benzene and toluene were observed at snap-shot locations bordering the northeast edge of the HBHA Pond. The highest benzene concentration (4780 ppb) was observed at sampling location A11 at a depth of 30.5 feet below ground surface (bgs). The highest toluene

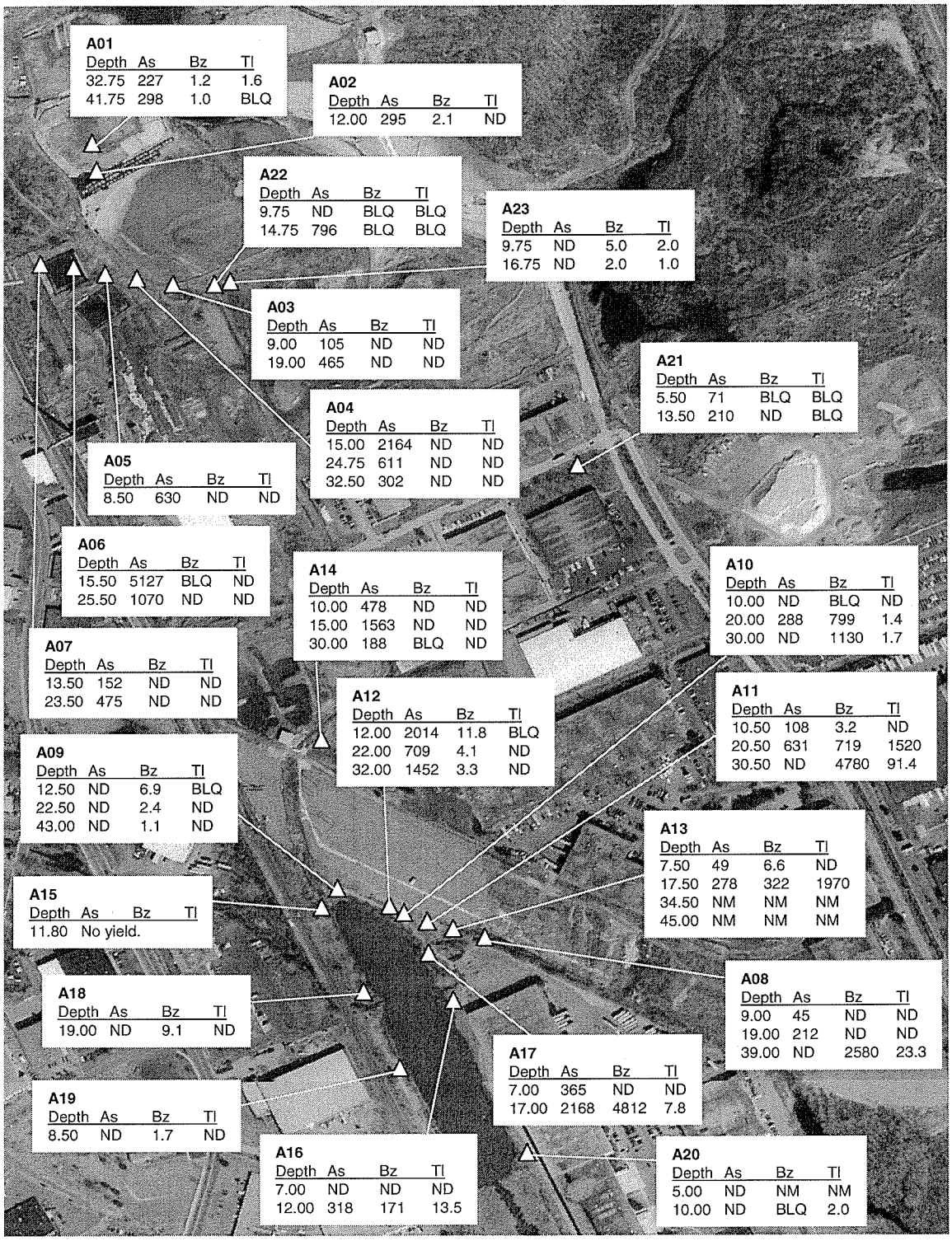
concentration (1970 ppb) was observed at sampling location A13 at a depth of 17.5 feet bgs. Based on the concentrations of these contaminants observed at all of the snap-shot monitoring points that bordered the HBH A Pond, it appears that the primary benzene/toluene plume is centered near the northeast edge of the HBHA Pond north of the 36 Cabot Road Building (formerly owned by Digital).

Elevated dissolved arsenic concentrations were more widely distributed throughout the Industri-Plex Superfund Site and GSIP Study Area. The highest concentration (5127 ppb) was observed at snap-shot location A06 at a depth of 15.5 feet bgs. This sampling point was located south of the West Hide Pile, but the concentration of arsenic observed within the hide pile boundary and immediately south of the West Hide Pile at similar depth was consistently less than 300 ppb (snap-shot locations A01 and A02). The arsenic concentration observed at location A06 suggests either 1) snap-shot location A06 coincides with the location of a source of contamination, 2) there is a source located between snap-shot location A02 and A06, or 3) an unidentified arsenic ground-water migration pathway from the West Hide Pile. Arsenic concentrations were also elevated (>200 ppb for at least one sampling depth) at locations A14, A12, A10, A11, A13, A08, A17, and A16. Snap-shot monitoring point A14 was located between the Industri-Plex Ground Water Treatment Building and the South Hide Pile. The remaining monitoring points bordered the northeast edge of the HBHA Pond and the parking lot north of the 36 Cabot Road Building (formerly owned by Digital). Only one location was sampled within the eastern portion of the Industri-Plex Superfund Site, and the concentration of arsenic was slightly elevated at this location (210 ppb). No arsenic was detected along the western edge and the southeast corner of the HBHA Pond.

The results from all sampling points confirm that elevated concentrations of arsenic at sampling locations adjacent to the northeastern edge of the HBHA Pond are derived from the Industri-Plex Superfund Site. Comparison of the arsenic concentrations observed for snap-shot monitoring locations with at least one depth showing >200 ppb As indicates that a major source of ground-water arsenic is derived from the western portion of the Industri-Plex Superfund Site for the area of coverage investigated. For example, locations A06, A04, A14, and A12 all had at least one depth with an arsenic concentration >1500 ppb. The variation of arsenic concentrations observed along a general north-south transect between the West Hide Pile and the HBHA Pond suggest that more than one arsenic source exists within this portion of the aquifer (locations and maximum As concentration: A06/5127 ppb, A14/1563 ppb, A12/2014 ppb).

Recent ground-water data collected by the ISRT confirm the presence of an arsenic plume derived from the western portion of the Industri-Plex Superfund Site (see Figure 1-3 in O'Brien & Gere Engineers, Inc., 2002). In addition, there are numerous locations within the aquifer down gradient from the East-Central Hidepile with dissolved As concentrations exceeding 100 ppb. However, ground-water monitoring transects south of the 36 Cabot Road Building (formerly owned by Digital) indicate either that ground water from this portion of the site discharges to the HBH~~A~~ Pond or As is currently being sequestered on to aquifer solids in this region of the aquifer. Comparison of all ground-water data collected during 1999-2002 indicates that the HBHA Pond receives the majority of As originating from the aquifer at the Industri-Plex Superfund Site.

Figure 1. Aerial distribution of arsenic (As), benzene (Bz), and toluene (Tl) concentrations from snap-shot ground water sampling locations for the Industri-Plex Site and GSIP Study Area. Reported concentrations are in units of parts per billion (ppb) for all contaminants and concentrations at each sampling depth are separated with a slash. See Appendices B and C for monitoring point locations and depths, respectively. ND = not detected, BLQ = below limit of quantitation. Image was derived from May 1995 aerial photograph obtained from MassGIS.



2.2 Fixed Ground-Water Locations

Based on the distribution of arsenic observed in the snap-shot monitoring points, permanent tubing wells were installed to capture the cross-section of the arsenic plume discharging to the HBHA Pond. One monitoring location was established within the Industri-Plex Superfund site boundary coincident with snap-shot location A14. This monitoring location served as a reference point for site-derived arsenic discharging to the HBHA Pond. The remaining tubing well locations were established between the northwest corner and the northeast edge of the HBHA Pond ending at the north end of the 36 Cabot Road Building (formerly owned by Digital). Within the GSIP Study Area, tubing wells were installed both on land adjacent to the HBHA Pond and below the sediments within the HBHA Pond. Locations of permanent tubing wells are documented in Figures A.4 and A.5 (Appendix A) and Tables B.1 and B.2 (Appendix B; locational data).

2.3 Hall's Brook Holding Area Pond

An effort was made to discern the impact of ground-water discharge on the chemistry within the HBHA Pond. This involved collection of surface water, ground water and sediments within and immediately adjacent to the HBHA Pond boundaries. A georeferenced bathymetric survey was carried out to establish depth to sediment within the HBHA Pond. Illustration of the data collection and resultant contour diagram of depth to sediment is shown in Appendix A (Figures A.6 and A.7, respectively). Details of the monitoring strategy are discussed below.

2.3.1 Water Column and Shallow Sediment Pore Water

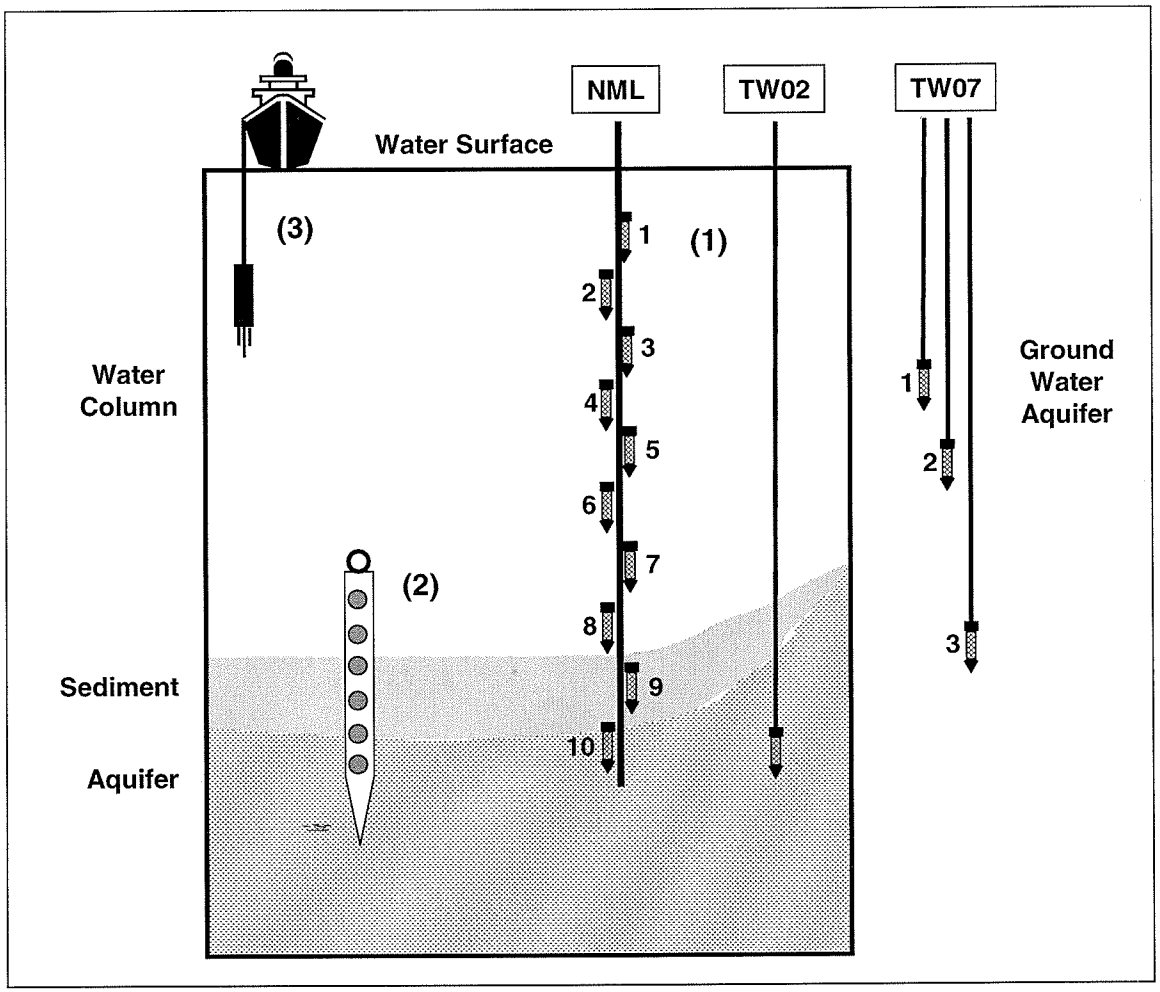
Several sampling strategies were employed in order to monitor the affects of ground water discharge into the HBHA Pond. Throughout the study period, water column samples were

collected at three locations within the north, central and south portions of the pond. In addition, periodic samples were also collected from the Atlantic Avenue Drainway inlet, the Hall's Brook inlet, and the HBHA Pond outlet. A permanent multi-level station with on-land sampling ports was also installed within the north end of the HBHA Pond during the March-April, 2000 field trip. This facilitated collection of depth-resolved water samples over closely spaced periods of time without the need to launch a boat. Finally, collection of pore water samples from shallow sediments was achieved through temporary installation of discrete multi-level samplers (DMLS) at select locations. All sampling locations within the HBHA Pond are displayed on Figure A.8 in Appendix A. A diagram illustrating the strategy to integrate ground water and surface water sampling is shown in Figure 2.

2.3.2 Sediments

Sediments were collected from the HBHA Pond (Figure A.9, Appendix A) employing two different approaches. The first approach involved use of Geoprobe® equipment to collect cores that penetrated through the sediment layer into the underlying aquifer. This was achieved from a boat by hand deploying a Geoprobe® core sampler. Sediment cores were sectioned in the field in order to obtain depth-resolved data at each sampling location. Sediment grab samples were also obtained via two methods: 1) hand sampling along near-shore locations, and 2) pumping unconsolidated sediment from the sediment-water interface at the bottom of the pond using a peristaltic pump. Sediment materials were characterized for total metals, total sulfur, and total organic carbon.

Figure 2. Idealized diagram of water sampling and characterization strategy for HBHA Pond: 1) permanent sampling points (tubing wells) for depth-resolved sampling of water column and adjacent aquifer, 2) diffusion samplers (DMLS) for depth-resolved sampling across sediment-aquifer interface, and 3) surface water vertical profiling throughout aerial extent of HBHA Pond.



2.4 HBHA Wetland and Wells G&H Wetland

Sediment samples were collected from the HBHA Wetland and Wells G&H Wetland (see Table F.6 for locations). Grab samples were collected from underneath the water surface, immediately placed in Ziplock bags, and frozen for shipment. Samples were maintained frozen prior to processing in a glove bag with an atmosphere of 97% N_2:3% H_2 v/v. Thawed samples were homogenized and split into two subsamples. One subsample was drained under moderate hand pressure and then allowed to dry at room temperature within the glove box. Select geochemical parameters and dissolved metals were analyzed on the isolated sediment pore water. Subsamples of the dried sediment were then subjected to leaching tests to assess arsenic release under oxic conditions. The chemical composition of the leaching solution was comparable to the average composition of shallow water within the HBHA Pond (specifically sampling location NML-2).

3.0 Extent of Arsenic Contamination

3.1 Ground Water

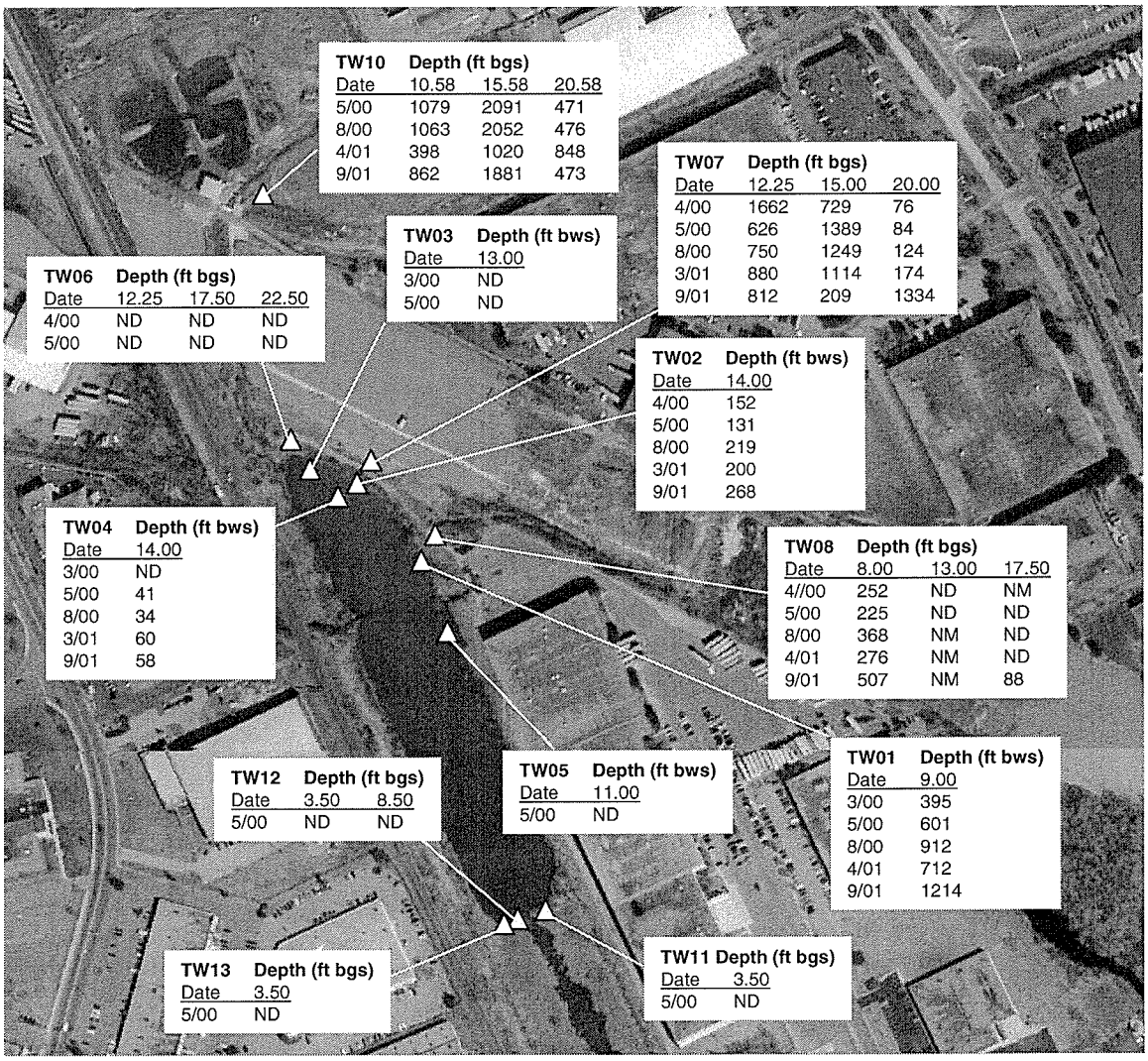
The results of ground water arsenic measurements at fixed monitoring locations from March 2000 to September 2001 are shown in Figure 3. The results of snap-shot monitoring locations A09, A15, A18, A19 (Figure 1) and fixed locations TW03, TW04, and TW06 indicate that there is not a significant source of arsenic in ground water along the western portion of the HBHA Pond. Only location TW04 had concentrations of arsenic above the analytical detection limit, and the concentration of arsenic was consistently <60 ppb. This is supported by ground-water data collected by USEPA Region 1 and the ISRT (O'Brien & Gere Engineers, Inc., 2002). In contrast, elevated concentrations of arsenic were consistently detected at locations TW01, TW02, TW07, and TW08. For these locations, the highest concentration observed for arsenic

was 1662 ppb at location TW07-1, which is a shallow ground-monitoring depth adjacent to the northeast bank of the HBHA Pond. The concentration of arsenic observed at these monitoring locations is consistent with observations at location TW10, which is upgradient from the HBHA Pond and situated between the Ground Water Treatment Building and the South Hidepile. While there are upward and downward fluctuations in the arsenic concentration at each monitoring location and depth, there is no consistent trend that supports an overall diminution in ground-water arsenic during this observation period. Comparison of the dissolved arsenic concentrations detected during this study to previous monitoring efforts dating back to 1990 indicate that there is a long term source of arsenic to ground-water that has not been eliminated by current site remedial efforts (Roux Associates et al., 1997).

Comparison of arsenic concentrations determined at snap-shot and fixed monitoring locations indicates that the focal point for arsenic discharge is along the eastern portion of the HBHA Pond. This discharge zone extends from the mid-point of the northern bank down to approximately the north exterior wall of the 36 Cabot Road Building (formerly owned by Digital). The predominance of arsenite among the species detected in ground water indicates that reducing conditions in the subsurface maintain arsenic mobility within the aquifer (see Appendices D and E). Based on one round of sampling, arsenic concentrations measured at fixed monitoring points at the southern edge of the HBHA Pond (TW11, TW12, TW13) indicate that there is insignificant arsenic discharge in shallow ground water down gradient to the HBHA Wetland. Thus, the monitoring data from the snap-shot and fixed monitoring points indicate that the HBHA Pond may intercept a significant fraction of ground-water arsenic derived from the Industri-Plex Superfund Site. This is supported by data from ground-water transects south of the

HBHA Pond down to Mishawaum Road completed by the ISRT (O'Brien & Gere Engineers, Inc., 2002).

Figure 3. Aerial distribution and time-dependent variability for total dissolved arsenic concentrations (ppb) detected in tubing wells established within the Industri-Plex Superfund site and GSIP Study Area. The designation for each tubing well location is shown; consult Figures A.4 and A.5 and Tables B.1 and B.2 in Appendices A and B, respectively. Depths are shown in feet below ground surface (ft bgs) and feet below water surface (ft bws) for tubing wells installed on land and within the HBHA Pond, respectively. Depths for tubing wells TW01, TW02, TW03, TW04, and TW05 were determined at the time of installation. NM = not measured, ND = not detected.



3.2 HBHA Pond Sediments

Bulk and trace metal concentrations for sediments collected within the HBHA Pond are documented in Appendix F. The aerial distribution and concentration of As, Pb, and Zn for a subset of these sediments is illustrated in Figure 4. This subset of samples represents shallow sediments collected from the sediment-water interface. The metal concentrations in this subset of samples range from 430-1680 ppm, 115-1180 ppm, and 583-17500 ppm for As, Pb and Zn, respectively. The highest concentrations of arsenic are generally located in the deepest portion of the HBHA Pond. However, the results shown in Figure 4 indicate that elevated levels of As are distributed throughout the HBHA Pond. The depth distribution of As, Pb and Zn in sediment cores is given in Tables F.1, F.2 and F.3 in Appendix F. In general, the highest concentration of these metals is associated with shallow sediments that have the highest concentrations of Fe, S and TOC.

Correlations between arsenic content and major sediment components are shown in Figure 5. The data presented include results for all samples listed in Appendix F. The values of total Fe, total S and TOC were determined directly by microwave-assisted acid digestion or x-ray fluorescence spectroscopy and sulfur/carbon coulometry. Sediments collected from locations WI01, WI02 and WI04 have an orangish-red hue and are produced from the rapid oxidation and precipitation of ferrous iron discharging into the HBHA Pond from shallow ground water seeps (see Figure F.1). Shallow sediments collected from the deeper portions of the HBHA Pond are black due to the high contents of iron sulfides and organic matter.

The arsenic content of sediments collected within the HBHA Pond is positively correlated with the total Fe content (Figure 5A). All Fe-As data pairs plot along a trend with little scatter with the exception of three of the oxic grab samples. These samples were collected

from the 'iron seep' area at the north end of the HBHA Pond (see Figure F.1). The iron content of these samples is exceptionally high, since they are composed primarily of the fine-grained precipitates that form from ferrous iron oxidation-precipitation. There is also a positive correlation between total S and TOC for all sediment samples (Figures 5B and 5C). The strong relationship between total Fe and As is preserved when results from down gradient wetland sediments are included in the plot, highlighting the important role of iron minerals in controlling arsenic partitioning to sediments (Figure 5A). Mass balance calculations based on sulfur measurements for HBHA Pond sediments indicate that Fe sulfides account for <50 % of the total amount of Fe. The remaining fraction of iron may be associated with iron carbonates, Fe-bearing clay minerals, organic matter or iron oxides. However, there is insufficient information collected as part of this study to determine the distribution of Fe minerals in HBHA Pond sediments. Other investigators have suggested that iron oxides persist in reducing sediments for this location, but these observations are as yet inconclusive (Aurilio et al., 1994; Hemond, 1995; Davis et al., 1996; Ahmann et al., 1997). HBHA Pond water column measurements discussed below indicate that a significant fraction of the iron oxides produced in this system are unstable under reducing conditions.

Figure 4. Arsenic, lead and zinc distribution within HBHA Pond sediments collected from sediment-water interface. Results shown for sediment cores NC01, CC02 and SC02 are for the first depth interval only. See Figure A.9 and Tables F.1-F.4 for sample identification. Results are reported in units of ppm on a dry mass basis.

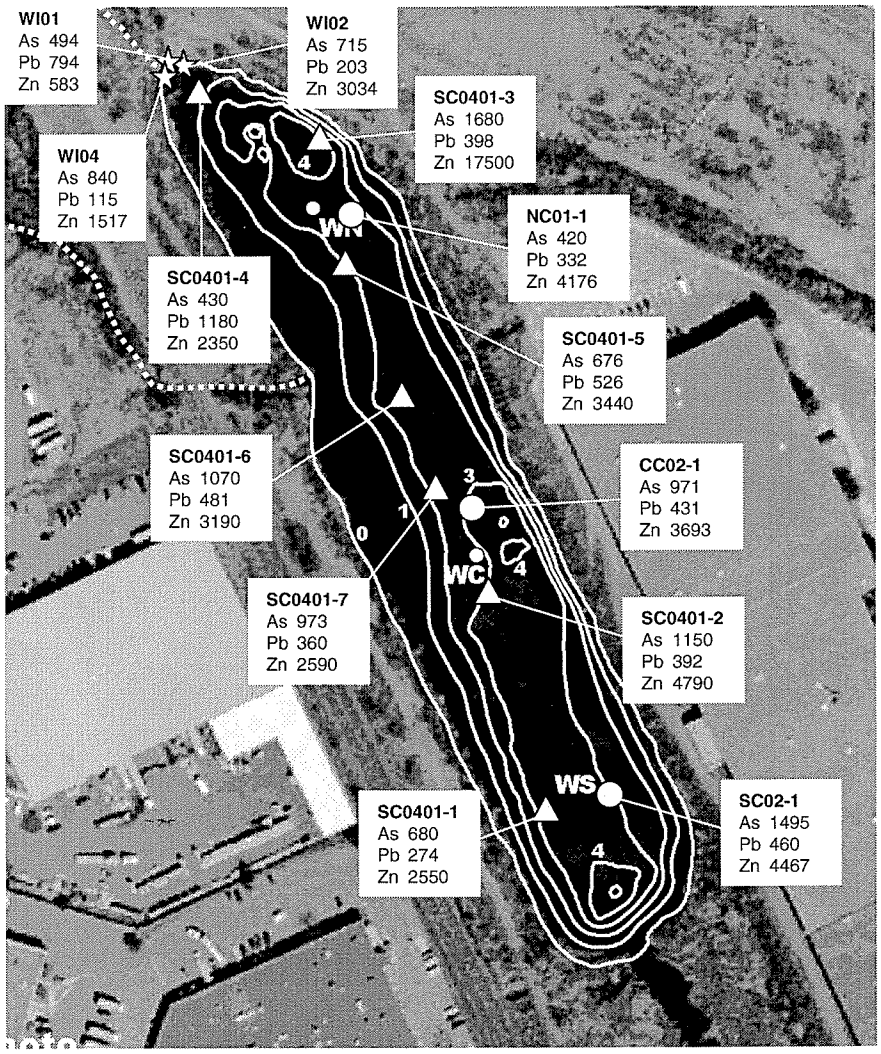
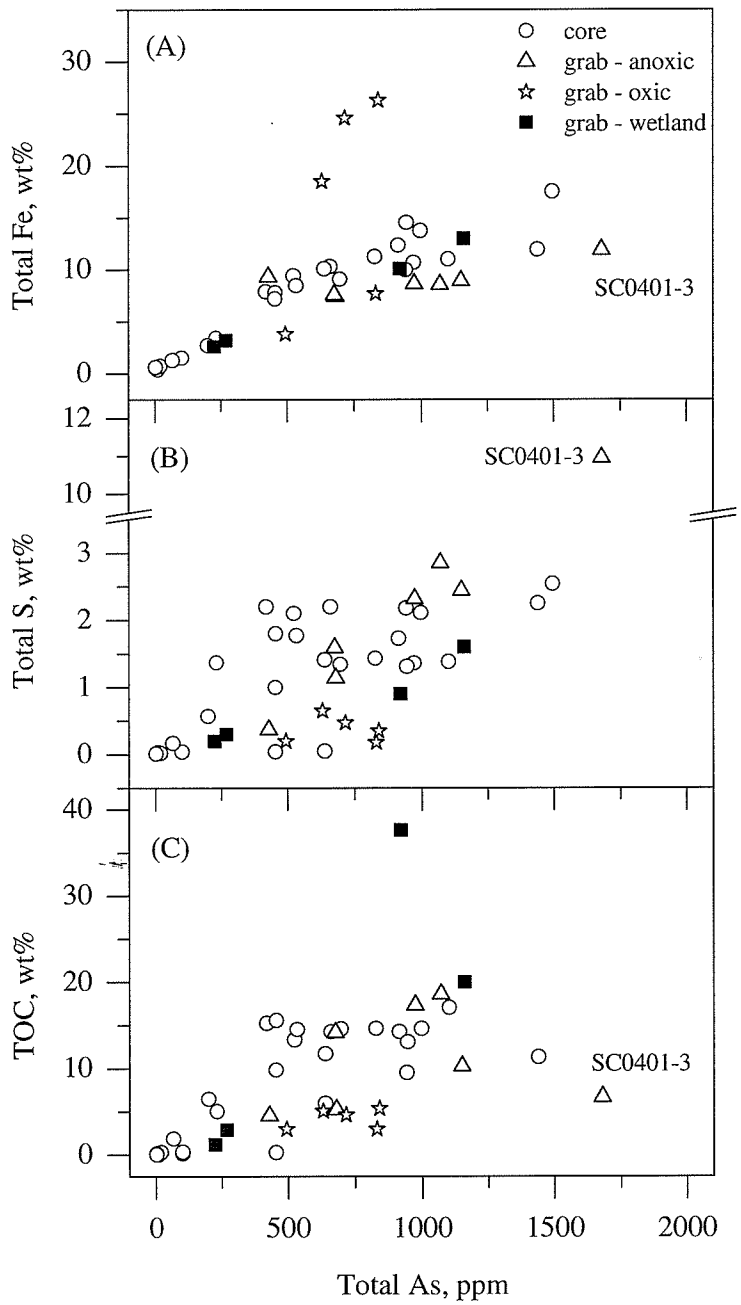


Figure 5. Correlations between sediment geochemical parameters and total arsenic content in sediments sampled from the HBHA Pond. Sample information is documented in the following locations: 1) core; Figure A.9 and Tables F.1-F.3, 2) grab – anoxic; Figure A.9 and Table F.4, 3) grab – oxic; Figure A.9 and Table F.4, and 4) grab – wetland; Table F.5. Symbol identifiers used in this figure correspond with those used in Figure A.9.



3.3 Surface Water – HBHA Pond

The results of monitoring water chemistry within the HBHA Pond are documented in Appendices C-E. A subset of these data is shown in Figures 6 and 7 below. Depth-resolved profiles for specific conductivity and dissolved arsenic at north, central and south sampling locations within the HBHA Pond (see Figure A.7) are shown in Figure 6. Values for these two chemical parameters were assessed for five dates over a period spanning from November 1999 to September 2001. The month and year of each sampling event is documented on the figure. Data for specific conductivity indicate that the HBHA Pond was chemically stratified during four of the five sampling dates. This is consistent with historical trends for this water body (Wick and Gschwend, 1998; Wick et al., 2000). Results for dissolved arsenic also show a general pattern of highest concentrations in the anoxic bottom water with a decrease to values typically <50 ppb in the shallow oxic waters. The highest concentration of arsenic (5043 ppb) was observed during September 2001 at a depth of 419 cm (13.7 ft) at the North Multi-level sampling station. However, elevated concentrations of dissolved arsenic were also observed within the central and south portions of the HBHA Pond with the highest observed values of 2170 ppb (central) and 2845 ppb (south) during September 2001. Since there is no evidence of a source of arsenic of this magnitude from ground-water discharge south of Hall's Brook, the elevated arsenic concentrations within the Central and South portions of the HBHA Pond are most likely associated with sediment dissolution.

The magnitude of sediment dissolution is illustrated in Figure 7. Time-dependent variations in specific conductivity and dissolved arsenic are shown for water samples collected from the North Multi-level sampling station following a large runoff event that occurred around March 31, 2001 (based on stream gage data at USGS station number 01102500 at Winchester,

MA). NML was designed to sample at ten depths, eight of which are positioned within the HBHA Pond water column and the remaining two located within the sediment layer and underlying aquifer, respectively. The relative position of sampling screens NML-1 to NML-10 with respect to the HBHA Pond water surface are shown to the right of the figure. The relative depths of screened intervals at tubing well TW07 are also shown. This shows that sampling depths NML-3 and NML-4 bracket sampling location TW07-1, sampling depth NML-5 coincides approximately with sampling location TW07-2, and sampling depth NML-8 coincides approximately with sampling location TW07-3. The relative position of NML and nearby tubing wells is also shown from an aerial perspective.

The specific conductivity depth profile at NML indicates that the large surface runoff event resulted in significant dilution within the HBHA Pond water column down to a depth of approximately 350 cm (11.5 ft). During the period of observation, the specific conductivity profile was re-established to a pre-runoff condition with time. Based on the monitoring dates, a steady-state profile was re-established again by May 14, 2001 and little variation outside of normal fluctuations was observed for subsequent sampling dates. The largest changes in specific conductivity were observed over a depth interval from 200 – 350 cm (6.6 – 11.5 ft). Significant changes were also observed for the dissolved arsenic depth profile over this period of observation. During the period April 5, 2001 to May 14, 2001, dissolved arsenic concentrations increased to the greatest extent over the depth interval 220 – 370 cm (7.2 – 12.1 ft). However, during the period May 14, 2001 to September 13, 2001 there was a significant increase in dissolved arsenic over the depth interval 220 – 420 cm (7.2 – 13.8 ft). A maximum dissolved arsenic concentration of 5043 ppb was observed at NML-8 (420 cm) on September 13, 2001. The concentrations of dissolved arsenic observed in the adjacent ground-water aquifer (tubing

well TW07) and the northern portion of the HBHA Pond water column over this period of observation are shown in Table 1.

Comparison of the behavior of specific conductivity and dissolved arsenic provide insight into the source of arsenic into the HBHA Pond water column. The time-dependent increase in dissolved arsenic with depth mimics the increase observed for specific conductivity during the period April 5, 2001 to May 14, 2001. The greatest change in both parameters is observed over the depth interval 220 – 370 cm (7.2 – 12.1 ft), of which the approximate location of maximum change is shown by the arrow in the left- and right-hand panels of Figure 7. The only source of water into the HBHA Pond with conductivity greater than 1000 μS/cm is from site-derived ground water. Based on the shape of the dissolved As vertical profile on May 14, 2001, a significant fraction of the observed increase of dissolved arsenic during the period April 5, 2001 to May 14, 2001 appears to derive from ground-water discharge. However, during the period May 14, 2001 to September 14, 2001 there is a significant shift in the dissolved arsenic depth profile without a corresponding shift in the specific conductivity depth profile. The dissolved arsenic concentration observed at NML-8 on September 13, 2001 (5043 ppb) is significantly higher than the concentration observed at TW07-3 (1334 ppb). Examination of dissolved As concentrations observed for ground-water sampling locations TW02, TW03, TW04 and TW07 immediately adjacent to the NML sampling location reveals the lack of a potential ground-water source that could account for the As concentration observed at NML-8 on September 13, 2001. This indicates that there is an additional source of arsenic to the HBHA Pond water column.

The regular increase in dissolved arsenic with depth indicates that the additional source of dissolved arsenic is dissolution of arsenic-bearing solids within the reducing zone of the HBHA Pond water column down to the sediment-water interface. This is supported by the

observation that the dissolved arsenic concentration is much lower at screened intervals NML-9 and NML-10 on September 14, 2001 (269 and 209 ppb, respectively). Since the water column over the depth spanned from NML-5 to NML-8 remained anoxic during the period of observation, the source of arsenic is primarily dissolution of arsenic-bearing iron oxides. These iron oxides are derived from two potential sources: 1) transport of oxic arsenic-rich iron oxides from the shallow near-shore portions of the HBHA Pond (e.g., see Appendix F, Figure F.1), and 2) deposition of arsenic-rich iron oxides following oxidation-precipitation of ferrous iron at the oxic-anoxic interface in the HBHA Pond water column (approximate location shown in Figure 7). A dissolved arsenic concentration of approximately 2000 ppb has consistently been observed at a depth greater than 250 cm (>8.2 ft) at the north, central and south surface water sampling stations throughout the period of this investigation (see Figure 6 and Figure A.7). The higher dissolved As concentration observed at depth on September 13, 2001 may be due to a large influx of As-bearing iron oxides from shallow near-shore sediments as a result of scouring during the large flow event at the end of March 2001. This is supported by the observed removal of a significant fraction of the orangish-red iron oxides that deposit near the outlet of the AAD following the large flow event.

However, it should be noted that the location of NML does not coincide with the north sampling station, and sampling depths NML-7 and NML-8 are actually in a deeper portion of the pond. There is no historical data to dispute that dissolved As concentrations observed on September 13, 2001 have not always occurred at this particular depth within the HBHA Pond prior to the large flow event at the end of March 2001. Dissolved arsenic concentrations from the northern portion of the HBHA Pond and TW07 are also shown for April 2000 and April 2, 2001 in Table 1. Instances in which the As concentration in the water column is lower than in

the adjacent aquifer for a given depth are indicative of 1) dilution following mixing of ground water and surface water and/or 2) loss of As due to uptake on iron oxides. However, instances in which the As concentration in the water column exceeds adjacent ground-water concentrations can be attributed to an additional source of arsenic. Again, since none of the adjacent ground-water sampling locations account for the As concentrations observed in the deeper portion of the HBHA Pond during September 2001, the most likely source of this additional As is from sediment dissolution. The significance of sediment dissolution as a source of dissolved arsenic to the HBHA Pond water column will be discussed in more detail below.

Figure 6. Depth-resolved values of specific conductivity and dissolved arsenic for surface water within the northern, central and southern portion of the HBHA Pond. The general location and sampling date is listed with each figure set. The horizontal scales for specific conductivity and arsenic are identical for each panel within each figure set. The scales for the North figure set span a larger range than shown for the Central and South figure sets. The vertical scale is identical for all figure sets. All water samples were collected from a pontoon boat except for North-09/01, which was collected from the North Multi-level sampling station.

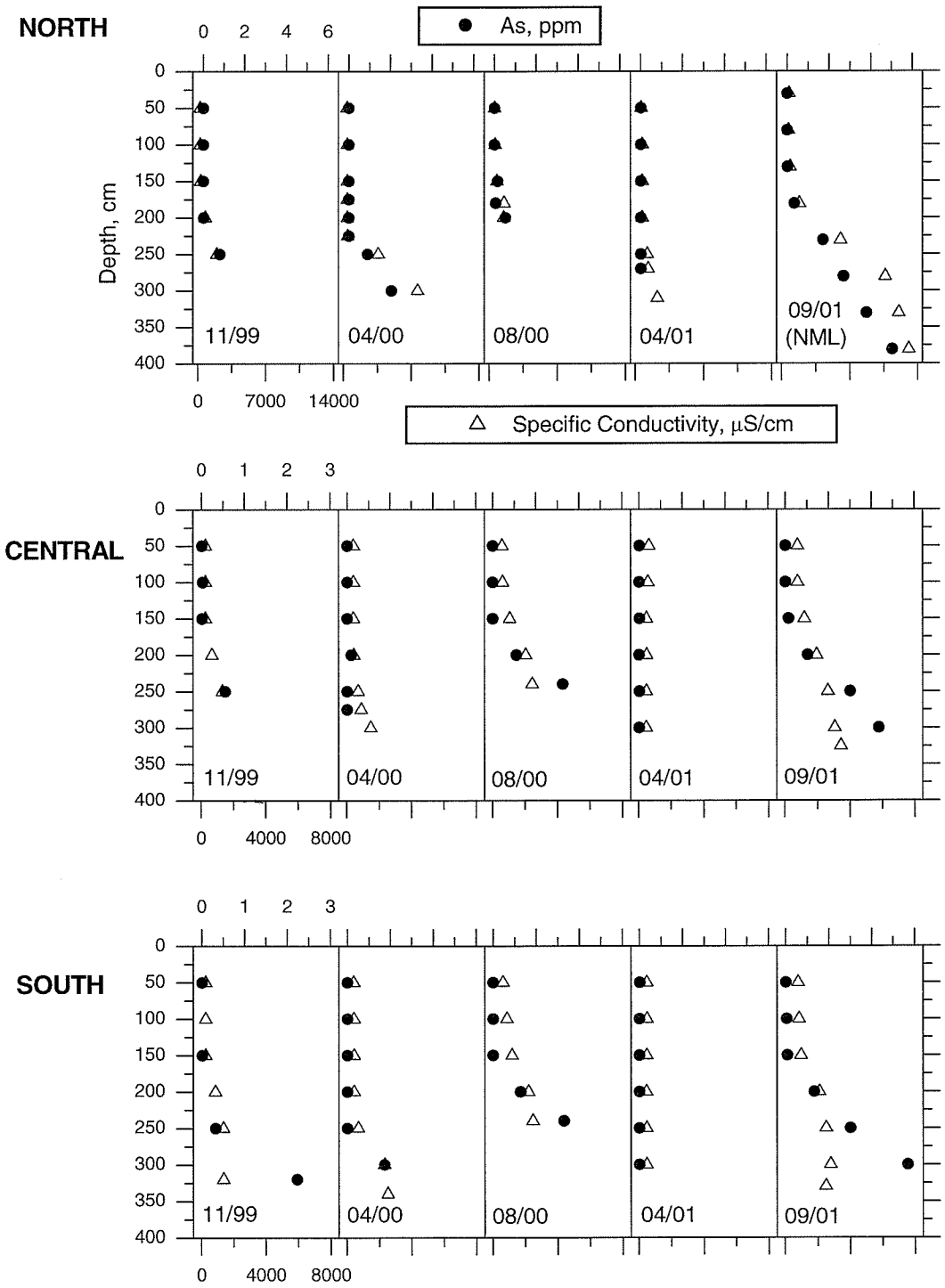
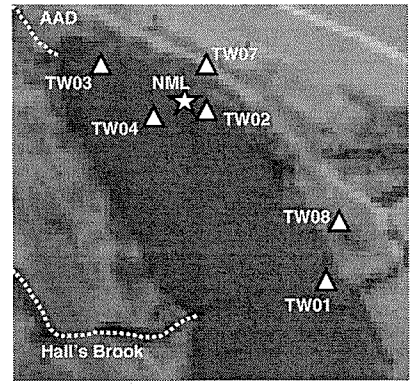


Figure 7. Trends in specific conductivity and dissolved arsenic observed at NML sampling station from April 5, 2001 to September 14, 2001. The location of NML within the pond is illustrated in the aerial photograph to the right (MassGIS, 1995). The location of each screened level for the NML sampling station is referenced to tubing well location TW07 to the right of the data figure. Screened intervals NML-1 through NML-8 are located within the HBHA Pond water column. Screened interval NML-9 is located within the HBHA Pond sediment layer and screened interval NML-10 is located within the underlying sandy aquifer. For consistency in presentation, the depth of each screened interval for all sampling dates has been referenced to the water level on April 5, 2001.



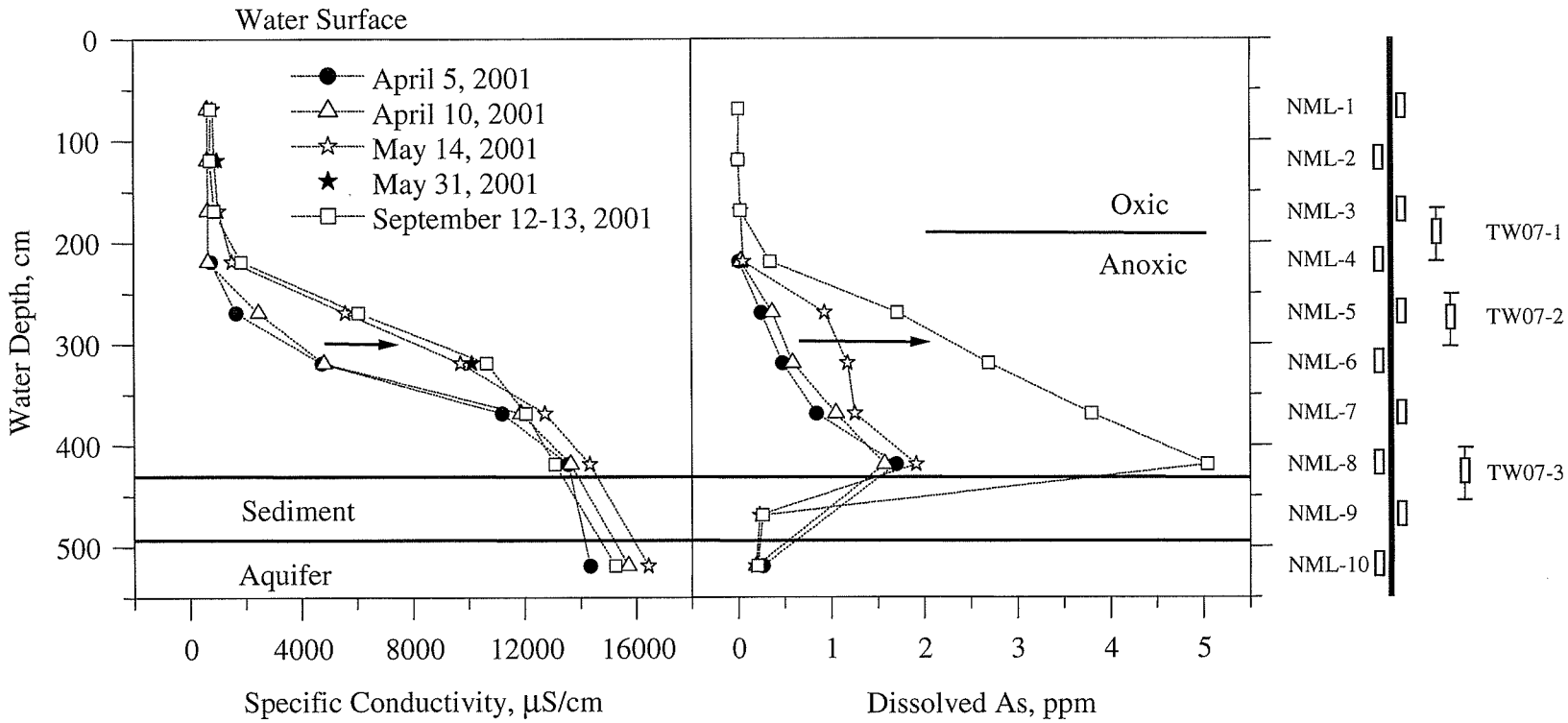


Table 1. Trends in dissolved arsenic during sampling dates April 4, 2000 and April 2, 2001 at the HBHA Pond north sampling location and the period April 5, 2001 to September 14, 2001 for tubing well location TW07 and screened intervals for the NML sampling station with approximately similar depth. NM = not measured, ND = not detected

Sampling Location	Dissolved As, ppb		Sampling Location	Dissolved As, ppb			
	April 4 2000	April 2 2001		April 5 2001	April 10 2001	May 14 2001	Sept. 13-14 2001
WN 150	ND	11	NML-3	NM	ND	33	30
TW07-1	*1705*	*879*	*TW07-1*	*880*	*NM*	*NM*	*812*
WN200	ND	15	NML-4	ND	33	60	349
WN250	904	15	NML-5	251	372	933	1718
TW07-2	*746*	*1066*	*TW07-2*	*1114*	*NM*	*NM*	*1334*
WN300	2040	257 [1]	NML-6	480	591	1179	2695
--	--	--	NML-7	844	1054	1253	3800
TW07-3	*81*	*130*	*TW07-3*	*174*	*NM*	*NM*	*209*
--	--	--	NML-8	1702	1576	1917	5043
--	--	--	NML-9	NM	NM	231	261

[1] WN300 depth was 310 cm on April 2, 2001.

3.4 HBHA Wetland and Wells G&H Wetland Sediments

Sediment grab samples were collected within the HBHA Wetland and the Wells G&H Wetland to assess the distribution and stability of sediment-associated arsenic down gradient of the HBHA Pond. Sediments were frozen immediately after collection and processed under an inert atmosphere within a glove box to prevent oxidation. Sediment pore water was collected from thawed sediments and characterized to assess geochemistry and arsenic concentration (see Table F.5). Sediment pore waters contained elevated concentrations of As ranging from approximately 160 to 670 ppb, which did not correlate directly with the sediment arsenic concentration for all sediments. Following removal of the major portion of pore water, the sediments were dried at room temperature within the glove box and then analyzed for total element concentrations (see Table F.6).

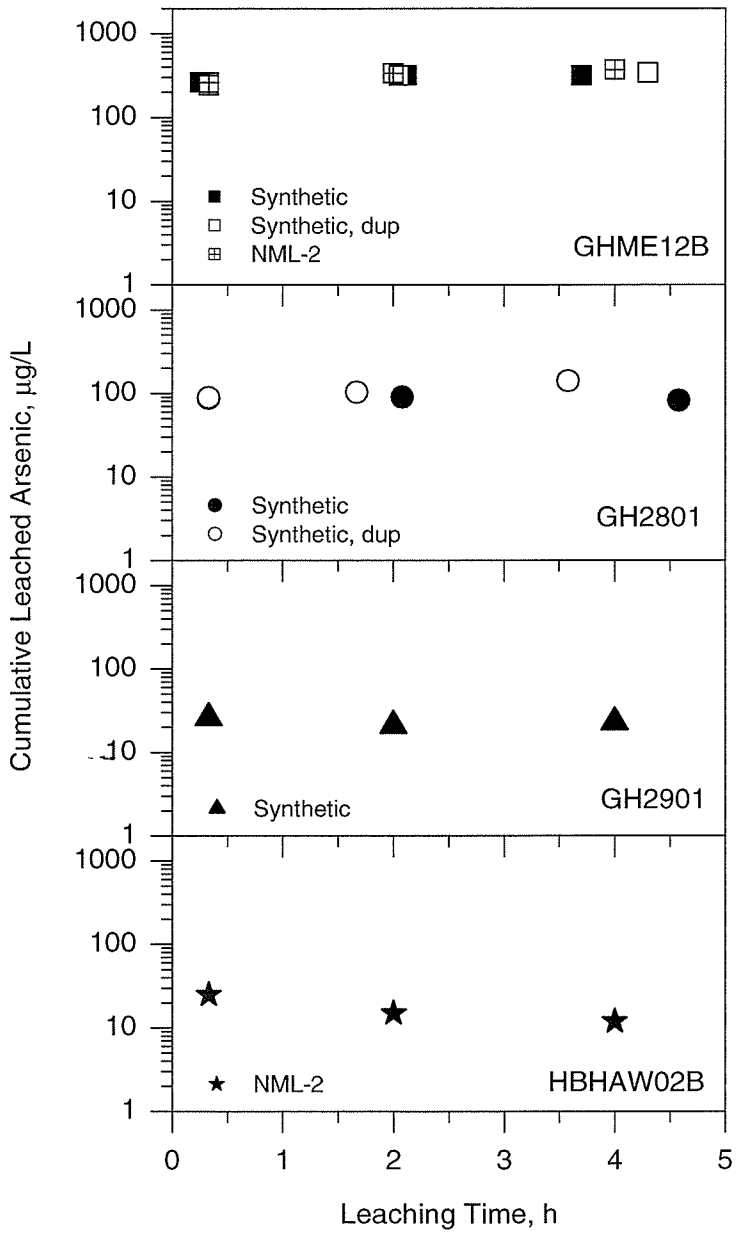
Arsenic release in the oxic leaching tests for the sediments are shown in Figure 8 and documented in Table F.7 (Appendix F). Measurements of the oxidation-reduction potential show that sediment suspensions become more oxidizing over time. In all cases, most of the leached arsenic had been released within a 30-minute reaction period (Figure 8, Table F.7). Sediment samples GHME12B and GH2801 showed the greatest As release with 341 ! 27 ppb (24 ! 1 μg/g sediment) and 112+42 ppb (3 ! 1 μg/g sediment) over a 4-hr period, respectively. Arsenic release was less for sediments GH2901 and HBHAW02B with concentrations of 23 ppb (0.2 μg/g sediment) and 12 ppb (0.1 μg/g sediment), respectively.

The extent of rapid arsenic release for all sediments indicates there is a relatively labile fraction of arsenic within the dried sediments. Since all sediment splits had residual pore water prior to drying, a portion of the rapidly released As could be attributed to re-dissolution of this As pool. The equivalent concentration of As derived from this source was estimated for all leach

experiments based on measured pore water concentrations and the mass of residual pore water in each split (see Table F.7). For sediments GHME12B and GH2801, residual pore water accounted for less than 4% and 26% of the leached As, respectively. In contrast, the estimated As concentration derived from residual sediment pore water could account for all of the leached arsenic for sediments GH2901 and HBHAW02B.

The concentration of leached As was consistently lower than the measured pore water concentration for all sediments samples. The in-place chemistry for these sediments was reducing based on the observation of high concentrations of ferrous iron. The oxidation of ferrous iron, leading to precipitation of iron oxides, is a likely process for the reduction in dissolved arsenic during sediment oxidation. However, as shown for sediments GHME12B and GH 2801, there is limited capacity for this process to prevent arsenic release and transport. Both sediment pore water measurements and oxic leach tests indicate that wetland sediments may be a long-term source of As to ground water and surface water. Consistent with observations in the HBHA Pond, the greatest risk of As release from sediments occurs under reducing conditions.

Figure 8. Arsenic released from wetland sediments (see Tables F.5 and F.6) as a function of time for oxic leach tests (see Table F.7). Explanation of legend descriptors: 'Synthetic' = synthetic shallow pond water, 'Synthetic, dup' = duplicate experiment with synthetic shallow pond water, 'NML-2' = water sample collected from NML-2 sampling location in HBHA Pond.



4.0 Conceptual Site Model

4.1 Arsenic and BTEX in Ground Water

The ground-water monitoring data collected during the period of this investigation indicate that arsenic and BTEX compounds derived from the ground-water aquifer underlying the Industri-Plex Superfund Site are discharged into the HBHA Pond. Current and historical data indicate that ground-water arsenic is derived from a much larger region than BTEX. The primary source of BTEX compounds originates from the eastern portion of the ground-water aquifer underlying the Industri-Plex Superfund Site. A general schematic for the distribution of these contaminants within the ground-water aquifer is shown in Figure 9. The concentration of dissolved arsenic observed at fixed monitoring points (tubing wells) indicate that there is an insignificant level of attenuation occurring within the ground-water aquifer upgradient to the HBHA Pond and Wetland. The site characterization effort for BTEX compounds under this investigation was insufficient for the purpose of delineating natural processes degrading these contaminants within the ground-water aquifer. The primary focus of the effort was to assess if these compounds were being discharged into the HBHA Pond and could thus serve as a source of degradable carbon. In this respect, the continued discharge of BTEX compounds into the HBHA Pond in part drives the microbial processes that govern the redox chemistry of this system.

4.2 Arsenic in HBHA Pond

The HBHA Pond was constructed in the early 1970s as a hydraulic equalization basin for flood control. The HBHA Pond is approximately 200 feet wide by 1100 feet long (in direction of water flow) and has a depth of approximately 20 feet in its deepest portion (see Figure A.7). The sides of the HBHA Pond are generally steep and the depth of water at the outlet is typically one foot or less during baseflow. The geometry of this basin coupled with the distinct difference

in surface water and ground water density are the likely cause for continued stratification of the water column. The impact of stratification within the HBHA Pond on the fate of As derived from ground water is discussed below.

In general, the geochemical processes active within the ground-water aquifer underlying the Industri-Plex Superfund Site and down gradient wetland area are similar to those observed at acid mine drainage sites. However, the ground water underlying the site is well buffered preventing acidification within the aquifer and down gradient wetland. Oxidative dissolution of iron sulfides contained within waste materials deposited on site results in the continued production of dissolved iron and sulfate (Davis et al., 1994). The aquifer redox chemistry is sufficiently reducing to facilitate transport and discharge of iron as Fe^{2+} into the HBHA Pond. In oxic zones within the HBHA Pond, the oxidation of Fe^{2+} results in the precipitation of iron oxides that scavenge dissolved arsenic concurrently discharged from the ground-water aquifer. Dissolved organic compounds (anthropogenic and natural) discharged into the HBHA Pond provide a readily degradable source of food for the microbial community within the sediments (Suarez and Rifai, 1999; Hertkorn et al., 2002/ and references therein). This microbial activity within the deeper portions of the HBHA Pond results in the generation of an anoxic zone in which iron and sulfate reduction processes are active. This redox stratification appears to be maintained for most of the year due to the stability of the chemocline within the water column. The formation and maintenance of this chemocline is driven by the discharge of primarily low conductivity water at shallow depths (Hall's Brook) and high conductivity water at deeper depths (site-derived ground water). The chemical stratification that is typical for the HBHA Pond is depicted in Figure 10.

The overall processes controlling arsenic chemical cycling within the HBHA Pond water column and sediments are depicted in Figure 11. As discussed previously, ground-water monitoring data indicate that there is a continual source of arsenic into the HBHA Pond. Water column measurements throughout the HBHA Pond indicate that the highest concentration of dissolved arsenic is confined to the deeper depths within the pond. The dissolved arsenic concentration near the sediment-water interface is generally higher than the predominant concentration of dissolved arsenic in ground-water discharge. The mass of dissolved arsenic in the HBHA Pond water column is controlled by a balance between the observed sources and removal processes listed below:

Source 1) ground-water discharge
2) suspended solid or sediment dissolution and re-suspension

Removal 1) sorption to solids deposited in the sediment
2) sorption to suspended solids produced by iron oxidation-precipitation
3) discharge at the HBHA Pond outlet

The concentrations of solid phase arsenic observed in the sediments and the dissolved arsenic observed near the sediment-water interface indicate that there is incomplete removal onto sediments. Sediment solids rich in iron, sulfur and organic matter sequester a fraction of the total arsenic at the sediment-water interface. It is unclear which of these phases controls arsenic partitioning during deposition. The remaining fraction of total arsenic at the sediment-water interface can be attributed to ground-water discharge and dissolution of iron oxides. Dissolved arsenic derived from these two inputs diffuses upward within the water column and is sequestered from solution during oxidation and precipitation of ferrous iron at the oxic-anoxic interface. The production and dissolution of iron oxides behaves as a steady-state process as long as the chemical stratification is maintained within the water column. Thus, while dissolved

arsenic concentrations can become high at depth, shallow water in the oxic zone remains much lower in dissolved arsenic.

A vertical profile of select chemical parameters is shown in Figure 12. These vertical profiles show a snap shot in time of the outcome of the competition between suspended solids or sediment dissolution and ferrous iron oxidation-precipitation at the oxic-anoxic interface within the water column. Dissolved Fe and As concentrations decline to near-zero values at a depth above the oxic-anoxic interface. A turbidity maximum is also observed at this interface, which can be attributed, in part, to the observed maximum in particulate iron. The particulate iron is dominated by iron oxides, which serve as a sink for arsenic. As the iron oxides settle back to the sediment-water interface, they begin to dissolve via reductive mechanisms causing the reduction in turbidity and particulate iron, and, subsequently, the release of arsenic.

Generalized chemical reactions controlling arsenic distribution between the sediments and the water column are depicted in Figure 13. Oxygen at shallow depth is derived from discharge from Hall's Brook and gas exchange at the air-water interface. The Atlantic Avenue Drainway may also serve as an intermittent source of oxygen. Electrons involved in iron- and sulfate-reducing processes are derived from microbial degradation of organic matter within the water column and sediments. Natural and contaminant dissolved organic compounds within the HBHA Pond water column provide a substrate for microbial metabolism, which controls the redox chemistry of the system. Wick et al. (2000) have observed that benzene degradation rates are greatest in the aerobic zone within the HBHA Pond, but degradation of fuel components can still be an active process in anaerobic zones (Suarez and Rifai, 1999). While ferrous sulfides are a likely source for arsenic uptake at the bottom of the HBHA Pond water column, insufficient

data is available to rule out sorption to other solids that are formed or deposited at the sediment-water interface.

Figure 9. Generalized schematic of arsenic and BTEX plumes in the ground-water aquifer upgradient from the HBHA Pond and Wetland. Image was derived from May 1995 aerial photograph obtained from MassGIS.

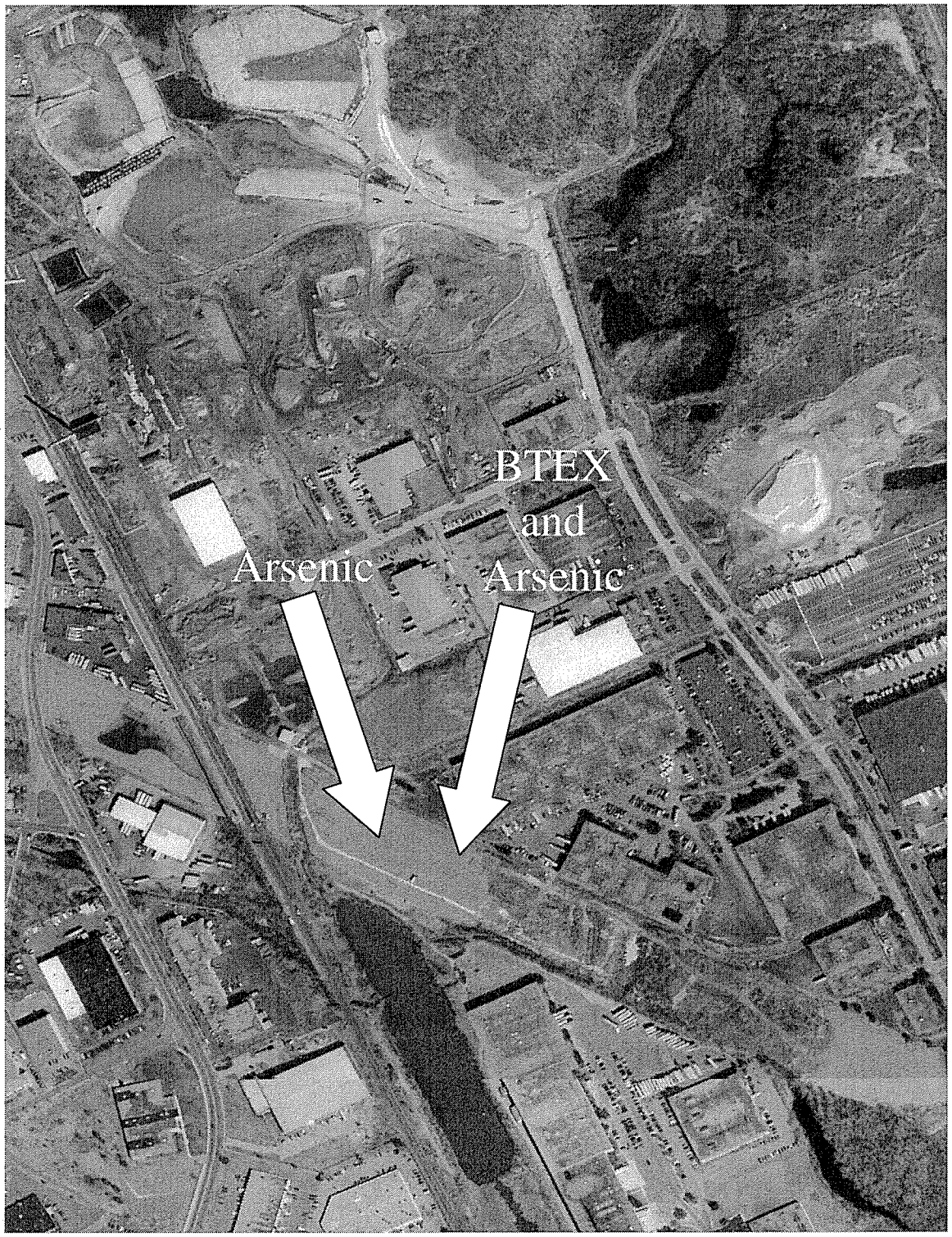


Figure 10. Conceptual diagram depicting important processes controlling water column chemistry in the HBHA Pond. Predominant inputs of water into the HBHA Pond include site-derived ground water and Hall's Brook. The inset graph depicts the chemical stratification that is common throughout the year. Iron and sulfate reduction processes are active at the sediment-water interface and within the shallow sediments.

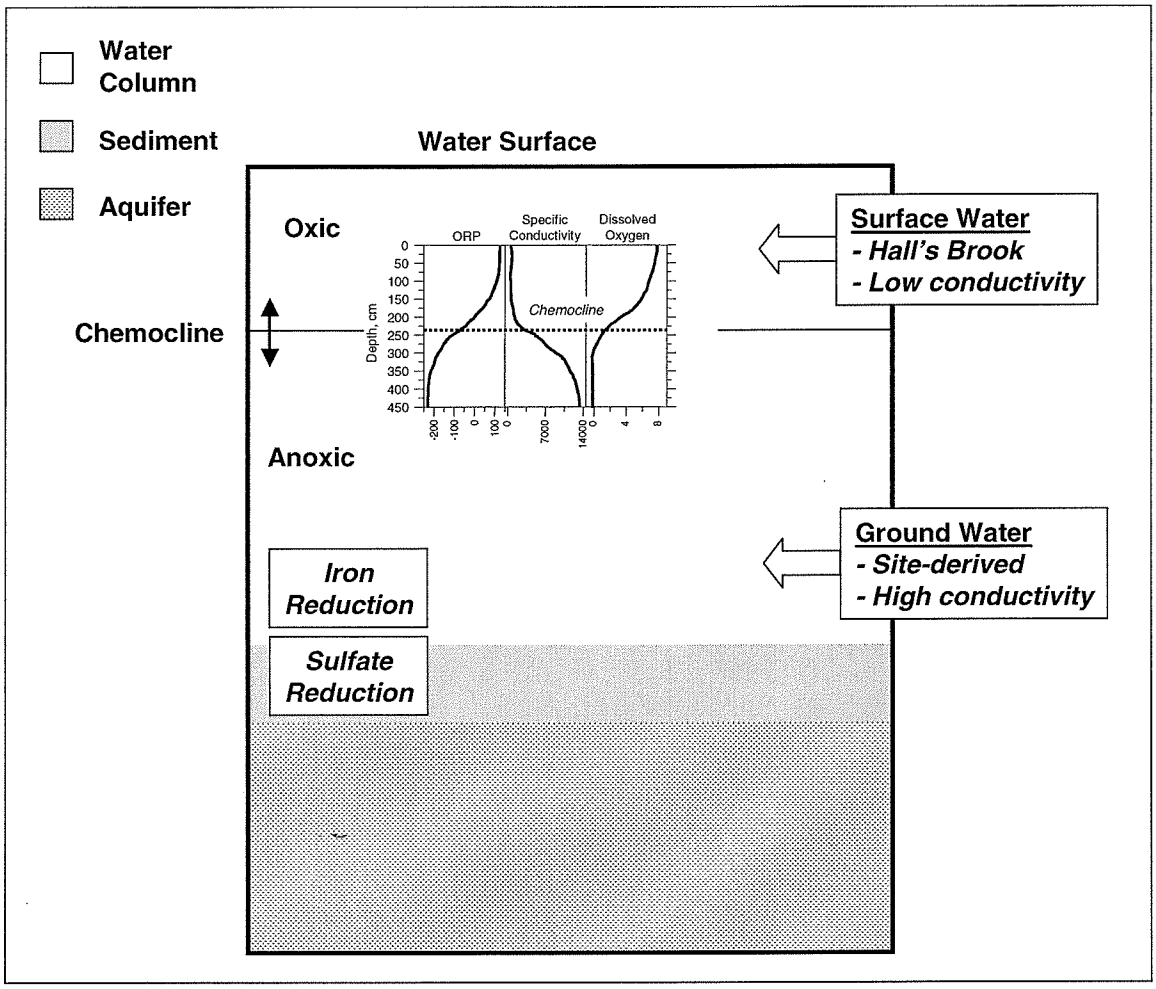


Figure 11. Diagram of the general processes controlling arsenic distribution between surface water and sediments within the HBHA Pond. Surface water inputs of arsenic include discharge of site-derived ground water and dissolution/re-suspension of contaminated sediments. Removal of arsenic from surface water occurs during iron oxidation-precipitation and settling at the chemocline and partitioning of arsenic to reduced sediments during diagenesis.

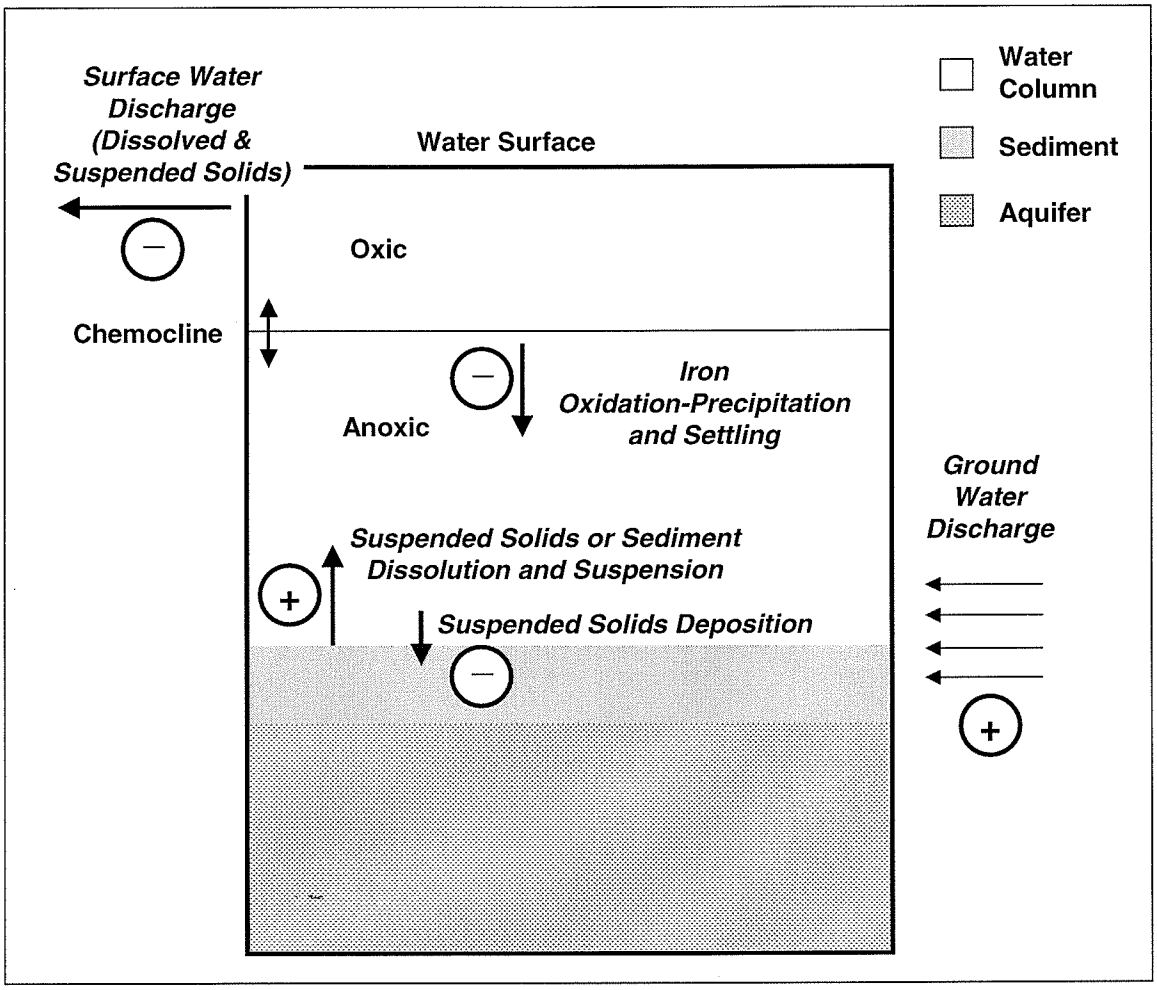


Figure 12. Depth trend for HBHA Pond geochemistry and dissolved/particulate As/Fe for South sampling location during December 1999. Particulate As/Fe was calculated by difference between total As/Fe in unfiltered and filtered samples. The concentration maximum for particulate Fe and As coincide with the turbidity maximum within the water column at this location.

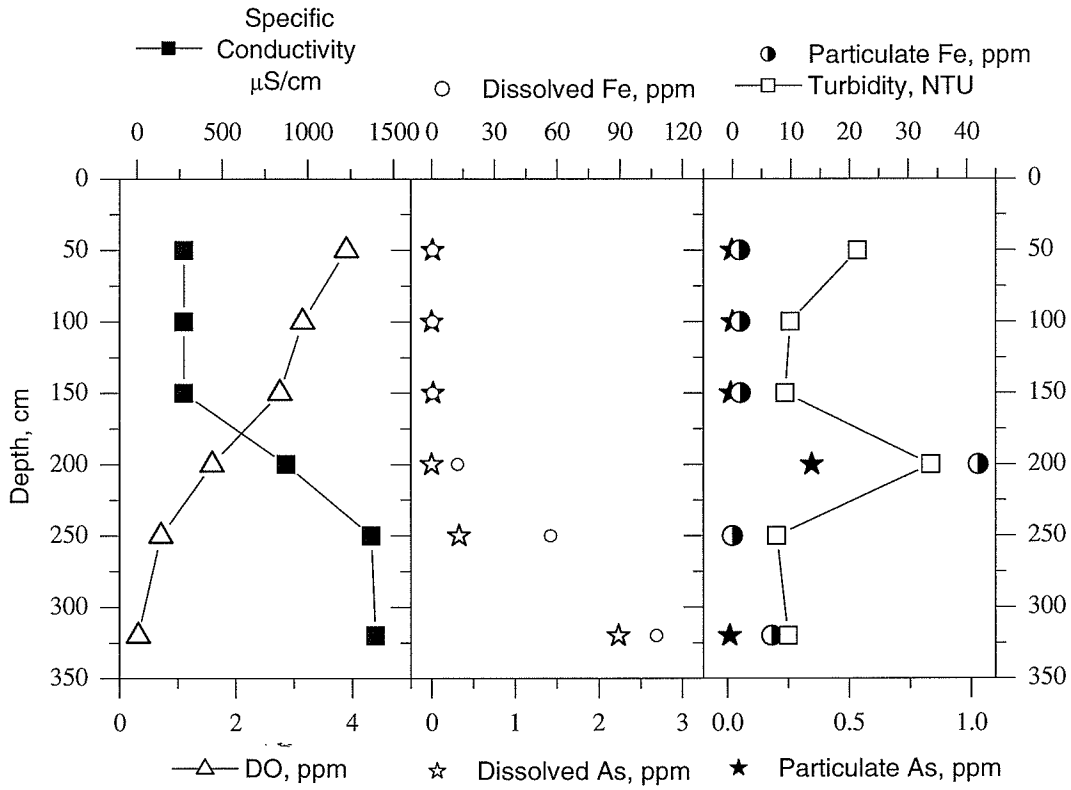
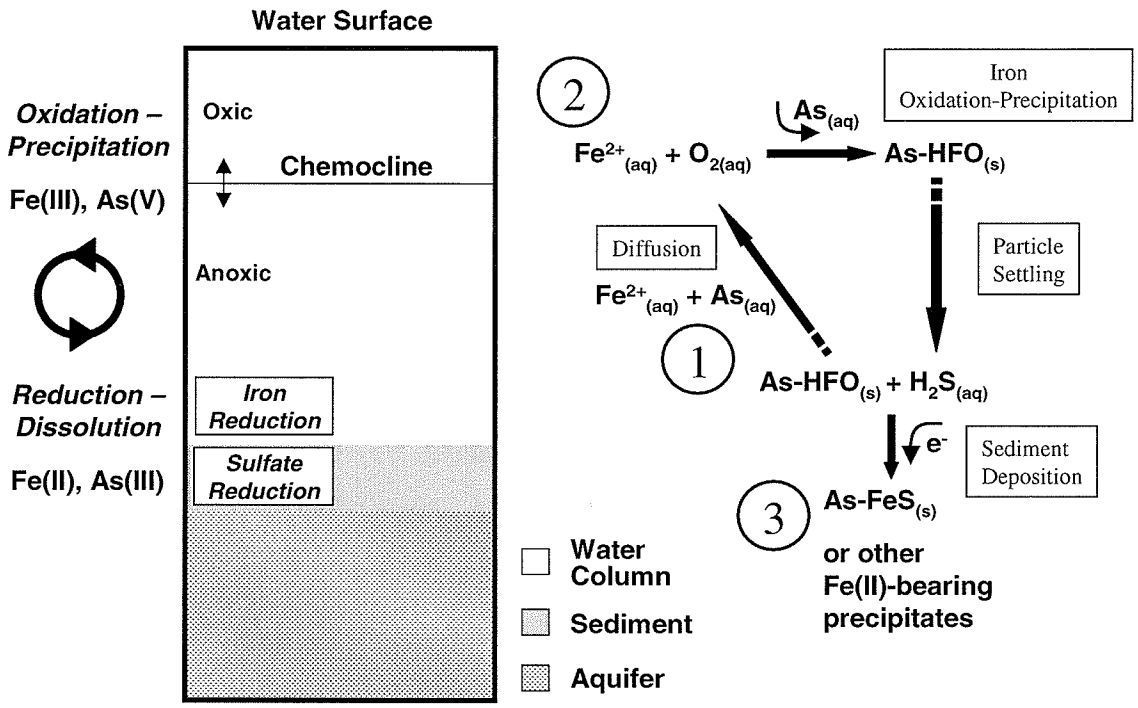


Figure 13. A general schematic of the chemical reactions controlling the internal iron and arsenic distribution between the aqueous phase and solid phase within the HBHA Pond. 1) Arsenic bound to authigenic ferric oxides is desorbed during reductive dissolution. 2) Dissolved arsenic is sorbed to ferric oxides precipitating at the chemocline due to ferrous iron oxidation. 3) Arsenic is repartitioned to ferrous sulfides or other Fe(II)-bearing precipitates during reductive dissolution of authigenic ferric oxides that settle out from the chemocline.



5.0 Assessment of Remedial Alternatives

5.1 Natural Attenuation Processes within HBHA Pond

Assessment of ground-water data collected during the ORD NAS and historic data collected within the Industri-Plex Superfund Site and GSIP Study Area indicate that the primary discharge point for contaminated ground water is into the HBHA Pond. Long-term monitoring at the HBHA Pond surface water discharge indicates that dissolved arsenic is typically below a concentration of 100 ppb. This indicates that arsenic discharged via site-derived ground water is partially sequestered within the HBHA Pond. However, observed release of arsenic from shallow sediments confirms the instability of iron oxides deposited on the bottom of the HBHA Pond. Although the HBHA Pond retains a significant fraction of As derived from ground-water discharge, it still supplies a continual flux of As to down gradient wetlands and the Aberjona River.

The critical factors maintaining arsenic at depth within the HBHA Pond hypolimnion are 1) the presence of a fairly stable chemocline and 2) the high capacity for arsenic sorption to iron oxides (Ford, 2002) formed at the oxic-anoxic transition zone. The capacity for arsenic sequestration from the HBHA Pond water column is dependent on a continual supply of ferrous iron into the system. The arsenic sequestration capacity will decline concurrent with a decline in ferrous iron from the upgradient aquifer. Since performance of the HBHA Pond for arsenic removal is also dependent on continued stratification of the water column, assessment of the long-term sedimentation capacity is also an important factor. The bathymetric profile of the HBHA Pond shown in Figure A.7 (Appendix A) indicates that the western portion of the pond (1-2 meters or 3-7 feet) is shallower than the eastern portion (>3 meters or >9 feet). Presumably this bathymetric profile is in part due to sediment deposition from Hall's Brook and the AAD.

Projections of sediment erosion or turnover within the HBHA Pond will depend on knowledge of modifications of the pond geometry over time.

Since the source term for arsenic (and iron) within the upgradient aquifer is poorly defined, it is difficult to assess the long-term capacity of the HBHA Pond. Given this level of uncertainty, it is recommended that a long-term monitoring strategy be implemented that continuously tracks arsenic and redox chemistry within the aquifer and the HBHA Pond. A proposed strategy is outlined below. Recommendations for site monitoring and potential remediation apply only to discharge of contaminated ground water into the HBHA Pond and are not intended to address potential contaminant migration in surface water and ground water down gradient from the HBHA Pond.

5.2 Engineered In-situ Technologies

Mitigation of arsenic discharge from the Industri-Plex Superfund Site to the down gradient wetland would benefit from control of arsenic release from suspected on-site source terms. However, the feasibility of this approach is limited by the widespread distribution of contaminated soils and hide piles throughout the site. Ground-water monitoring data from this study and historic site assessment activities indicate that there has been little diminution in the concentration of arsenic in site-derived ground water. The extent to which the HBHA Pond could continue to serve as a partial sink for arsenic would be extended by elimination of ground-water inputs of arsenic. This could be achieved via emplacement of a permeable barrier that would intercept and remove arsenic from the ground-water contaminant plume prior to discharge into the HBHA Pond. The use of zero valent iron (ZVI) as a reactive media for arsenic removal has been evaluated at the bench scale (Lackovic et al., 2000; Su and Puls, 2001). These studies show that ZVI has a significant capacity for arsenic removal, but there are no long-term studies

to evaluate the longevity of this removal capacity and the stability of sequestered arsenic. Long-term monitoring at sites where ZVI has been used to treat TCE and chromium ground-water contamination indicate that high specific conductivity water reduces the performance capabilities of this material (Wilkin et al., 2002). However, it should also be noted that the chemistry controlling arsenic sequestration in the HBHA Pond is in part poised by the characteristics of the discharging ground water. Changes in ground-water composition, such as a reduction in dissolved iron concentration, are expected to negatively impact the performance of the HBHA Pond for arsenic removal. Given these limitations, there is no immediate advantage to installation of a permeable reactive barrier over a long-term monitoring strategy for the HBHA Pond. In addition, treatment of up gradient ground water will only remove one of the sources of As to the down gradient wetlands and the Aberjona River. Release of sediment-bound As will still act as a second source for contaminant migration.

5.3 Long-Term Site Monitoring

As stated in Section 5.1, the HBHA Pond currently serves to remove a fraction of the ground-water arsenic derived from the Industri-Plex Superfund Site. However, the ability of the HBHA Pond to function in this capacity over the long term will be controlled by 1) continued maintenance of the chemical stratification within the water column and 2) continued supply of iron and sulfate from site ground water for the production of iron oxides and sulfides.

As shown via HBHA Pond water column sampling during April 2001, high surface water flow events can perturb the chemical stratification. While the chemocline was re-established within the HBHA Pond, there is insufficient monitoring data to track the impact of these transient flow events on the long-term performance of the HBHA Pond for arsenic sequestration. Forecasting the impact of surface flow events is critical due to site development, which can

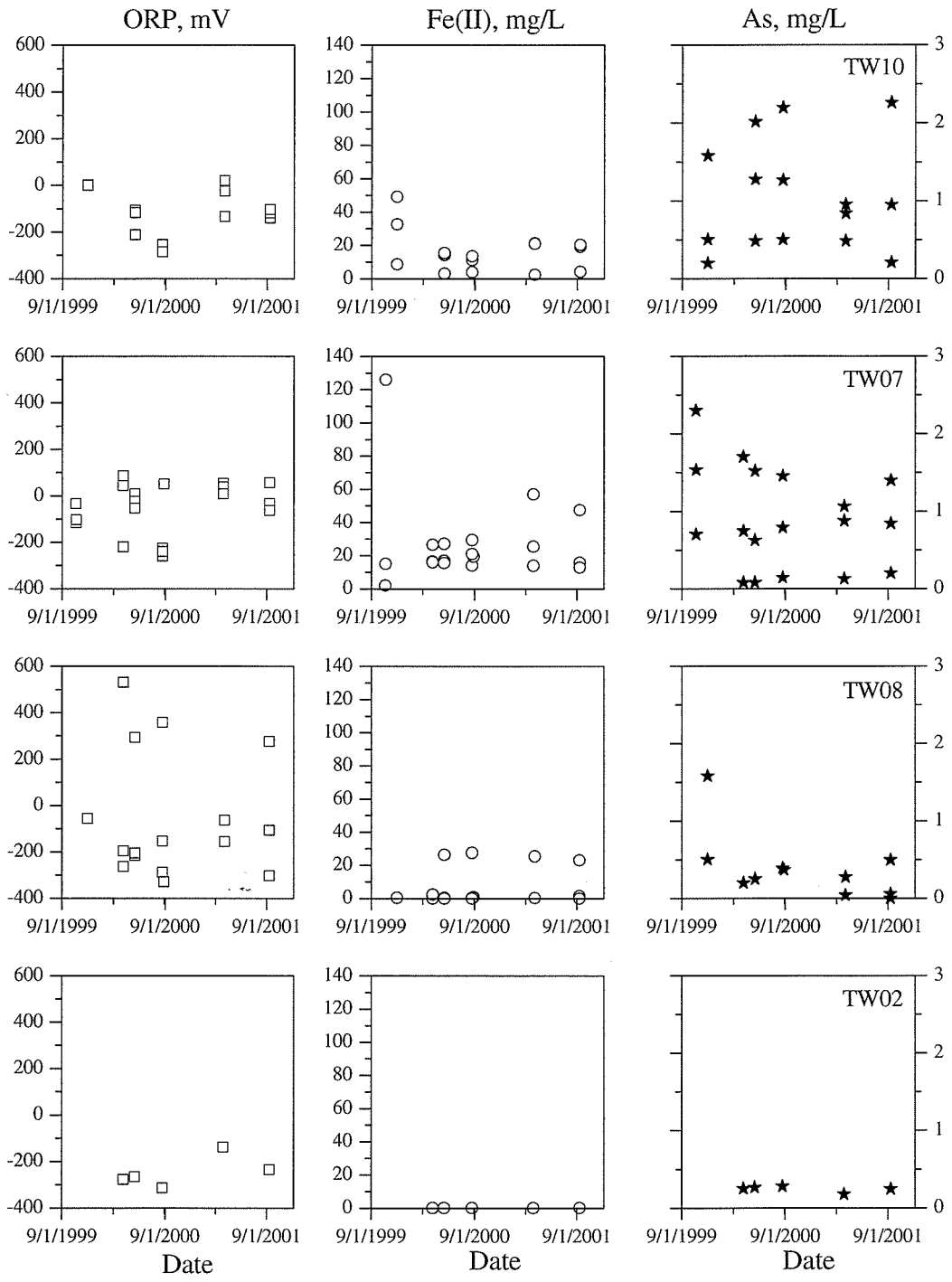
modify patterns in surface runoff into the HBHA Pond via the Atlantic Avenue Drainway. It is recommended that a long-term monitoring program incorporate input and output flow measurements for the HBHA Pond in order to establish whether the major flow event occurring at the end of March 2001 was anomalous or is likely to occur on a more frequent basis. Note that continued discharge from Hall's Brook should be maintained, since this continuous source of fresh water helps maintain chemical stratification within the HBHA Pond. As demonstrated by depth-resolved measurements, the highest concentration of dissolved As occurs at the bottom of the HBHA Pond and is relatively invariant throughout the year. This mass of dissolved As will be distributed throughout the water column during turnover, leading to increased mass flux of As at the shallow outlet. This is a critical factor, since the HBHA Pond is a potential long-term source of arsenic transport to the Aberjona River.

Site development may also exert an influence on the geochemistry of the shallow aquifer underlying the Industri-Plex Superfund Site. The paved area adjacent to the Regional Transportation Center (RTC) limits the amount of oxygen introduced into the shallow aquifer by gas exchange or recharge from precipitation. It is suspected that chemical conditions within this region of the saturated aquifer will become more reducing over time. It is uncertain what impact changes in aquifer redox chemistry will exert on the long-term release and mobility of arsenic. Examination of trends in ORP, dissolved ferrous iron and dissolved arsenic for a representative set of ground-water monitoring locations over time do not reveal a change in aquifer redox chemistry since the installation of the Regional Transportation Center (Figure 14). However, insufficient time may have passed to observe large-scale changes in aquifer chemistry, since this development was completed in late Fall 2000. The RTC overlies a region of the aquifer in which high arsenic concentrations were observed at the beginning of this study period (see discussion

of snap-shot ground water locations in Section 2.1). Since the RTC property occupies most of the area that can be developed on the western portion of the site (see Figure A.5, Appendix A), it is anticipated that post-installation monitoring data will be of value for projecting future arsenic flux into the HBHA Pond.

It is recommended that a more comprehensive site monitoring strategy be implemented in the near-term to better track performance of the HBHA Pond system and detect possible failure. The current focus for site monitoring has entailed extensive evaluation of surface water inputs and discharge points within the HBHA down to Mishawaum Road. In order to properly assess system performance, it is recommended that a permanent ground-water monitoring network be established within the aquifer upgradient and down gradient to the HBHA Pond. The network should be sufficient to document the extent of the arsenic contaminant plume and its elimination down gradient to the HBHA Pond. Contaminants of concern and the general redox chemistry of ground water should be monitored concurrent with surface water sampling events. In general, quarterly sampling will provide sufficient frequency to monitor the dynamics of the ground-water plume and the HBHA system, but it is recommended that additional efforts be made to assess system response to storm events. Consistent with requirements set forth in the EPA OSWER Directive on monitored natural attenuation, establishing a long-term monitoring plan for performance monitoring and evaluation is a critical component to application of this remedial technology (USEPA, 1999). Assessment of seasonal patterns in arsenic mobility and sequestration within the HBHA Pond is required to establish the long-term viability of natural attenuation as a partial remedy to mitigate arsenic discharge down gradient to the HBHA Wetland and Aberjona River.

Figure 14. Time trends in oxidation-reduction potential (ORP), dissolved ferrous iron, and dissolved arsenic at ground-water monitoring locations down gradient from the Regional Transportation Center located within the Industri-Plex Superfund Site boundary. Locations of ground-water monitoring points are shown in Figure A.5 (Appendix A). Data from all depths are shown together for locations TW10, TW07 and TW08.



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Appendix A

Summary of maps showing ground-water, surface water, and sediment sampling locations within the Industri-Plex Superfund Site and GSIP Study Area, and results of bathymetric survey in HBHA Pond.

Figure A.1. Prominent land features within the Industri-Plex Site and GSIP Study Area. Image was derived from May 1995 aerial photograph obtained from MassGIS.

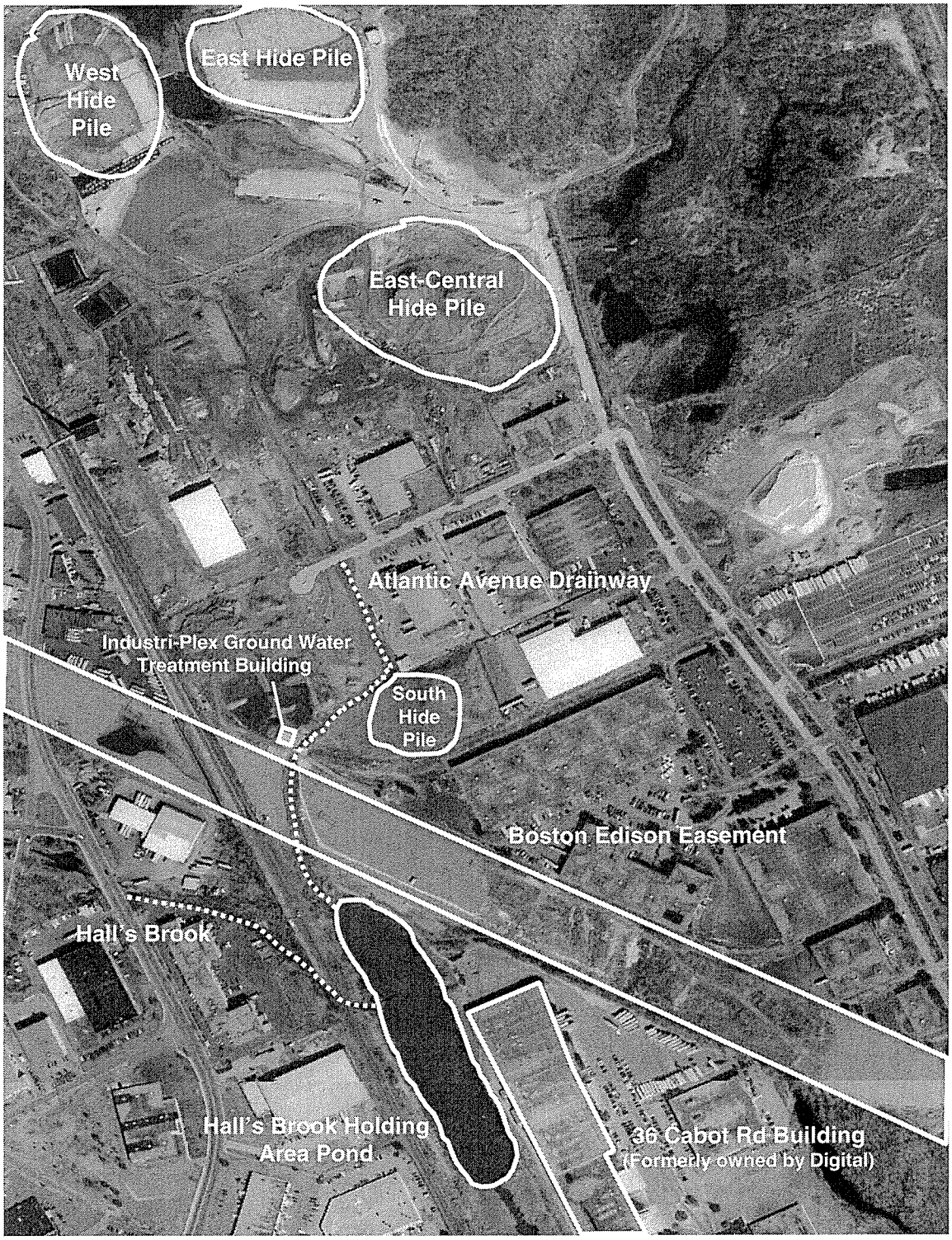


Figure A.2. Snap-shot ground water sampling locations for the Industri-Plex Site and GSIP Study Area. Image was derived from May 1995 aerial photograph obtained from MassGIS.

Figure A.3. Snap-shot ground water sampling locations for the Industri-Plex Site and GSIP Study Area. Image was derived from April 2001 aerial photograph obtained from MassGIS.

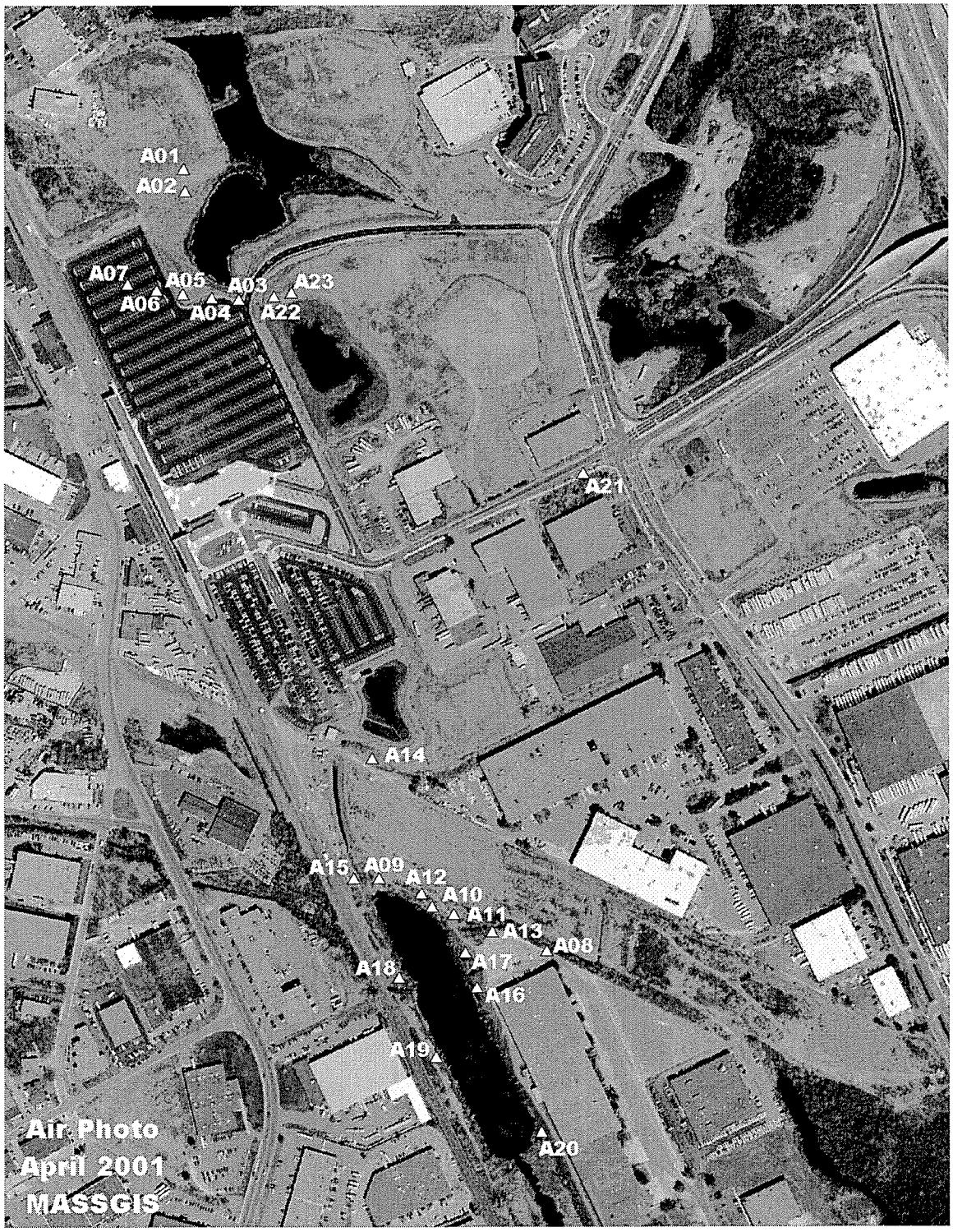


Figure A.4. Fixed ground water monitoring locations for the Industri-Plex Site and GSIP Study Area. Image was derived from May 1995 aerial photograph obtained from MassGIS.

Figure A.5. Fixed ground water monitoring locations for the Industri-Plex Site and GSIP Study Area. Image was derived from April 2001 aerial photograph obtained from MassGIS.

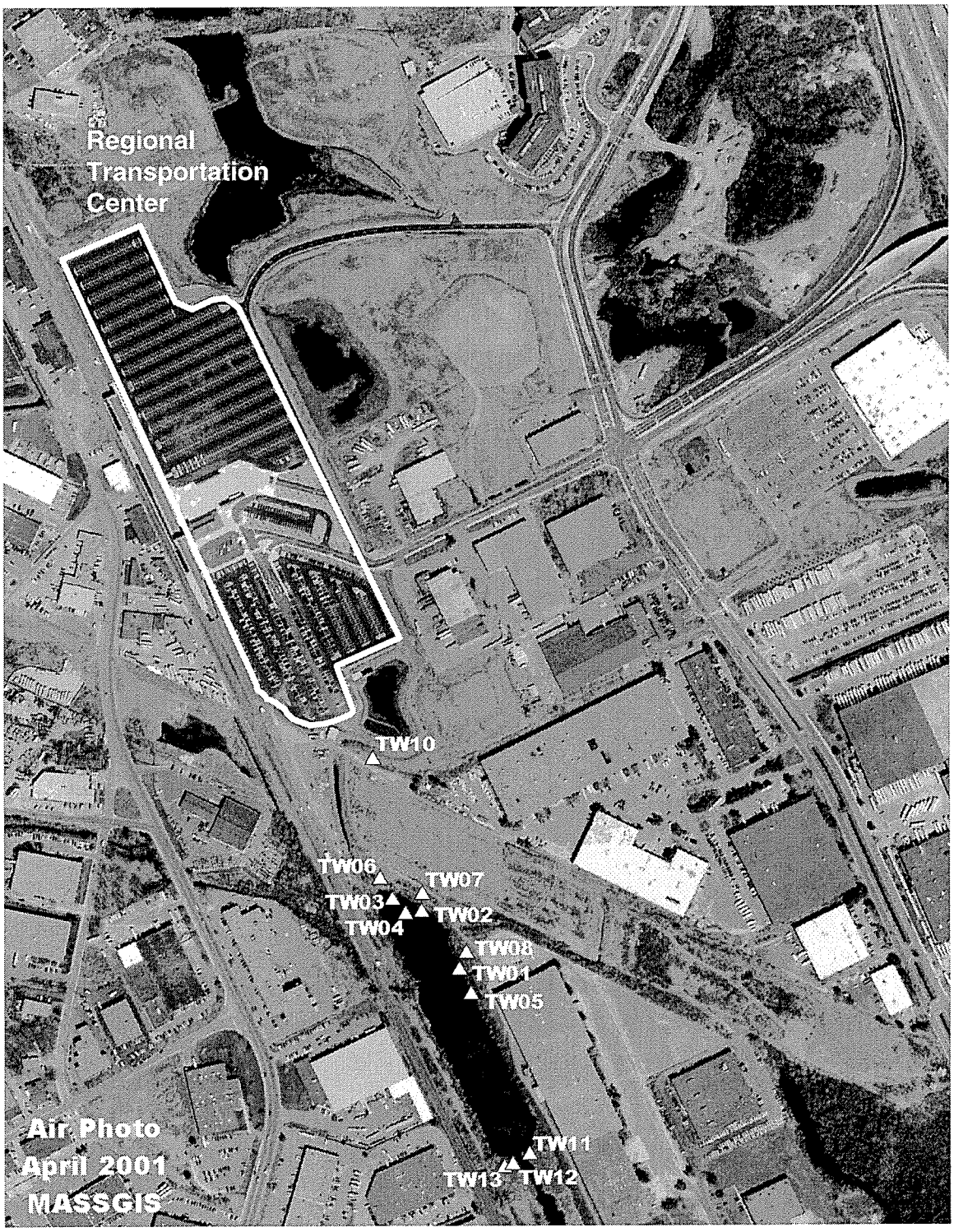


Figure A.6. Location of the data collection transects used to develop a bathymetric survey of depth to sediment within the HBHA Pond. The number of GPS and water depth readings is indicated for each transect. The north (WN), central (WC), and south (WS) surface water sampling locations are also shown. Image was derived from April 2001 aerial photograph obtained from MassGIS.

Figure A.7. Results of bathymetric survey for depth to sediment within the HBHA Pond. Contours are shown at one meter intervals. The north (WN), central (WC), and south (WS) surface water sampling locations are also shown. Image was derived from April 2001 aerial photograph obtained from MassGIS.

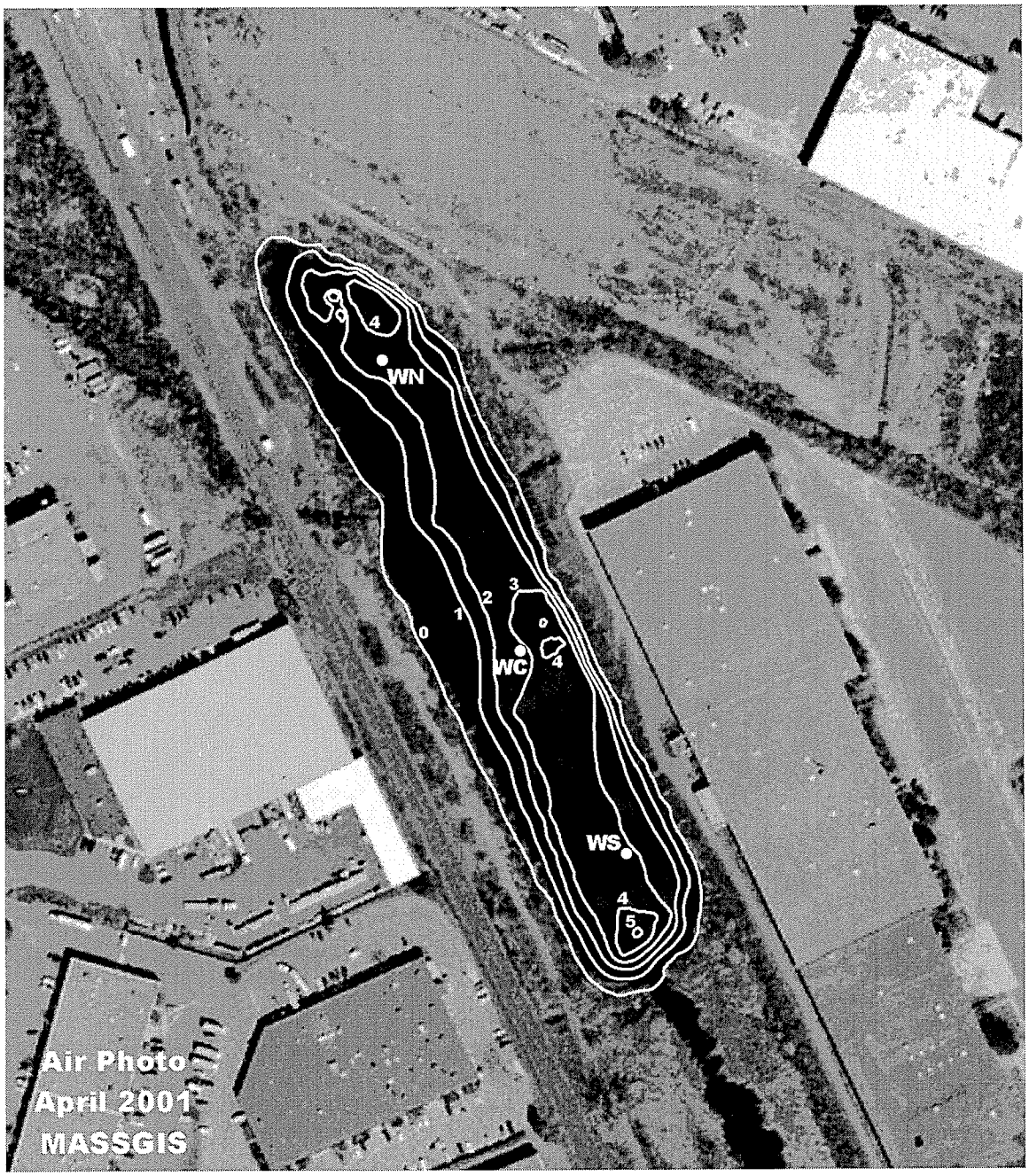


Figure A.8. Surface water and sediment porewater monitoring locations within the Hall's Brook Holding Area Pond. Image was derived from November 1995 aerial photograph obtained from MassGIS.

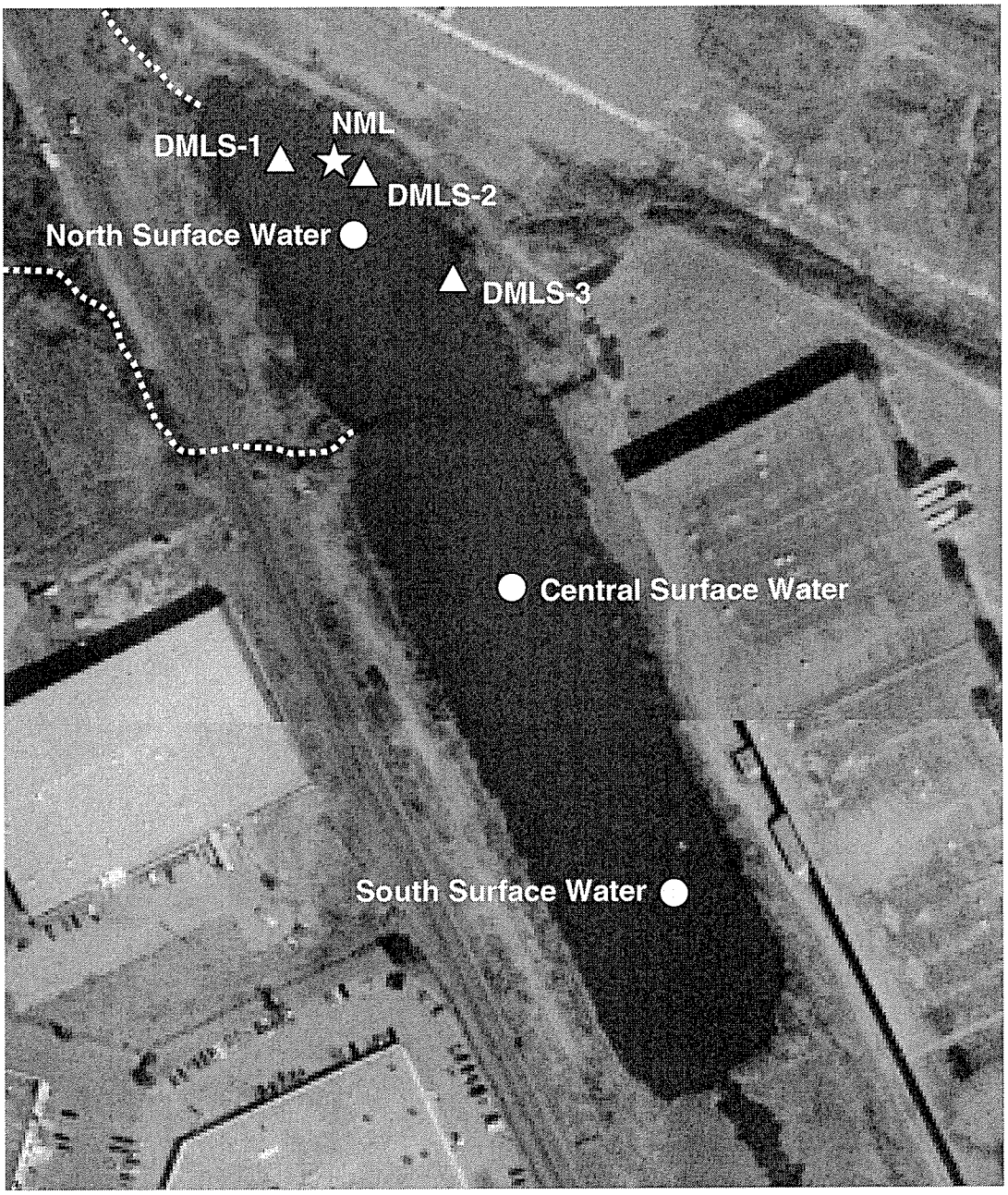
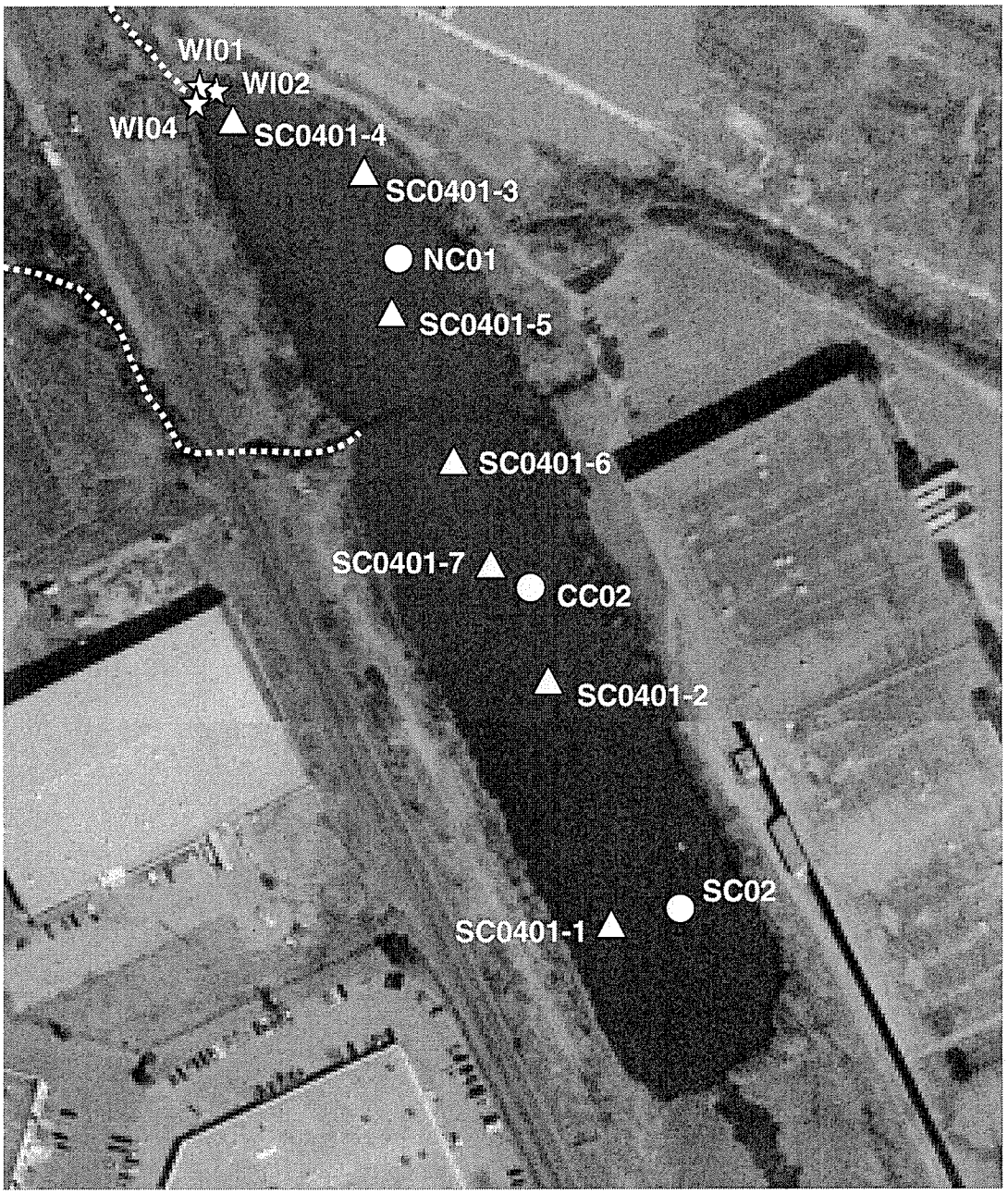


Figure A.9. Location of sediment samples collected from Hall's Brook Holding Area Pond. Symbol notations: ♠ solids pumped from sediment-water interface, sediment cores collected using Geoprobe® coring device with 2" sleeves, ★ shallow grab samples. Image was derived from November 1995 aerial photograph obtained from MassGIS.



Appendix B

Summary of locational data for snap-shot and fixed ground-water monitoring locations.

Table B.1. Latitude and longitude for sampling points within the Industri-Plex Site and GSIP Study Area. Data was collected using a Trimble GPS according to USEPA Region 1 SOP and are referenced to NAD83.

Location ID	Latitude (North)			Longitude (West)		
	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds
A01	42	31	15.364	71	8	40.007
A02	42	31	14.581	71	8	39.961
A03	42	31	10.659	71	8	37.343
A04	42	31	10.724	71	8	38.676
A05	42	31	10.873	71	8	40.078
A06	42	31	11.013	71	8	41.343
A07	42	31	11.225	71	8	42.751
A08	42	30	47.078	71	8	22.526
A09	42	30	49.736	71	8	30.642
A10	42	30	48.699	71	8	28.078
A11	42	30	48.435	71	8	27.032
A12	42	30	49.188	71	8	28.574
A13	42	30	47.775	71	8	25.175
A14	42	30	54.093	71	8	30.937
A15	42	30	49.732	71	8	31.876
A16	42	30	45.771	71	8	25.942
A17	42	30	47.046	71	8	26.491
A18	42	30	46.132	71	8	29.666
A19	42	30	43.261	71	8	27.943
A20	NM					
A21	42	31	4.331	71	8	20.650
A22	42	31	10.765	71	8	35.631
A23	42	31	10.899	71	8	34.783
TW01	NM					
TW02	42	30	48.537	71	8	28.605
TW03	42	30	48.991	71	8	30.033
TW04	42	30	48.456	71	8	29.399
TW05	NM					
TW06	42	30	49.736	71	8	30.642
TW07	42	30	49.188	71	8	28.574
TW08	42	30	47.046	71	8	26.491
TW10	42	30	54.093	71	8	30.937
TW11	NM					
TW12	NM					
TW13	NM					

Table B.2. Northing and easting positional data for sampling points within the Industri-Plex Site and GSIP Study Area (UTM Z19 NAD83).

Location ID	Northing (meters)	Easting (meters)
A01	4709850	323854.3
A02	4709820	323854.7
A03	4709700	323911.4
A04	4709700	323881.0
A05	4709710	323849.2
A06	4709710	323820.4
A07	4709720	323788.5
A08	4708960	324231.1
A09	4709050	324048.0
A10	4709020	324105.7
A11	4709010	324129.4
A12	4709030	324094.8
A13	4708990	324171.2
A14	4709180	324044.7
A15	4709050	324019.8
A16	4708930	324152.2
A17	4708960	324140.6
A18	4708940	324067.5
A19	4708850	324104.5
A20	NM	NM
A21	4709494.549	324287.3875
A22	4709701.65	323950.5582
A23	4709705.294	323970.0125
TW01 [1]	4708947.11	324144.871
TW02	4709011.95	324093.554
TW03	4709026.78	324061.32
TW04	4709009.91	324075.371
TW05 [1]	4708909.61	324152.671
TW06	4709050.11	324048.003
TW07	4709032.01	324094.769
TW08	4708967.74	324140.634
TW10	4709180	324044.7
TW11	NM	NM
TW12	NM	NM
TW13	NM	NM

[1] Position for TW01 estimated based on distance from TW08. Position for TW05 estimated based on distance from A16 sampling location.

Appendix C

Summary of geochemical parameters for ground water and surface water sampling performed within the Industri-Plex Superfund Site and the GSIP Study Area.

Table C. 1. Summary of field geochemical data collected during snap-shot ground water sampling on October 13-21, 1999 at the Industri-Plex Site and GSIP Study Area. The following abbreviations are used within the table: ft bgs = feet below ground surface, COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NM = not measured.

Location	Date	Screen Depth ft bgs	Depth to Water Table ft	Depth to Bedrock ft bgs	Temp. °C	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
A01-1	10/14/99	32.75	NM	NM	NM	3470	6.62	-140.0	NM	NM	>1000	NM	NM
A01-2	10/15/99	41.75	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A02-1	10/14/99	12.00	2.25	14.08	NM	2870	6.70	-119.1	0.29	>0.04, <1	77.0	16.40	1035
A03-1	10/15/99	9.00	1.00	22.00	NM	2090	6.61	-39.5	0.55	0.30	78.0	2.91	273
A03-2	10/15/99	19.00	11.00	22.00	NM	818	6.66	-55.7	0.36	0.30	43.0	2.93	159
A04-1	10/15/99	15.00	5.29	32.50	NM	1345	6.92	-140.1	0.14	0.04	40.0	2.14	431
A04-2	10/15/99	24.75	15.04	32.50	NM	NM	NM	NM	NM	NM	NM	5.35	NM
A04-3	10/15/99	32.50	22.79	32.50	NM	NM	NM	NM	NM	NM	NM	2.27	233
A05-1	10/15/99	8.50	NM	8.50	NM	1330	6.72	-137.2	0.14	NM	5.1	2.54	452
A06-1	10/18/99	15.50	NM	27.50	NM	2270	7.27	-148.1	0.2	0.10, 0.04	20.9	1.69	738
A06-2	10/18/99	25.50	NM	27.50	NM	1656	6.26	-7.1	0.19	0.20	101.0	1.16	409
A07-1	10/18/99	13.50	NM	NM	NM	854	6.03	14.4	0.58	0.04	7.0	1.73	194
A07-2	10/18/99	23.50	NM	NM	NM	974	6.39	-83.7	0.63	NM	201.0	1.49	148
A08-1	10/19/99	9.00	3.42	64.00	7.50	296	6.72	-33.6	0.53	0.40	2.9	2.89	79
A08-2	10/19/99	19.00	13.42	64.00	8.10	730	6.57	-47.3	0.92	0.02	75.3	1.75	240
A08-3	10/19/99	39.00	33.42	64.00	NM	5560	7.07	-116.5	--	NM	>1000	8.55[1]	1500
A09-1	10/19/99	12.50	2.83	47.08	NM	308	6.14	40.3	0.34	0.30	6.5	0.84	43
A09-2	10/19/99	22.50	12.83	47.08	11.40	NM	NM	NM	NM	NM	NM	2.55[1]	184
A09-3	10/19/99	43.00	33.33	47.08	NM	NM	NM	NM	NM	NM	NM	NM	NM
A10-1	10/20/99	10.00	NM	NM	NM	1673	6.46	-107.0	0.2	0.10	2.1	1.30	375
A10-2	10/20/99	20.00	NM	NM	11.10	5250	7.14	-195.0	0.34	0.35	7.3	1.93	144
A10-3	10/20/99	30.00	NM	NM	11.60	13220	7.51	-260.0	0.05	0.35	8.9	1.56	6460
A11-1	10/20/99	10.50	1.67	NM	NM	1046	6.68	-76.7	0.25	0.40	2.5	1.43	302
A11-2	10/20/99	20.50	11.67	NM	NM	11620	7.80	-155.4	0.19	0.10	50.0	0.41	6350
A11-3	10/20/99	30.50	21.67	NM	NM	11220	7.79	-73.8	0.06	0.50	46.1	1.48	2100
A12-1	10/20/99	12.00	4.70	NM	12.80	1456	6.19	-34.0	0	0.15	27.7	1.99	236
A12-2	10/21/99	22.00	14.70	NM	11.90	3310	6.37	-116.0	0.13	0.15	195.0	126.00	404
A12-3	10/21/99	32.00	24.70	NM	12.60	3590	6.58	-102.0	0.02	0.10	52.3	15.10	456
A13-1	10/20/99	7.50	1.08	45.00	NM	242	6.88	-18.5	0.42	0.15	9.6	1.24	65
A13-2	10/20/99	17.50	11.08	45.00	NM	21500	8.04	-237.4	0.04	0.10	181.0	0.80	12080
A13-3	10/20/99	34.50	28.08	45.00	NM	NM	NM	NM	NM	NM	NM	NM	NM
A13-4	10/20/99	45.00	38.58	45.00	NM	NM	NM	NM	NM	NM	NM	NM	NM

[1] Filtered through 0.45 µm pore size membrane filter.

Table C.2. Summary of field geochemical data collected during snap-shot ground water sampling on November 30 – December 3, 1999 at the Industri-Plex Site and GSIP Study Area. The following abbreviations are used within the table: ft bgs = feet below ground surface, COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Screen Depth ft bgs	Depth to Water Table ft	Depth to Bedrock ft bgs	Temp. °C	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
A14-1	11/30/99	10.00	0.71	NM	5.2	524	5.56	1.9	0.39	0.15	2.9	8.75	130
A14-2	11/30/99	15.00	5.71	NM	6.4	1414	6.40	-0.4	1.44	0.05	40.3	32.76	206
A14-3	11/30/99	30.00	20.71	NM	NM	NM	NM	NM	NM	NM	NM	49.25	292
A15-1[1]	11/30/99	11.80	NA	11.80	NM	NM	NM	NM	NM	NM	NM	NM	NM
A16-1	12/01/99	7.00	1.67	NM	6.3	76	6.13	178.0	3.19	>1.0	0.6	0.89	5
(dup) [2]	12/01/99	7.00	1.67	NM	NM	NM	NM	NM	NM	NM	NM	NM	10
A16-2	12/01/99	12.00	6.67	NM	NM	NM	NM	NM	NM	NM	>1000	2.45	964
A17-1	12/01/99	7.00	3.00	NM	9.6	425	7.11	-55.6	0.49	<1.0	2.1	0.41	124
A17-3	12/01/99	17.00	13.00	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
A18-1	12/02/99	19.00	10.19	NM	13.0	628	6.27	58.4	1.56	0.5	50.4	3.60	53
(dup)	12/02/99	19.00	10.19	NM	NM	NM	NM	NM	NM	NM	NM	4.00	52
A19-1	12/02/99	8.50	1.50	NM	10.7	208	6.01	124.0	2.12	>1.0	1.6	0.89	18
(dup)	12/02/99	8.50	1.50	NM	NM	NM	NM	NM	NM	NM	NM	0.87	14

1 Ground water yield too low to connect to flow cell.
2 Duplicate analysis of select geochemical parameters.

Table C.3. Summary of field geochemical data collected during snap-shot and fixed point ground water sampling on March 27 – April 6, 2000 at the Industri-Plex Site and GSIP Study Area. The following abbreviations are used within the table: ft bgs = feet below ground surface, COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Screen Depth ft bgs	Depth to Water Table ft	Depth to Bedrock ft bgs	Temp. °C	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
20-1	3/28/00	5.00	2.38	NM	11.9	428	6.47	-430.0	0.08	0.00	2.2	12.20	130
20-2	3/28/00	10.00	7.38	NM	12.4	880	6.21	-470.0	0.10	NM	2.5	2.10	88
21-1	3/30/00	5.50	2.00	NM	13.4	264	6.62	NM	0.99	NM	3.4	12.80	NM
21-2	3/30/00	13.50	10.00	NM	10.2	1464	6.88	NM	0.22	0.2-0.3	6.3	3.00	NM
22-1	3/31/00	9.75	3.50	NM	13.5	1315	5.53	125.6	3.38	0.3-0.4	2.8	15.50	44
22-2	3/31/00	14.75	8.50	NM	11.8	1112	6.24	25.7	0.68	0.2-0.3	4.7	18.40	240
23-1	3/31/00	9.75	2.75	NM	13.7	1327	4.64	141.8	0.24	0.4-0.6	ND	13.50	ND
23-2 [1]	4/3/00	16.75	9.75	NM	NM	NM	NM	NM	NM	NM	NM	21.50	48
TW01	3/29/00	9.00 [2]	NA	NM	11.1	12660	NM	-161.0	0.11	NM	6.2	NM	4160
TW02	4/6/00	14.00 [2]	NA	NM	8.1	9200	7.56	-277.1	0.11	0.3-0.4	2.6	0.08	4030
TW03	3/29/00	13.00 [2]	NA	NM	13.8	1266	6.06	267.0	0.54	0.6	1.4	ND	206
TW04	3/29/00	14.00 [2]	NA	NM	10.9	2240	5.94	22.0	0.69	0	0.9	11.20	24
TW05	NS	11.00 [2]	NA	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
TW06-1	4/5/00	12.25	NM	47.08	13.1	477	6.44	130.8	0.97	NM	31.0	0.60	67
TW06-2	4/5/00	17.50	NM	47.08	10.9	537	5.99	268.3	1.85	0.4-0.6	9.4	0.15	24
TW06-3	4/5/00	22.50	NM	47.08	9.8	921	5.04	210.1	1.12	0.3-0.4	35.1	1.48	22
TW07-1	4/4/00	12.25	NM	NM	13.1	1151	6.16	44.2	0.28	0.06-0.08	1.1	16.60	142
TW07-2	4/5/00	15.00	NM	NM	12.0	1293	5.90	86.1	0.19	0.1-0.2	0.7	16.10	114
TW07-3	4/5/00	20.00	NM	NM	11.8	2150	6.03	-218.9	0.17	0.05-0.1	1.6	26.60	170
TW08-1	4/6/00	8.00	NM	NM	6.7	6.2	8.02	-262.7	0.35	0.4	13.4	0.28	2735
TW08-2	4/6/00	13.00	NM	NM	6.1	99.8	5.42	530.9	8.00	NM	27.0	0.05	6
TW08-3	4/6/00	17.50	NM	NM	8.1	11070	6.70	-196.3	0.22	0.3-0.4	97.0	2.41	2540

1 Ground water yield too low to connect to flow cell.
2 Screen depth is below water surface of Hall's Brook Holding Area Pond determined at the time of installation.

Table C.4. Summary of field geochemical data collected during fixed point ground water sampling on May 16-18, 2000 at the Industri-Plex Site and GSIP Study Area. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Screen Depth ft bgs	Depth to Water Table ft	Depth to Bedrock ft bgs	Temp. °C	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
TW01	5/17/00	9.00 [1]	NA	NM	14.1	13430	7.26	-214.0	0.02	0.6-0.8	1.9	12.50	5948
TW02	5/16/00	14.00 [1]	NA	NM	16.8	8850	7.72	-265.0	0.02	0.1-0.2	1.3	0.15	4530
TW03	5/16/00	13.00 [1]	NA	NM	16.6	1191	5.95	168.5	0.46	0.8-1.0	1.0	0.08	210
TW04	5/16/00	14.00 [1]	NA	NM	15.4	2110	6.19	-17.0	0.18	0	0.4	19.60	94
TW05	5/17/00	11.00 [1]	NA	NM	14.1	6180	5.22	100.0	0.39	0.6-0.8	2.0	158.75	69
TW06-1	5/16/00	12.25	NM	47.08	14.6	499	6.32	94.0	0.15	0.3-0.4	22.9	0.64	NM
TW06-2	5/16/00	17.50	NM	47.08	14.1	430	5.83	271.0	0.25	0.3-0.4	0.3	0.00	NM
TW06-3	5/16/00	22.50	NM	47.08	13.7	944	5.25	195.0	0.15	0.2-0.3	0.7	1.37	32
TW07-1	5/16/00	12.25	NM	NM	16.0	1283	5.72	9.1	0.31	NM	5.0	17.00	126
TW07-2	5/16/00	15.00	NM	NM	13.8	940	5.82	-24.5	0.06	0.1-0.2	2.0	15.60	122
TW07-3	5/16/00	20.00	NM	NM	15.3	2130	5.86	-53.1	0.28	0.4	3.0	27.20	146
TW08-1	5/17/00	8.00	NM	NM	15.5	6240	7.82	-215.6	0.08	0.3-0.4	5.0	0.36	3060
TW08-2	5/17/00	13.00	NM	NM	14.3	58	5.33	293.1	7.08	6-8	1.0	0.02	3
TW08-3	5/17/00	17.50	NM	NM	15.9	11160	6.63	-204.9	0.16	0.3	29.0	26.40	3232
TW10-1	5/16/00	10.58	NM	NM	14.8	474	6.65	-212.2	0.13	0.2-0.3	29.1	3.14	134
TW10-2	5/16/00	15.58	NM	NM	15.4	1504	6.12	-107.3	0.27	0.3-0.4	37.0	14.20	204
TW10-3	5/16/00	20.58	NM	NM	16.2	1705	6.24	-117.9	0.18	0.2-0.3	9.0	15.50	272

1 Screen depth is below water surface of Hall's Brook Holding Area Pond determined at the time of installation.

Table C.5. Summary of field geochemical data collected during fixed point ground water sampling on August 22-30, 2000 at the Industri-Plex Site and GSIP Study Area. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Screen Depth ft bgs	Depth to Water Table ft	Depth to Bedrock ft bgs	Temp. (°C)	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
TW01	8/23/00	9.00 [1]	NA	NM	20.7	14820	7.26	-273.0	4.88	0.2-0.3	2.2	2.35	7628
	8/28/00	9.00 [1]	NA	NM	22.0	15400	7.35	-302.0	0.16	0.1-0.2	1.9	3.10	NM
TW02	8/23/00	14.00 [1]	NA	NM	17.9	9170	7.44	-314.6	0.39	0.1	1.2	0.11	4440
TW03	8/22/00	13.00 [1]	NA	NM	21.4	989	5.97	NM	0.46	1-2	3.7	0.03	210
TW04	8/23/00	14.00 [1]	NA	NM	18.7	2230	6.13	-243.5	0.85	0	0.8	2.44	152
TW05	8/23/00	11.00 [1]	NA	NM	18.9	7000	5.12	-162.3	0.70	0.6	1.5	148.00	74
TW06-1	8/22/00	12.25	NM	47.08	21.9	578	6.15	130.8	0.17	0.8	10.2	0.48	76
TW06-2	8/22/00	17.50	NM	47.08	20.5	136	5.83	260.0	2.07	0.8	1.7	0.01	37.5
TW06-3	8/22/00	22.50	NM	47.08	18.6	1019	5.21	224.5	NM	0.8	1.3	0.31	32.4
TW07-1	8/23/00	12.25	NM	NM	15.7	1374	5.90	-225.3	0.66	0.1	1.7	14.10	68
	8/28/00	12.25	NM	NM	17.1	1395	5.77	51.0	0.40	0.1-0.2	0.5	19.50	NM
TW07-2	8/23/00	15.00	NM	NM	17.1	1246	6.07	-258.8	0.40	0.05	0.9	29.50	208
TW07-3	8/23/00	20.00	NM	NM	15.6	2220	6.04	-238.9	0.40	0.05	1.5	21.10	72
TW08-1	8/23/00	8.00	NM	NM	20.6	6600	7.80	-287.0	0.29	NM	2.9	0.32	284
	8/28/00	8.00	NM	NM	18.9	6660	7.72	-329.0	0.14	0.2	0.8	0.75	NM
TW08-2	8/23/00	13.00	NM	NM	21.2	128	5.14	359.0	0.55	1	0.5	0.01	5
TW08-3	8/23/00	17.50	NM	NM	22.1	11530	6.78	-154.0	25.10	0.6	8.1	27.50	3496
TW10-1	8/22/00	10.58	NM	NM	22.0	400	6.45	-281.5	11.22	0.2	0.5	4.00	110
TW10-2	8/22/00	15.58	NM	NM	20.8	1523	6.04	-253.7	5.04	0.6	1.6	11.30	210
TW10-3	8/22/00	20.58	NM	NM	19.0	1740	6.26	-285.1	6.69	0.4	1.8	13.60	288
TW11	8/30/00	3.50	1.50	NM	17.7	968	6.14	153.0	0.60	0.2	14.6	0.43	77
TW12-1	8/30/00	3.50	1.50	NM	20.1	1002	6.28	-302.0	0.14	0.05	35.2	3.30	170
TW12-2	8/30/00	8.50	1.50	NM	20.1	1054	6.25	-249.0	0.22	0.2	6.7	0.58	126
TW13	8/30/00	3.50	1.50	NM	22.4	686	6.28	-273.0	0.21	NM	6.0	2.90	56

1 Screen depth is below water surface of Hall's Brook Holding Area Pond determined at the time of installation.

Table C.6. Summary of field geochemical data collected during fixed point ground water sampling on March 28 – April 3, 2001 at the Industri-Plex Site and GSIP Study Area. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Screen Depth ft bgs	Depth to Water Table ft)	Depth to Bedrock ft bgs	Temp. (°C)	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
TW01	4/3/2001	9.00 [1]	NA	NM	7.4	13410	7.02	-149.9	0.27	0.3	1.6	30.75	5360
TW02	3/29/01	14.00 [1]	NA	NM	8.6	8410	7.67	-137.6	0.40	NM	2.0	0.10	4080
TW03	NS	13.00 [1]	NA	NM	--	--	--	--	--	--	--	--	--
TW04	3/29/01	14.00 [1]	NA	NM	7.5	2140	6.73	-13.0	1.19	0	1.4	3.06	122
TW05	NS	11.00 [1]	NA	NM	--	--	--	--	--	--	--	--	--
TW06-1	NS	12.25	NM	47.08	--	--	--	--	--	--	--	--	--
TW06-2	NS	17.50	NM	47.08	--	--	--	--	--	--	--	--	--
TW06-3	NS	22.50	NM	47.08	--	--	--	--	--	--	--	--	--
TW07-1	3/29/01	12.25	NM	NM	8.5	1172	5.99	54.2	0.83	0.4	1.0	25.50	136
(dup) [2]	3/29/01	12.25	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	122
TW07-2	3/29/01	15.00	NM	NM	7.6	570	6.23	38.0	0.73	0.3	1.73	14.00	188
TW07-3	3/29/01	20.00	NM	NM	9.7	1919	6.14	7.9	0.80	0.1-0.2	1.48	57.00	184
TW08-1	4/3/01	8.00	NM	NM	8.3	3260	8.02	-62.8	0.74	0.4-0.6	1.25	0.28	1292
TW08-2	NS	13.00	NM	NM	--	--	--	--	--	--	--	--	--
TW08-3	4/3/01	17.50	NM	NM	9.8	11840	6.73	-156.1	0.29	0.2-0.3	4.8	25.40	3448
TW10-1	4/2/01	10.58	NM	NM	4.2	210	6.72	-24.1	0.42	0.4-0.6	2.5	2.42	33
TW10-2	4/2/01	15.58	NM	NM	4.9	1362	6.38	21.3	0.61	0.2-0.3	12.5	21.40	178
TW10-3	4/2/01	20.58	NM	NM	6.6	1673	6.46	-133.6	0.68	0.4	3.4	21.00	260
TW11	NS	3.50	1.50	NM	--	--	--	--	--	--	--	--	--
TW12-1	NS	3.50	1.50	NM	--	--	--	--	--	--	--	--	--
TW12-2	NS	8.50	1.50	NM	--	--	--	--	--	--	--	--	--
TW13	NS	3.50	1.50	NM	--	--	--	--	--	--	--	--	--

1 Screen depth is below water surface of Hall's Brook Holding Area Pond determined at the time of installation.
2 Duplicate analysis of select geochemical parameters.

Table C.7. Summary of field geochemical data collected during fixed point ground water sampling on September 13 – 17, 2001 at the Industri-Plex Site and GSIP Study Area. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Screen Depth ft bgs	Depth to Water Table ft	Depth to Bedrock ft bgs	Temp. °C	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
TW01	9/11/01	9.00 [1]	NA	NM	23.7	14770	7.37	-187.0	0.18	NM	2.7	5.30	7308
TW02	9/11/01	14.00 [1]	NA	NM	21.8	8630	7.39	-234.0	0.14	0.3	2.0	0.14	4072
TW03	NS	13.00 [1]	NA	NM	--	--	--	--	--	--	--	--	--
TW04	9/11/01	14.00 [1]	NA	NM	22.8	2170	6.13	-114.0	0.87	0	1.0	25.20	122
TW05	9/13/01	11.00 [1]	NA	NM	19.7	6530	5.64	70.2	0.54	NM	1.0	100.50	156
(dup) [2]	9/13/01	11.00 [1]	NA	NM	NM	NM	NM	NM	NM	NM	NM	112.00	140
TW06-1	NS	12.25	NM	47.08	--	--	--	--	--	--	--	--	--
TW06-2	NS	17.50	NM	47.08	--	--	--	--	--	--	--	--	--
TW06-3	NS	22.50	NM	47.08	--	--	--	--	--	--	--	--	--
TW07-1	9/11/01	12.25	NM	NM	17.6	1101	5.65	56.0	0.86	0-0.05	3.7	15.90	106
(dup) [2]	9/11/01	12.25	NM	NM	NM	NM	NM	NM	NM	0.08-0.1	NM	17.70	NM
TW07-2	9/11/01	15.00	NM	NM	18.8	749	5.90	-33.6	0.80	0	0.6	47.50	220
TW07-3	9/11/01	20.00	NM	NM	17.8	2270	5.73	-62.9	0.40	0	1.5	12.90	122
(dup) [2]	9/11/01	20.00	NM	NM	NM	NM	NM	NM	NM	0.04-0.06	NM	NM	NM
TW08-1	9/10/01	8.00	NM	NM	21.3	5730	7.66	-302.6	0.20	0.3	0.8	1.57	2592
(dup) [2]	9/10/01	8.00	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	2580
TW08-2	9/10/01	13.00	NM	NM	21.2	114	5.11	276.0	0.93	0.8-1.0	0.3	0.01	6
TW08-3	9/10/01	17.50	NM	NM	21.3	11820	6.78	-105.9	0.54	0.2-0.3	7.0	23.10	3418
TW10-1	9/12/01	10.58	NM	NM	21.5	446	6.67	-139.5	0.64	0.3	0.4	4.20	156
(dup) [2]	9/12/01	10.58	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	113
TW10-2	9/12/01	15.58	NM	NM	21.2	1445	6.25	-119.0	0.25	0.2	1.8	20.90	204
(dup) [2]	9/12/01	15.58	NM	NM	NM	NM	NM	NM	NM	0.1	NM	17.50	198
TW10-3	9/12/01	20.58	NM	NM	22.2	1624	6.25	-104.1	0.33	0.4	5.4	20.40	208
(dup) [2]	9/12/01	20.58	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	166
TW11	NS	3.50	1.50	NM	--	--	--	--	--	--	--	--	--
TW12-1	NS	3.50	1.50	NM	--	--	--	--	--	--	--	--	--
TW12-2	NS	8.50	1.50	NM	--	--	--	--	--	--	--	--	--
TW13	NS	3.50	1.50	NM	--	--	--	--	--	--	--	--	--

1 Screen depth is below water surface of Hall's Brook Holding Area Pond determined at the time of installation.
2 Duplicate analysis of select geochemical parameters.

Table C.8. Summary of field geochemical data collected during surface water sampling on November 30 – December 3, 1999 in the Hall's Brook Holding Area Pond. Data were collected using a YSI submersible multi-electrode sonde. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Sonde Depth cm	Temp. °C	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	As mg/L	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
WN50	11/30/99	50	7.07	275	6.32	115.2	3.72	3.0-4.0	11.4	0.008	0.02	96
WN100	11/30/99	100	7.14	279	6.32	103.2	3.58	3.0-4.0	7.9	0.011	0.02	70
WN150	11/30/99	150	7.29	331	6.22	101.1	2.89	3.0	16.2	0.008	0.00	130
WN200	11/30/99	200	9.44	800	6.08	48.0	1.45	1.0-2.0	47.3	0.024	0.05	254
WN250	11/30/99	250	11.53	2000	6.49	-154.1	0.69	<1.0	10.3	0.810	48.00	1242
WN260	11/30/99	260	NM	NM	NM	NM	NM	NM	NM	NM	61.50	1812
WC50	11/30/99	50	7.07	274	6.34	80.4	3.29	3.0-4.0	10.2	0.008	0.03	72
WC100	11/30/99	100	7.08	275	6.31	80.0	3.24	3.0-4.0	8.2	0.025	0.00	84
(dup) [1]	11/30/99	100	NM	NM	NM	NM	NM	NM	NM	NM	0.01	76
WC150	11/30/99	150	7.11	276	6.32	80.4	3.07	3.0-4.0	8.2	0.018	0.00	72
WC200	11/30/99	200	8.05	688	6.12	52.3	1.05	1.0-2.0	8.1	<0.007	0.01	236
WC250	11/30/99	250	9.7	1327	6.49	-85.0	0.54	<1.0	9.1	0.562	2.42	584
WS50	11/30/99	50	6.99	275	6.29	80.9	3.90	3.0-4.0	21.4	0.012	0.00	76
WS100	11/30/99	100	6.99	275	6.3	79.8	3.15	3.0-4.0	9.9	<0.007	0.01	110
WS150	11/30/99	150	7.01	275	6.29	80.2	2.76	NM	9.0	0.016	0.00	92
WS200	11/30/99	200	9.3	875	6.21	4.9	1.59	1.0-2.0	33.9	<0.007	0.03	310
(dup) [1]	11/30/99	200	NM	NM	NM	NM	NM	NM	NM	NM	0.06	316
WS250	11/30/99	250	9.54	1371	6.45	-81.1	0.71	<1.0	7.6	0.328	2.20	552
WS300	11/30/99	320	10.16	1395	6.84	-180.6	0.32	<1.0	9.6	2.233	1.69	664

1 Duplicate analysis of select geochemical parameters.

Table C.9. Summary of field geochemical data collected during surface water sampling on March 27 – April 6, 2000 in the Hall's Brook Holding Area Pond. Data were collected using a YSI submersible multi-electrode sonde. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Sonde Depth cm	Temp. °C	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	As mg/L	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
WN50	4/4/00	50	10.83	412	6.79	135.0	7.10	NM	11.5	<0.033	0.05	74
WN100	4/4/00	100	10.82	413	6.95	132.3	7.00	NM	9.8	<0.033	0.45	78
WN150	4/4/00	150	10.87	415	7.02	85.1	6.80	NM	8.1	<0.033	0.65	80
WN175	4/4/00	175	10.87	420	7.04	72.3	6.7	NM	8.1	<0.033	0.35	NM
WN200	4/4/00	200	10.89	426	7.05	78.3	6.7	NM	7.7	<0.033	0.50	82
(dup) [1]	4/4/00	200	NM	NM	NM	NM	NM	NM	NM	<0.033	NM	84
WN225	4/4/00	225	10.91	452	6.96	48	3.5	NM	7.8	<0.033	0.90	78
WN250	4/4/00	250	10.83	3590	7.19	-118.2	0.485	NM	5.7	0.904	>8.0	1316
WN300	4/4/00	300	10.44	7650	7.51	-199.5	0.295	NM	9.7	2.040	>8.0	2380
(dup) [1]	4/4/00	300	NM	NM	NM	NM	NM	NM	NM	NM	NM	2500
WC50	4/4/00	50	11.39	418	7.03	48.2	7	NM	9.7	<0.033	0.45	66
WC100	4/4/00	100	11.46	419	6.98	47.1	7.2	NM	7.8	<0.033	0.25	74
WC150	4/4/00	150	11.52	419	6.97	49.1	6.4	NM	7.9	<0.033	0.35	72
(dup) [1]	4/4/00	150	NM	NM	NM	NM	NM	NM	NM	<0.033	NM	72
WC200	4/4/00	200	11.05	438	6.81	45.9	4.7	NM	17.2	0.092	0.85	90
WC250	4/4/00	250	9.95	693	6.5	48.3	2.9	NM	32.7	<0.033	1.30	150
WC275	4/4/00	275	9.95	901	6.58	20.5	0.5	NM	22.7	<0.033	1.20	194
WC300	4/4/00	300	9.60	1476	7.35	-180.1	0.13	NM	7.9	<0.033	NM	NM
WS50	4/4/00	50	11.61	420	6.99	31.5	5.5	NM	8.3	<0.033	0.00	68
WS100	4/4/00	100	10.92	429	6.87	45.2	5.7	NM	9.6	<0.033	0.00	68
WS150	4/4/00	150	10.78	439	6.78	50.4	5.8	NM	7.7	<0.033	0.00	78
WS200	4/4/00	200	10.40	452	6.7	55.1	5.3	NM	12.0	<0.033	0.25	82
WS250	4/4/00	250	9.31	696	6.39	47.9	0.71	NM	17.1	<0.033	0.00	134
WS300	4/4/00	300	8.98	2333	7.12	-131.1	0.21	NM	28.7	0.870	NM	1500
WS340	4/4/00	340	8.94	2534	7.33	-173	0.1	NM	15.2	NM	NM	NM

1 Duplicate analysis of select geochemical parameters.

Table C.10. Summary of field geochemical data collected during surface water sampling on August 22-30, 2000 in the Hall's Brook Holding Area Pond. Data were collected using a YSI submersible multi-electrode sonde. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Sonde Depth (cm)	Temp. (°C)	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	As mg/L	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
WN50	8/25/00	50	19.00	600	7.12	59.6	3.74	NM	11.4	<0.033	0.14	168
WN100	8/25/00	100	18.54	644	7.28	33.3	2.77	NM	14.5	<0.033	0.99	141
WN150	8/25/00	150	17.76	832	7.16	15.5	2.01	NM	35.6	0.151	2.16	128
WN180	8/25/00	180	15.29	1544	7.37	-66.4	0.13	0.3	136.0	0.059	9.70	444
WN200	8/25/00	200	14.28	1527	7.20	-44.6	0.09	0.2	55.2	0.525	2.12	682
WC50	8/25/00	50	22.26	592	7.52	44.1	4.33	NM	16.8	<0.033	0.01	142
WC100	8/25/00	100	19.23	619	7.39	35.8	3.13	NM	11.5	<0.033	0.01	136
WC150	8/25/00	150	17.74	1071	7.35	-13.1	4.60	4-6	27.9	<0.033	0.03	264
WC200	8/25/00	200	15.23	2054	7.76	-106.9	0.14	NM	110.0	0.548	17.40	748
WC250	8/25/00	240	15.23	2462	8.02	-159.0	0.10	0.2	43.3	1.626	45.40	832
WS50	8/29/00	50	20.47	644	6.75	66.7	3.27	NM	7.7	<0.033	0.02	128
WS100	8/29/00	100	19.30	875	6.58	20.5	0.80	NM	8.1	<0.033	0.03	204
WS150	8/29/00	150	18.57	1190	6.61	11.7	2.12	NM	8.0	<0.033	0.04	370
WS200	8/29/00	200	15.99	2209	7.21	-158.0	0.12	0.2	72.4	0.636	15.30	708
WS240	8/29/00	240	15.08	2483	7.31	-210.5	0.27	0.2	23.8	1.669	38.50	836

Table C.11. Summary of field geochemical data collected during surface water sampling on March 28 – April 3, 2001 in the Hall's Brook Holding Area Pond. Data were collected using a YSI submersible multi-electrode sonde. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Sonde Depth (cm)	Temp. (°C)	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	As mg/L	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
WN50	4/2/01	50	4.1	623	6.34	104.8	NM	5.5	8.2	0.010	0.45	50.5
WN100	4/2/01	100	4.1	740	6.13	76.2	NM	4.0	4.6	0.011	0.60	52.7
WN150	4/2/01	150	4.1	758	6.16	75.7	NM	5.0	4.0	0.011	0.60	53.7
WN200	4/2/01	200	4.1	758	6.16	74.6	NM	4.0	4.2	0.015	0.60	53.7
WN250	4/2/01	250	4.4	1255	6.71	-19.5	NM	4.0	4.4	0.015	0.80	57.2
WN270	4/2/01	270	4.6	1340	6.46	-36.1	NM	3.0	4.7	0.018	1.00	55.9
WN310	4/2/01	310	6.4	2300	6.50	-40.1	NM	0.4	39.1	0.257	35.00	360.9
WC50	4/2/01	50	4.0	640	5.10	155.7	NM	4.0	4.3	0.008	0.20	46.2
WC100	4/2/01	100	4.5	574	5.23	177.1	NM	4.0	4.3	0.007	0.20	45.2
WC150	4/2/01	150	4.8	493	5.03	149.9	NM	4.0	4.0	0.007	0.10	45.8
WC200	4/2/01	200	4.9	505	5.82	73.5	NM	4.0	4.0	0.006	0.10	44.0
WC250	4/2/01	250	4.8	486	6.29	45.0	NM	4.0	4.0	0.009	0.10	47.6
WC300	4/2/01	300	4.9	474	6.53	31.1	NM	3.5	4.3	0.006	0.20	45.6
WS50	4/2/01	50	5.1	491	6.20	99.0	NM	4.0	4.3	0.008	0.10	47.6
WS100	4/2/01	100	5.3	504	6.17	52.2	NM	4.5	4.2	0.006	0.10	47.6
WS150	4/2/01	150	5.2	491	6.43	37.3	NM	4.0	4.2	0.005	0.10	46.4
WS200	4/2/01	200	5.4	481	6.63	25.3	NM	4.0	4.2	0.005	0.10	46.0
WS250	4/2/01	250	5.2	489	6.72	16.5	NM	3.5	4.8	0.006	0.10	47.0
WS300	4/2/01	300	5.2	489	6.78	16.5	NM	3.5	4.0	0.006	0.10	45.6

Table C.12. Summary of field geochemical data collected during surface water sampling on September 13 – 17, 2001 in the Hall's Brook Holding Area Pond. Data were collected using a YSI submersible multi-electrode sonde. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Sonde Depth (cm)	Temp. (°C)	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	As mg/L	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
WC50	9/17/01	50	16.4	785	6.58	219.4	6.93	NM	8.8	0.002	0.01	100.0
WC100	9/17/01	100	16.3	793	6.56	217.8	6.40	NM	9.5	0.005	0.02	132.0
WC150	9/17/01	150	16.5	1203	6.33	65.5	1.25	>1	44.9	0.077	7.40	266.0
WC200	9/17/01	200	16.5	1959	6.42	-56.0	1.89	0.1	13.5	0.518	21.00	512.0
WC250	9/17/01	250	16.0	2644	6.60	-128.9	1.98	0.0	13.5	1.508	46.25	750.0
WC300	9/17/01	300	15.7	3075	6.57	-151.5	2.00	0.0	13.2	2.172	54.25	902.0
WC320	9/17/01	320	15.6	3443	6.72	-198.4	2.00	NM	NM	NM	NM	NM
WS50	9/17/01	50	17.0	809	6.66	159.3	7.60	NM	11.1	0.007	0.01	116.0
WS100	9/17/01	100	16.8	864	6.69	155.3	15.08	NM	40.6	0.028	0.04	140.0
WS150	9/17/01	150	16.4	980	6.37	139.0	3.01	0.3	56.3	0.048	0.16	178.0
WS200	9/17/01	200	16.8	2112	6.50	-66.0	1.04	0.1-0.2	13.0	0.665	27.20	524.0
WS250	9/17/01	250	16.0	2537	6.65	-112.1	1.70	0.1	15.1	1.507	60.50	706.0
WS300	9/17/01	300	15.2	2798	6.79	-159.6	1.66	0.05	16.2	2.845	74.00	822.0
WS330	9/17/01	330	14.7	2519	7.17	-256.9	1.46	NM	NM	NM	NM	NM

Table C.13. Field geochemical parameters and measured concentrations of arsenic and iron for inlets and outlet of the Hall's Brook Holding Area Pond. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	T (°C)	ALK mg/L $CaCO_3$	DO (Electrode) mg/L	DO (Chemet) mg/L	ORP mV	pH	COND µS/cm	Turbidity NTU	As mg/L	Fe mg/L
Hall's Brook Inlet	4/5/00	11.5	64.0	11.50	6.8	273.3	7.93	383	NM	<0.033	0.504
	5/18/00	14.0	78.8	7.74	6-8	231.0	7.44	555	NM	<0.033	0.914
	8/29/00	17.6	112.0	5.10	NM	181.0	7.24	489	NM	<0.033	0.105
	8/30/00	19.4	106.0	4.03	4	264.0	7.22	548	9.6	NM	NM
	4/5/01	11.0	NM	NM	6.5	168.9	6.86	668	NM	<0.033	0.272
	9/16/01	15.1	66.2	6.63	NM	353.6	6.97	593	3.5	0.002	0.176
Atlantic Ave. Drainway	4/5/00	11.1	50.0	NM	7.0	95.0	7.14	NM	NM	<0.033	<0.035
	5/18/00	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
	8/24/00, A [1]	16.7	76.0	NM	NM	-55.8	6.33	498	NM	0.041	14.24
	8/24/00, B [1]	18.2	62.0	NM	NM	-28.0	5.94	591	NM	<0.033	5.492
HBHA Pond Outlet	4/5/00	12.0	80.0	NM	6.1	68.1	6.70	320	NM	<0.033	0.727
	5/18/00	16.0	81.6	7.67	6-8	216.0	7.14	544	NM	<0.033	1.317
	8/30/00	22.6	NM	5.38	6-8	277.0	6.95	760	9.4	<0.033	0.069
	4/5/01	10.9	NM	NM	5.5	78.6	6.76	710	NM	<0.033	1.400
	9/16/01	21.6	115.6	7.60	NM	374.7	6.73	799	9.1	0.006	0.117

1 Dates 8/24/00, A and 8/24/00, B refer to samples collected at two closely spaced locations at Atlantic Avenue Drainway outlet.

Table C.14. Summary of field geochemical data collected during water sampling from North Multi-Level Station in the Hall's Brook Holding Area Pond. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured.

Location	Date	Screen Depth (cm)	Temp. (°C)	COND µS/cm	pH	ORP mV	DO (electrode) mg/L	DO (Chemet) mg/L	Turbidity NTU	As mg/L	Ferrous Iron mg/L	ALK mg/L $CaCO_3$
NML-1	4/5/01	69	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
	4/10/01		11.8	640	6.18	85.7	9.44	NM	6.0	<0.033	NM	NM
	5/14/01		14.1	832	6.63	525.5	NM	5	7.2	<0.033	NM	100
	9/14/01		15.8	763	6.25	118.9	7.4	NM	14.0	0.010	0.00	109.5
NML-2	4/5/01	119	9.5	765	6.53	126.1	NM	4.5	5.1	<0.033	0.30	66.4
	4/10/01		10.5	650	6.15	220.8	9.60	NM	6.4	<0.033	NM	NM
	5/14/01		13.6	887	6.54	151.3	NM	3.5	6.1	<0.033	NM	124
	5/31/01		15.6	994	6.44	271.5	NM	3	22.5	NM	NM	150
	9/14/01		16.1	726	6.31	121.2	6.65	NM	14.0	0.009	0.02	143.0
NML-3	4/5/01	169	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
	4/10/01		11.4	653	6.28	29.2	9.90	NM	5.5	<0.033	NM	NM
	5/14/01		13.9	1039	6.21	91.6	NM	3.5	9.8	0.033	NM	160
	9/14/01		16.4	888	5.23	-58.1	5.30	>1.0	15.6	0.030	0.56	143.0
NML-4	4/5/01	219	9.4	768	6.53	97.5	NM	4.0	5.5	<0.033	0.60	73.2
	4/10/01		10.9	665	6.54	140.4	9.84	NM	6.0	0.033	NM	NM
	5/14/01		14.2	1523	6.24	49.7	NM	0.5	18.1	0.060	NM	324
	9/14/01		16.3	1856	6.11	-40.1	NM	0.4-0.6	12.3	0.349	19.25	390.0
NML-5	4/5/01	269	9.9	1670	6.42	-2.8	NM	1.0	5.5	0.251	12.00	26.8
	4/10/01		10.6	2480	6.71	-7.0	3.26	NM	36.6	0.372	NM	NM
	5/14/01		14.1	5590	6.54	-111.5	NM	0.4	2.9	0.933	NM	1388
	9/13/01		22.9	6060	6.68	-138.2	0.54	1.0	57.9	1.718	63.00	1768
NML-6	4/5/01	319	9.6	4740	6.64	-69.7	NM	0.4	6.2	0.480	40.00	952.0
	4/10/01		10.6	4820	6.56	-106.0	0.88	NM	3.1	0.591	NM	NM
	5/14/01		14.8	9710	6.81	-163.6	NM	0.3	8.7	1.179	NM	3396
	5/31/01		15.2	10110	7.03	-155.0	NM	0.6	29	NM	NM	3908
	9/13/01		23.9	10650	6.84	-183.0	0.08	0.4	79.9	2.695	56.50	4116.0
NML-7	4/5/01	369	9.9	11200	7.14	-163.3	NM	0.2	9.6	0.844	100.00	4380.0
	4/10/01		11.3	11880	6.62	-165.5	0.78	NM	9.3	1.054	NM	NM
	5/14/01		14.8	12740	6.73	-194.7	NM	0.35	6.8	1.253	NM	4924
	9/13/01		24.8	12050	6.73	-211.1	0.12	0.70	53.1	3.800	57.00	4790.0
NML-8	4/5/01	419	10.4	13570	6.86	-192.7	NM	0.2	47.7	1.702	175.00	4760.0
	4/10/01		10.7	13660	6.68	-208.7	0.30	0.4	10.9	1.576	NM	NM
	5/14/01		16.4	14340	6.74	-223.0	NM	0.3	7.8	1.917	NM	5256
	9/13/01		27.5	13090	6.79	-203.5	0.14	<1.0	99.3	5.043	84.50	5196.0
NML-9	4/5/01	469	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
	4/10/01		NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
	5/14/01		NM	NM	NM	NM	NM	NM	NM	0.231	NM	NM
	9/14/01		NM	NM	NM	NM	NM	NM	NM	0.261	NM	NM
NML-10	4/5/01	519	10.1	14350	7.49	-5.2	NM	NM	NM	0.265	NM	7420.0
	4/10/01		12.7	15730	7.28	-150.8	0.75	0.4	10.9	0.197	NM	NM
	5/14/01		15.9	16440	7.09	-144.5	NM	NM	11.0	0.188	NM	8148
	9/13/01		21.3	15260	7.46	-71.9	0.68	NM	14.2	0.209	6.00	8052.0

Table C.15. Summary of field geochemical data collected from Discrete Multi-level Samplers installed within the Hall's Brook Holding Area Pond. The following abbreviations are used within the table: COND = conductivity, ORP = oxidation-reduction potential (measured with platinum electrode), DO = dissolved oxygen, ALK = alkalinity, NA = not applicable, NS = not sampled, NM = not measured, SWI = sediment-water interface.

Location	Relative Depth cm	ALK mg/L $CaCO_3$	ORP mV	pH	COND µS/cm	As mg/L	Fe mg/L	Comments
DMLS-1	0.0	NM	NM	NM	NM	0.638	60.650	Above SWI
	11.4	NM	NM	NM	NM	0.670	33.265	Above SWI
Installed: 4/3/00	22.9	NM	NM	NM	NM	<0.055	28.920	Above SWI
	34.3	NM	NM	NM	NM	0.275	35.980	Above SWI
Retrieved: 8/29/00	45.7	NM	NM	NM	NM	<0.055	62.500	Above SWI
	57.2	NM	NM	NM	NM	<0.055	126.910	Above SWI
	74.6	NM	NM	NM	NM	<0.366	170.675	Below SWI
	86.0	NM	NM	NM	NM	<0.366	197.250	Below SWI
	97.5	NM	NM	NM	NM	<0.055	160.370	Below SWI
	108.9	NM	NM	NM	NM	NM	NM	Below SWI; sample cell not recovered
	120.3	NM	NM	NM	NM	NM	NM	Below SWI; sample cell not recovered
DMLS-2	0.0	NM	-144.9	6.85	3800	0.340	89.390	Above SWI
	11.4	NM	-142.8	6.90	4300	0.370	102.830	Above SWI
Installed: 8/30/00	22.9	NM	-210.8	7.49	10400	0.830	30.450	Above SWI
	34.3	NM	NM	NM	NM	0.420	11.450	Below SWI
Retrieved: 4/3/01	45.7	NM	-112.0	7.31	9900	0.160	2.990	Below SWI
	57.2	NM	-144.4	7.46	11400	0.180	15.080	Below SWI
	74.6	NM	-162.8	7.38	9700	0.100	8.960	Below SWI
	86.0	NM	NM	NM	NM	NM	NM	Below SWI ; sample cell not recovered
	97.5	NM	-137.8	7.27	10900	0.050	8.560	Below SWI
	108.9	NM	NM	NM	NM	0.070	8.360	Below SWI
	120.3	NM	-151.9	7.61	12200	0.120	5.820	Below SWI
DMLS-3	0.0	NM	NM	6.96	6980	0.473	2.019	Below SWI
	11.4	2600.0	NM	6.90	6630	0.358	1.419	Below SWI
Installed: 4/3/01	22.9	NM	NM	6.93	6590	0.218	1.352	Below SWI
	34.3	2275.0	NM	6.95	6900	0.127	1.467	Below SWI
Retrieved: 9/12/01	45.7	2320.0	NM	7.07	5770	0.097	1.522	Below SWI
	57.2	NM	NM	6.81	6730	0.097	2.747	Below SWI
	74.6	NM	NM	6.84	6550	0.036	3.899	Below SWI
	86.0	2111.1	NM	6.97	6760	0.085	5.778	Below SWI
	97.5	2100.0	NM	6.86	7230	0.049	4.735	Below SWI
	108.9	2133.3	NM	6.86	6430	0.073	6.512	Below SWI
	120.3	1877.8	NM	6.88	6810	0.067	6.603	Below SWI

Appendix D

Summary of arsenic speciation data for ground-water and surface water samples collected within the Industri-Plex Superfund Site and GSIP Study Area.

Table D.1. Arsenic speciation data for snap-shot ground water samples collected from the Industri-Plex Site and GSIP Study Area. Two separate samples were collected and filtered for total arsenic. The HCl-acidified sample was used for determination of arsenic speciation. The following abbreviations are used within the table: As = arsenic, As(V) = arsenate, As(III) = arsenite, MMA = monomethylarsonic acid, DMA = dimethylarsinic acid, NM = not measured, NA = not applicable due to lack of Total As value, ft bgs = feet below ground surface.

Location	Screen Depth ft bgs	Date	Total As mg/L (HNO_3)	Total As mg/L (HCl)	As(III) mg/L	As(V) mg/L	MMA mg/L	DMA mg/L	Percent Recovery [1]
A01-1	32.75	10/14/99	0.014	0.227	<0.001	<0.001	NM	NM	0
A01-2	41.75	10/15/99	<0.007	0.298	<0.001	<0.001	NM	NM	0
A02-1	12.00	10/14/99	0.362	0.295	<0.001	<0.001	NM	NM	0
A03-1	9.00	10/15/99	0.069	0.105	<0.001	<0.001	NM	NM	0
A03-2	19.00	10/15/99	0.635	0.465	0.440	0.194	NM	NM	136
A04-1	15.00	10/15/99	2.798	2.164	2.218	0.403	NM	NM	121
A04-2	24.75	10/15/99	0.706	0.611	0.392	0.261	NM	NM	107
A06-1	15.50	10/18/99	6.012	5.127	5.118	0.639	NM	NM	112
A06-2	25.50	10/18/99	1.156	1.070	0.970	0.403	NM	NM	128
A08-1	9.00	10/19/99	0.042	0.044	<0.001	<0.001	NM	NM	0
A08-2	19.00	10/19/99	0.199	0.212	<0.001	<0.001	NM	NM	0
A08-3	39.00	10/19/99	0.011	<0.021	<0.001	<0.001	NM	NM	NA
A09-1	12.50	10/19/99	<0.007	<0.021	<0.001	<0.001	NM	NM	NA
A09-2	22.50	10/19/99	<0.007	<0.021	<0.001	<0.001	NM	NM	NA
A09-3	43.00	10/19/99	0.172	<0.021	<0.001	<0.001	NM	NM	NA
A10-1	10.00	10/20/99	NS	<0.021	<0.001	<0.001	NM	NM	NA
A10-2	20.00	10/20/99	0.423	0.288	0.106	0.150	NM	NM	0
A10-3	30.00	10/20/99	0.037	<0.021	<0.001	<0.001	NM	NM	NA
A11-1	10.50	10/20/99	0.127	0.108	0.080	0.055	NM	NM	125
A11-2	20.50	10/20/99	0.615	0.631	0.507	0.073	NM	NM	92
A11-3	30.50	10/20/99	<0.007	<0.021	<0.001	<0.001	NM	NM	NA
A12-1	12.00	10/20/99	2.302	2.014	1.711	<0.010	NM	NM	85
A13-1	7.50	10/20/99	0.047	0.049	0.016	0.053	NM	NM	141
A13-2	17.50	10/20/99	1.215	0.279	0.203	0.083	NM	NM	103
A13-4	45.00	10/20/99	NS	<0.021	<0.001	<0.001	NM	NM	NA
A14-1	10.00	11/30/99	0.504	0.490	0.408	0.144	NM	NM	113
A14-2	15.00	11/30/99	1.582	1.564	0.495	1.087	NM	NM	102
A16-1	7.00	12/1/99	<0.007	<0.007	<0.001	<0.001	NM	NM	NA
A16-2	12.00	12/1/99	0.405	0.318	0.215	0.116	NM	NM	104
A18-1	19.00	12/2/99	0.034	<0.032	<0.001	<0.001	NM	NM	NA
A19-1	8.50	12/2/99	<0.007	<0.032	<0.001	<0.001	NM	NM	NA
A20-2	10.00	3/28/00	<0.033	<0.033	0.054	0.006	<0.005	<0.005	NA
A21-1	5.50	3/30/00	0.074	0.072	0.052	0.019	<0.005	<0.005	99
A21-2	13.50	3/30/00	0.252	0.210	0.190	0.085	<0.005	<0.005	131
A22-1	9.75	3/31/00	<0.033	<0.033	0.009	0.010	<0.005	<0.005	NA
A22-2	14.75	3/31/00	0.823	0.796	0.840	0.040	<0.005	<0.005	111
A23-1	9.75	3/31/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
A23-2	16.75	4/3/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA

[1] Percent recovery is calculated as follows: 100*[Total As mg/L (HCl)]/[Sum of Individual Species].

Table D.2. Arsenic speciation data for fixed monitoring point ground water samples collected from the Industri-Plex Site and GSIP Study Area. Two separate samples were collected and filtered for total arsenic. The HCl-acidified sample was used for determination of arsenic speciation. The following abbreviations are used within the table: As = arsenic, As(V) = arsenate, As(III) = arsenite, MMA = monomethylarsonic acid, DMA = dimethylarsinic acid, NM = not measured, NA = not applicable due to lack of Total As value, ft bgs = feet below ground surface.

Location	Screen Depth ft bgs	Date	Total As mg/L (HNO_3)	Total As mg/L (HCl)	As(III) mg/L	As(V) mg/L	MMA mg/L	DMA mg/L	Percent Recovery [1]
TW06-1	12.25	4/5/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
		5/16/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
TW06-2	17.50	4/5/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
		5/16/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
TW06-3	22.50	4/5/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
		5/16/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
TW07-1	12.25	4/4/00	1.705	1.662	1.367	0.092	<0.005	<0.005	88
		5/16/00	0.626	0.642	0.513	<0.005	<0.005	<0.005	80
		8/28/00	0.791	0.750	0.782	0.030	<0.010	<0.010	108
		3/29/01	0.879	0.880	0.811	0.059	<0.005	<0.005	99
		9/11/01	0.844	0.812	0.738	0.076	<0.005	<0.005	100
TW07-2	15.00	4/5/00	0.746	0.729	0.591	0.043	<0.005	<0.005	87
		5/16/00	1.523	1.389	0.877	<0.005	<0.005	<0.005	62
		8/23/00	1.458	1.249	1.280	0.070	<0.010	<0.010	108
		3/29/01	1.066	1.114	1.083	0.088	<0.005	<0.005	105
		9/11/01	1.400	1.334	1.236	0.117	<0.005	<0.005	101
TW07-3	20.00	4/5/00	0.081	0.076	0.109	0.009	<0.005	<0.005	155
		5/16/00	0.082	0.084	0.103	<0.005	<0.005	<0.005	123
		8/23/00	0.145	0.124	0.130	<0.010	<0.010	<0.010	105
		3/29/01	0.130	0.174	0.147	0.018	<0.005	<0.005	95
		9/11/01	0.202	0.209	0.193	0.025	<0.005	<0.005	104
TW08-1	8.00	4/6/00	0.200	0.252	0.109	0.053	<0.005	<0.005	64
		5/17/00	0.252	0.225	0.102	0.042	<0.005	<0.005	64
		8/28/00	0.390	0.368	0.219	0.029	<0.010	<0.010	67
		4/3/01	0.276	0.276	0.233	0.027	<0.005	<0.005	94
		9/10/01	0.496	0.507	0.348	0.053	<0.005	0.039	87
TW08-2	13.00	4/6/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
		5/17/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
TW08-3	17.50	4/6/00	<0.033	NM	NM	NM	NM	NM	NA
		5/17/00	<0.033	<0.033	0.010	<0.005	<0.005	<0.005	NA
		8/23/00	<0.033	<0.033	0.015	<0.010	<0.010	<0.010	NA
		4/3/01	0.041	<0.165	0.013	0.014	<0.005	<0.005	NA
		9/10/01	0.057	0.088	0.044	<0.005	<0.005	<0.005	50
TW10-1	10.58	5/16/00	1.279	1.079	0.827	<0.005	<0.005	<0.005	77
		8/22/00	1.268	1.063	1.065	<0.010	<0.010	<0.010	100
		4/2/01	0.487	0.398	0.385	0.045	<0.005	<0.005	108
		9/12/01	0.951	0.862	0.832	0.027	<0.005	<0.005	100
TW10-2	15.58	5/16/00	2.017	2.091	1.629	<0.005	<0.005	<0.005	78
		8/22/00	2.198	2.052	2.097	0.071	<0.010	<0.010	106
		4/2/01	0.956	1.020	0.941	0.058	<0.005	<0.005	98
		9/12/01	2.262	2.104	1.881	0.114	<0.005	<0.005	95
TW10-3	20.58	5/16/00	0.486	0.471	0.408	<0.005	<0.005	<0.005	87
		8/22/00	0.504	0.476	0.478	0.025	<0.010	<0.010	106
		4/2/01	0.840	0.848	0.794	0.045	<0.005	<0.005	99
		9/12/01	0.209	0.473	0.472	0.037	<0.005	<0.005	108
TW11	3.50	8/30/00	<0.033	NM	NM	NM	NM	NM	NA
TW12-1	3.50	8/30/00	<0.033	NM	NM	NM	NM	NM	NA
TW12-2	8.50	8/30/00	<0.033	NM	NM	NM	NM	NM	NA
TW13	3.50	8/30/00	<0.033	NM	NM	NM	NM	NM	NA

[1] Percent recovery is calculated as follows: 100*[Total As mg/L (HCl)]/[Sum of Individual Species].

Table D.3. Arsenic speciation data for fixed monitoring point ground water samples collected from the aquifer underlying the Hall's Brook Holding Area Pond. Two separate samples were collected and filtered for total arsenic. The HCl-acidified sample was used for determination of arsenic speciation. The following abbreviations are used within the table: As = arsenic, As(V) = arsenate, As(III) = arsenite, MMA = monomethylarsonic acid, DMA = dimethylarsinic acid, NM = not measured, NA = not applicable due to lack of Total As value, ft bws = feet below water surface.

Location	Screen Depth ft bws [1]	Date	Total As mg/L (HNO_3)	Total As mg/L (HCl)	As(III) mg/L	As(V) mg/L	MMA mg/L	DMA mg/L	Percent Recovery [2]
TW01	9.00	3/29/00	0.412	0.395	0.251	0.310	<0.005	<0.005	142
		5/17/00	0.707	0.601	0.247	0.039	<0.005	0.233	86
		8/28/00	0.812	0.912	0.441	0.105	<0.010	0.103	71
		4/3/01	0.620	0.712	0.683	0.055	<0.005	0.043	110
		9/11/01	1.128	1.214	0.282	0.307	<0.005	0.524	92
TW02	14.00	4/6/00	0.252	0.152	0.049	<0.005	<0.005	<0.005	32
		5/16/00	0.267	0.131	0.060	<0.005	0.024	<0.005	65
		8/23/00	0.280	0.219	0.075	<0.010	<0.010	<0.010	34
		3/29/01	0.180	0.200	0.173	0.009	0.020	<0.005	101
		9/11/01	0.246	0.268	0.104	0.007	<0.005	0.017	48
TW03	13.00	3/29/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
		5/16/00	<0.033	<0.033	<0.005	<0.005	<0.005	<0.005	NA
TW04	14.00	3/29/00	<0.033	<0.033	0.045	0.010	<0.005	<0.005	NA
		5/16/00	0.059	0.041	0.042	<0.005	<0.005	<0.005	102
		8/23/00	0.036	0.034	0.037	<0.010	<0.010	<0.010	109
		3/29/01	0.057	0.060	0.043	0.011	<0.005	<0.005	90
		9/11/01	0.053	0.058	0.035	0.014	<0.005	<0.005	84
TW05	11.00	5/17/00	<0.033	<0.033	<0.010	<0.010	<0.010	<0.010	NA

[1] Depth was established at time of installation.
[2] Percent recovery is calculated as follows: 100*[Total As mg/L (HCl)]/[Sum of Individual Species].

Table D.4. Arsenic speciation data for surface water samples collected from the Hall's Brook Holding Area Pond. Two separate samples were collected and filtered for total arsenic. The HCl-acidified sample was used for determination of arsenic speciation. The following abbreviations are used within the table: As = arsenic, As(V) = arsenate, As(III) = arsenite, MMA = monomethylarsonic acid, DMA = dimethylarsinic acid, NM = not measured, NA = not applicable due to lack of Total As value, cm bws = centimeters below water surface.

Location	Sampling Depth cm bws	Date	Total As mg/L (HNO_3)	Total As mg/L (HCl)	As(III) mg/L	As(V) mg/L	MMA mg/L	DMA mg/L	Percent Recovery [1]
North	225	4/4/00	<0.033	<0.033	0.019	0.006	<0.005	<0.005	NA
	250	4/4/00	0.904	0.850	0.056	0.871	<0.005	<0.005	108
	180	8/25/00	0.059	0.058	0.052	<0.005	<0.005	<0.005	90
	200	8/25/00	0.525	0.472	0.489	0.032	<0.005	<0.005	110
	50	4/2/01	0.010	<0.033	0.008	0.006	<0.005	<0.005	NA
	100	4/2/01	0.011	<0.033	0.006	0.006	<0.005	<0.005	NA
	150	4/2/01	0.011	<0.033	0.009	<0.005	<0.005	<0.005	NA
	200	4/2/01	0.015	<0.033	<0.005	<0.005	<0.005	<0.005	NA
	250	4/2/01	0.015	<0.033	0.010	0.005	<0.005	<0.005	NA
	270	4/2/01	0.018	<0.033	0.017	0.005	<0.005	<0.005	NA
	310	4/2/01	0.257	0.355	0.296	0.014	<0.005	<0.005	87
Central	50	11/30/99	0.008	<0.032	<0.010	<0.010	NM	NM	NA
	100	11/30/99	0.025	<0.032	<0.010	<0.010	NM	NM	NA
	150	11/30/99	0.018	<0.032	<0.010	<0.010	NM	NM	NA
	200	11/30/99	0.015	<0.032	<0.010	<0.010	NM	NM	NA
	300	11/30/99	NM	2.456	0.487	1.661	NM	NM	87
	275	4/4/00	<0.033	<0.033	<0.005	0.022	<0.005	<0.005	NA
	200	8/25/00	0.525	0.442	0.467	0.032	<0.005	<0.005	113
	250	8/25/00	1.626	1.559	1.549	0.139	<0.005	<0.005	108
	50	4/2/01	0.008	<0.033	<0.005	0.005	<0.005	<0.005	NA
	100	4/2/01	0.007	<0.033	<0.005	0.007	<0.005	<0.005	NA
	150	4/2/01	0.007	<0.033	0.005	0.006	<0.005	<0.005	NA
	200	4/2/01	0.006	<0.033	0.006	0.006	<0.005	<0.005	NA
	250	4/2/01	0.009	<0.033	<0.005	<0.005	<0.005	<0.005	NA
	300	4/2/01	0.006	<0.033	0.005	0.009	<0.005	<0.005	NA
	200	9/17/01	0.518	0.534	0.529	0.046	<0.005	<0.005	108
	250	9/17/01	1.508	1.588	1.437	0.155	<0.005	<0.005	100
	300	9/17/01	2.172	2.111	1.823	0.208	<0.005	<0.005	96
South	300	11/30/99	2.233	2.231	2.071	0.333	NM	NM	108
	200	8/29/00	0.636	0.737	0.726	0.058	<0.005	<0.005	106
	240	8/29/00	1.668	1.630	1.409	0.127	<0.005	<0.005	95
	50	4/2/01	0.008	<0.033	<0.005	<0.005	<0.005	<0.005	NA
	100	4/2/01	0.006	<0.033	<0.005	<0.005	<0.005	<0.005	NA
	150	4/2/01	0.005	<0.033	<0.005	<0.005	<0.005	<0.005	NA
	200	4/2/01	0.005	<0.033	<0.005	<0.005	<0.005	<0.005	NA
	250	4/2/01	0.006	<0.033	<0.005	0.007	<0.005	<0.005	NA
	300	4/2/01	0.006	<0.033	<0.005	<0.005	<0.005	<0.005	NA
	150	9/17/01	0.048	0.068	0.027	0.034	<0.005	<0.005	90
	200	9/17/01	0.665	1.496	0.642	0.053	<0.005	<0.005	102
	250	9/17/01	1.507	2.839	1.391	0.139	<0.005	<0.005	102

[1] Percent recovery is calculated as follows: 100*[Total As mg/L (HCl)]/[Sum of Individual Species].

Table D.5. Arsenic speciation data for water samples collected from the North multi-level sampling station within the Hall's Brook Holding Area Pond. Two separate samples were collected and filtered for total arsenic. The HCl-acidified sample was used for determination of arsenic speciation. The following abbreviations are used within the table: As = arsenic, As(V) = arsenate, As(III) = arsenite, MMA = monomethylarsonic acid, DMA = dimethylarsinic acid, NM = not measured, NA = not applicable due to lack of Total As value, cm bws = centimeters below water surface.

Location	Screen Depth cm bws [1]	Date	Total As mg/L (HNO_3)	Total As mg/L (HCl)	As(III) mg/L	As(V) mg/L	MMA mg/L	DMA mg/L	Percent Recovery [2]
NML-2	69	4/5/01	<0.033	<0.033	0.006	<0.005	<0.005	<0.005	NA
NML-4	119	4/5/01	<0.033	<0.033	0.007	0.006	<0.005	<0.005	NA
NML-5	169	4/5/01	0.251	0.239	0.245	0.020	<0.005	<0.005	111
		9/13/01	1.718	1.758	1.573	0.246	<0.005	<0.005	103
NML-6	319	4/5/01	0.480	0.541	0.456	0.035	<0.005	<0.005	91
		9/13/01	2.695	2.752	2.398	0.219	<0.005	<0.005	95
NML-7	369	4/5/01	0.844	0.854	0.673	0.098	<0.005	0.005	91
		9/13/01	3.800	3.725	3.143	0.352	<0.005	<0.005	95
NML-8	419	4/5/01	1.702	1.714	1.482	0.125	<0.005	<0.005	94
		9/13/01	5.043	4.035	3.415	0.369	<0.005	<0.005	94
NML-10	519	4/5/01	0.265	0.294	0.246	0.071	<0.005	0.007	110
		9/13/01	0.209	0.250	0.118	0.044	<0.005	<0.005	65

[1] Depth established at time of installation.
[2] Percent recovery is calculated as follows: 100*[Total As mg/L (HCl)]/[Sum of Individual Species].

Appendix E

Graphical summary of depth and time trends for total and analytically speciated arsenic in ground water collected from fixed monitoring points.

Figure E.1. Pattern of aqueous arsenic species concentrations as a function of season and depth for fixed ground water monitoring location TW07 installed within the GSIP Study Area. This location is coincident with the snap-shot ground water monitoring point A12.

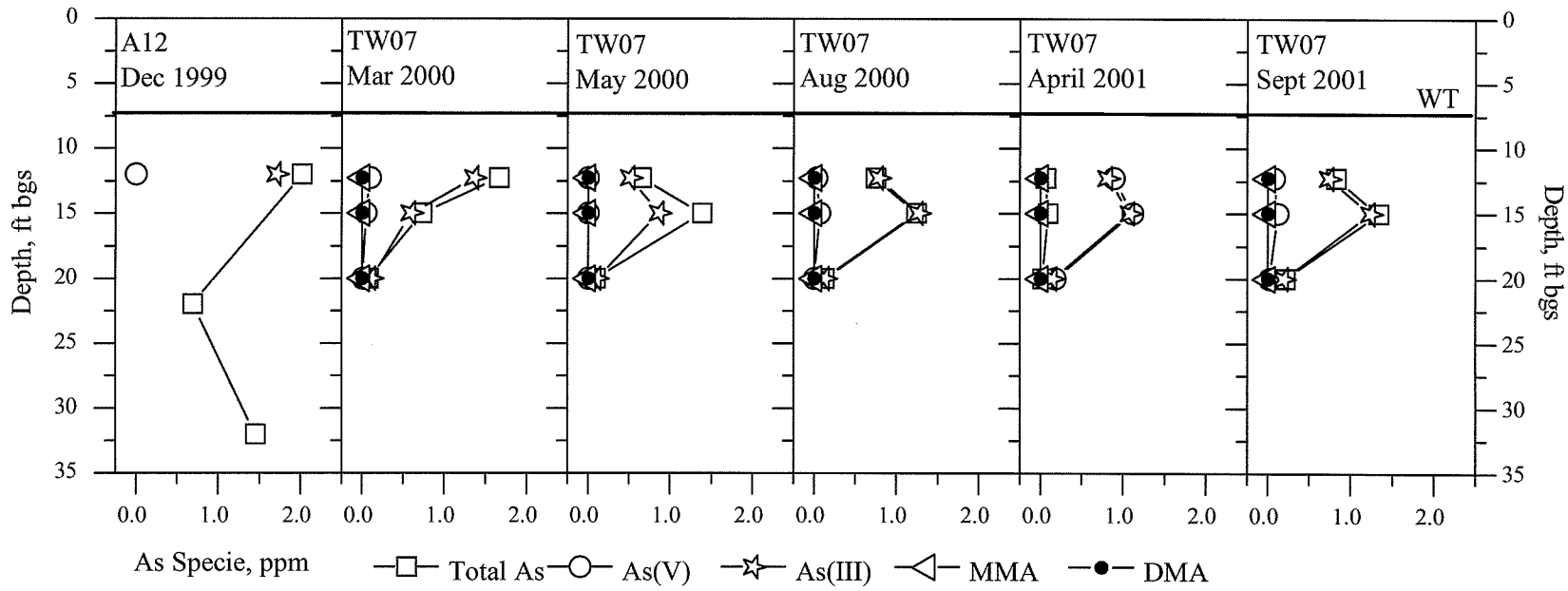


Figure E.2. Pattern of aqueous arsenic species concentrations as a function of sampling date for fixed ground water monitoring location TW08 installed within the GSIP Study Area. This location is coincident with the snap-shot ground water monitoring point A17.

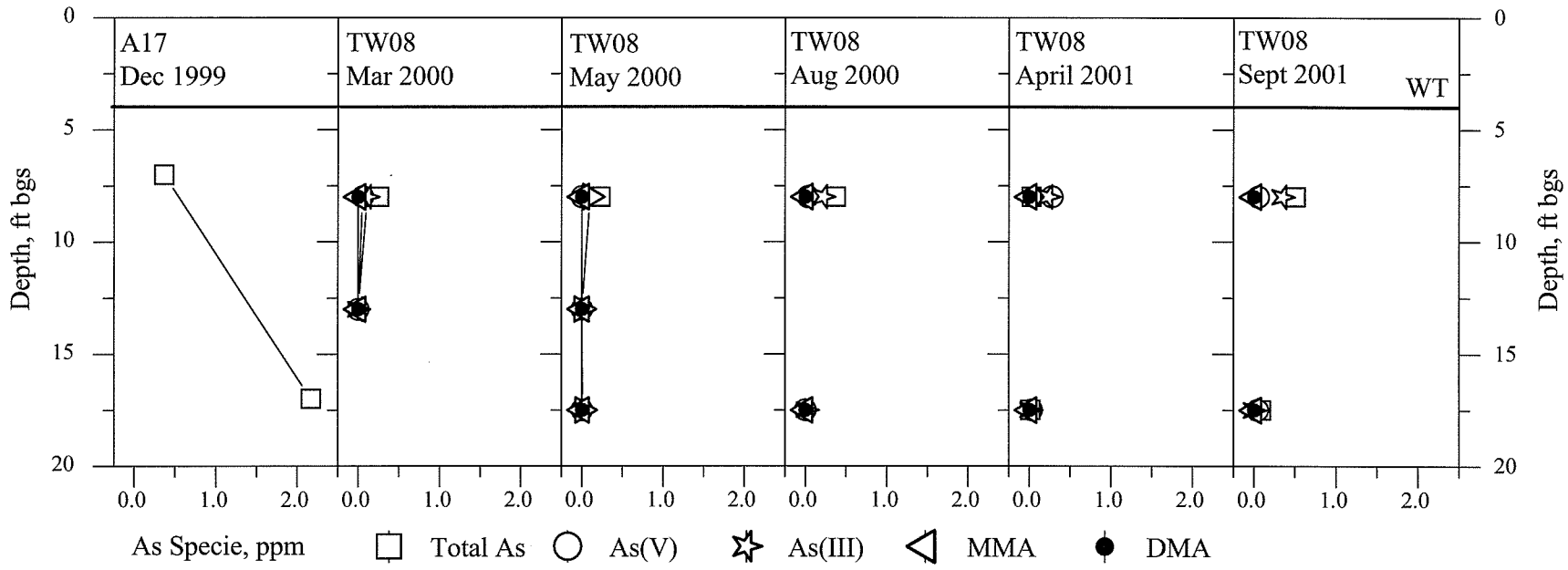


Figure E.3. Pattern of aqueous arsenic species concentrations as a function of sampling date for fixed ground water monitoring location TW10 installed within the Industri-Plex Superfund Site. This location is coincident with the snap-shot ground water monitoring point A14.

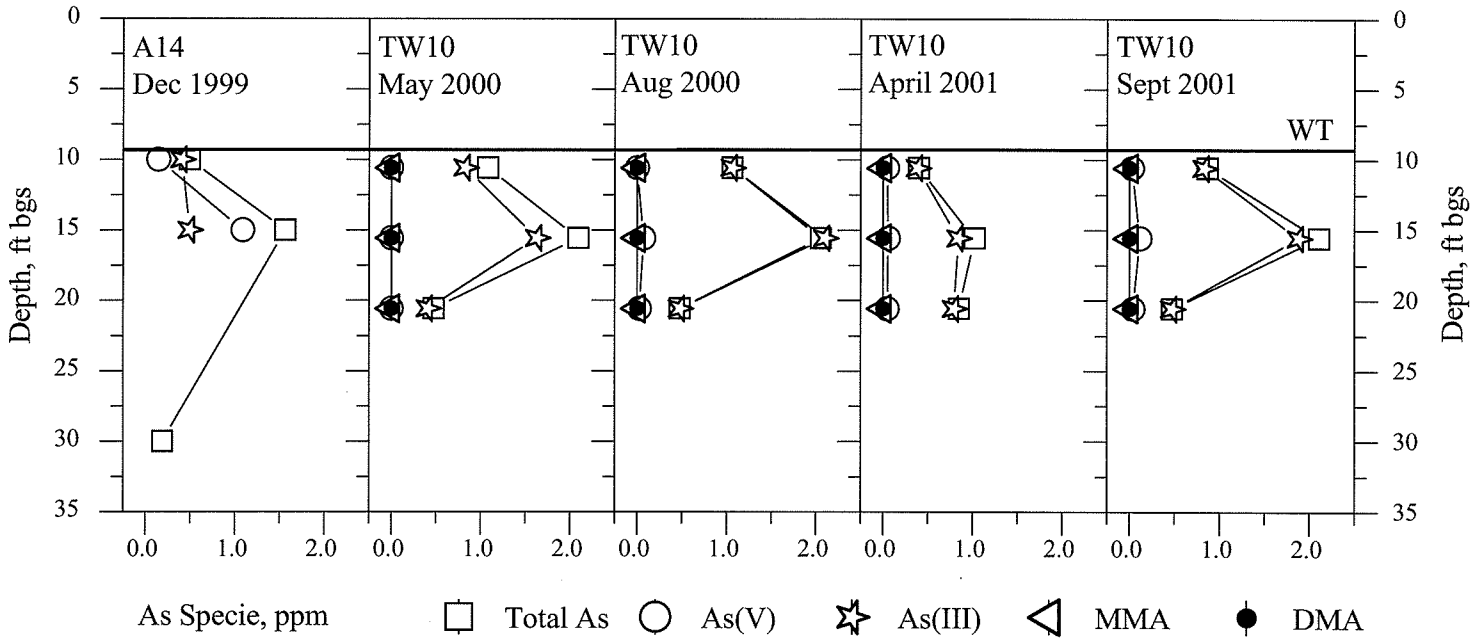
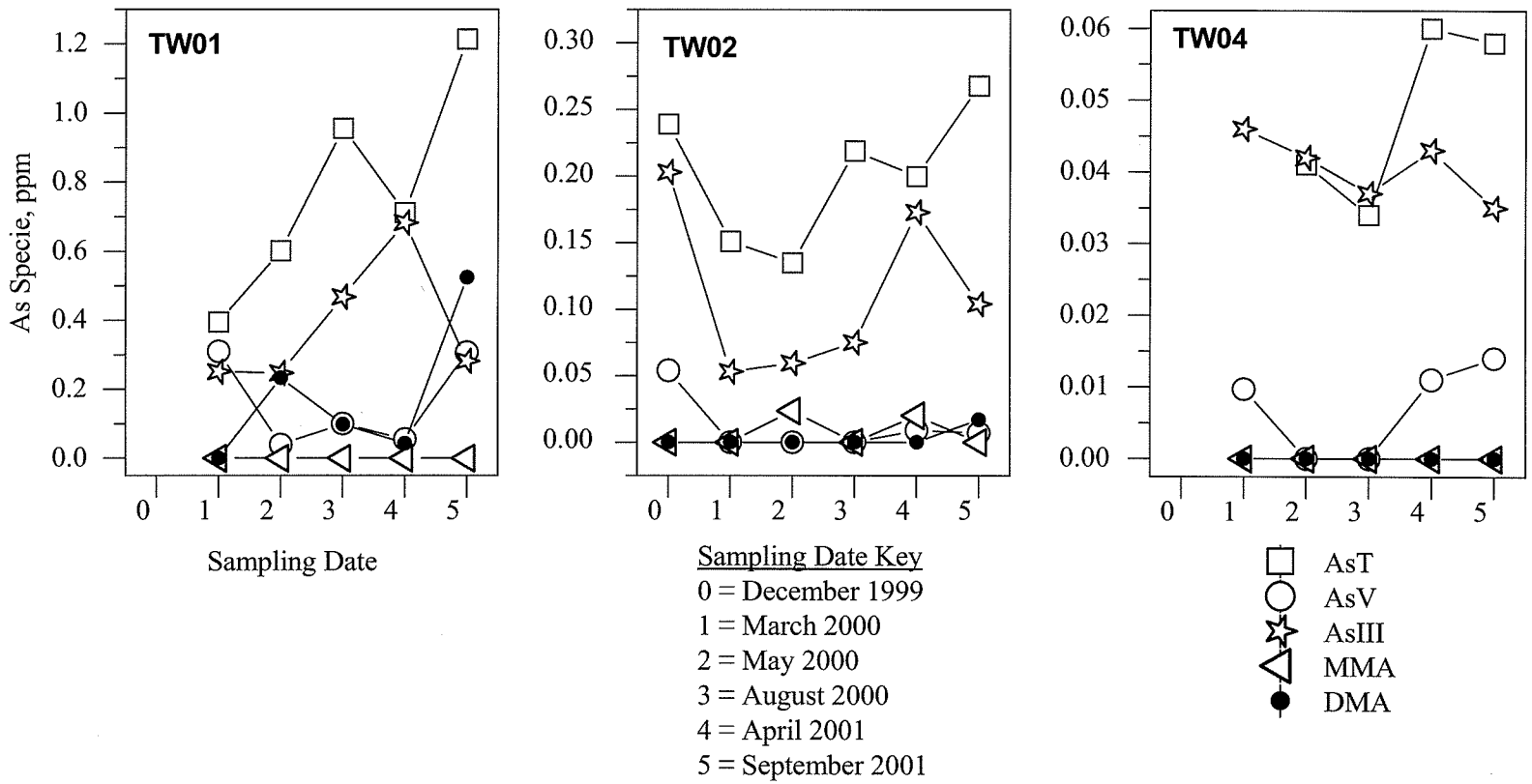


Figure E.4. Pattern of aqueous arsenic species concentrations as a function of sampling date for fixed ground water monitoring locations TW01, TW02, and TW04 installed below sediments within the Hall's Brook Holding Area Pond.



Appendix F

Summary of sediment data for Hall's Brook Holding Area Pond within the GSIP Study Area and the Wells G&H wetland.

Table F.1. Concentrations of selected elements in sediment core NC01 collected within Hall's Brook Holding Area Pond.

Sample ID	Depth Interval cm	Fe wt%	S wt%	TOC wt%	As µg/gm	Pb µg/gm	Cr µg/gm	Zn µg/gm
NC01-1	0.0-1.4	7.89	2.20	15.24	420	332	518	4176
NC01-2	1.4-2.8	7.8	1.80	15.58	456	395	634	4418
NC01-3	2.8-4.2	10.31	2.20	14.27	660	524	912	5603
NC01-4	4.2-5.6	13.76	2.11	14.61	997	806	1079	6915
NC01-5	5.6-7.0	9.42	2.10	13.32	524	456	630	4281
NC01-6	7.0-8.4	8.49	1.77	14.52	534	444	570	4282
NC01-7	8.4-10.0	10.10	0.05	5.95	639	606	691	3990
NC01-8	10.0-18.3	7.21	0.04	0.27	455	507	501	2850
NC01-9	18.3-26.6	1.51	0.04	0.17	101	106	87	609
NC01-10	26.6-34.9	0.37	0.03	0.03	10	34	14	71

Notes: Core collected 4/03/2000. Fe, As, Pb, Cr, and Zn determined by microwave-assisted nitric acid digestion with ICP detection (RSKSOP-180 Rev.2). NM = not measured. TOC = total carbon minus inorganic carbon determined using an UIC, Inc. Carbon Coulometer. S = total sulfur determined using an UIC, Inc. Sulfur Coulometer.

Table F.2. Concentrations of selected elements in sediment core CC02 collected within Hall's Brook Holding Area Pond.

Sample ID	Depth Interval cm	Fe wt%	S wt%	TOC wt%	As µg/gm	Pb µg/gm	Cr µg/gm	Zn µg/gm
CC02-1	0.0-2.1	10.70	1.36	NM	971	431	567	3693
CC02-2	2.1-4.2	11.01	1.38	17.06	1101	425	573	3489
CC02-3	4.2-6.3	9.10	1.34	14.58	697	378	548	3274
CC02-4	6.3-8.4	11.27	1.43	14.64	827	438	731	3861
CC02-5	8.4-10.5	12.36	1.73	14.26	914	521	826	4420
CC02-6	10.5-12.6	14.55	1.31	13.09	945	633	830	4884
CC02-7	12.6-14.7	10.10	1.41	11.71	639	606	691	3990
CC02-8	14.7-16.8	7.21	1.00	9.81	455	507	501	2850
CC02-9	16.8-25.4	1.51	0.04	0.33	101	106	87	609
CC02-10	25.4-31.9	0.37	0.03	0.20	10	34	14	71
CC02-11	31.9-38.4	0.74	0.02	0.29	19	50	32	373
CC02-12	38.4-45.9	0.61	0.01	0.12	1.8	9.8	16	121
CC02-13	45.9-53.4	0.62	0.01	0.05	1.5	4.7	9	45

Notes: Core collected 4/03/2000. Fe, As, Pb, Cr, and Zn determined by microwave-assisted nitric acid digestion with ICP detection (RSKSOP-180 Rev.2). NM = not measured. TOC = total carbon minus inorganic carbon determined using an UIC, Inc. Carbon Coulometer. S = total sulfur determined using an UIC, Inc. Sulfur Coulometer.

Table F.3. Concentrations of selected elements in sediment core SC02 collected within Hall's Brook Holding Area Pond.

Sample ID	Depth Interval cm	Fe wt%	S wt%	TOC wt%	As µg/gm	Pb µg/gm	Cr µg/gm	Zn µg/gm
SC02-1	0.0-3.0	17.53	2.54	NM	1495	460	812	4467
SC02-2	3.0-6.0	11.94	2.25	11.32	1439	455	594	3612
SC02-3	6.0-9.0	9.98	2.18	9.51	942	399	618	3477
SC02-4	9.0-12.0	3.4	1.37	5.04	232	315	328	1790
SC02-5	12.0-15.0	2.72	0.57	6.46	200	452	462	1860
SC02-6	15.0-18.0	1.28	0.17	1.86	66	226	219	357
SC02-7	18.0-21.0	NM	0.03	0.13	NM	NM	NM	NM

Notes: Core collected 4/03/2000. Fe, As, Pb, Cr, and Zn determined by microwave-assisted nitric acid digestion with ICP detection (RSKSOP-180 Rev.2). NM = not measured. TOC = total carbon minus inorganic carbon determined using an UIC, Inc. Carbon Coulometer. S = total sulfur determined using an UIC, Inc. Sulfur Coulometer.

Table F.4. Concentrations of selected elements in surface sediments collected within the Hall's Brook Holding Area Pond.

Sample ID	Fe wt%	S wt%	TOC wt%	As, µg/gm		Pb µg/gm	Cr µg/gm	Zn µg/gm
				<2 mm	<2 µm			
SC0401-1	7.46	1.14	5.24	680	NM	274	511	2550
SC0401-2	8.94	2.44	10.26	1150	NM	392	698	4790
SC0401-3	11.9	10.95	6.69	1680	NM	398	250	17500
SC0401-4	9.34	0.37	4.53	430	NM	1180	NM	2350
SC0401-5	7.59	1.59	14.18	676	NM	526	593	3440
SC0401-6	8.56	2.85	18.61	1070	NM	481	694	3190
SC0401-7	8.65	2.32	17.34	973	NM	360	549	2590
WI01	3.8	0.20	3.10	494	2536	794	197	583
WI01-NEP	7.7	0.18	3.00	830	3564	572	122	767
WI02	24.6	0.47	4.75	715	1036	203	106	3034
WI02-NEP	18.5	0.65	5.24	630	803	262	162	4589
WI04	26.3	0.35	5.26	840	995	115	49	1517

Notes: Sediments with 'SC' designation collected on 4/03/2001; sediments with 'WI' designation collected on 8/24/2000. Fe, As, Pb, Cr, and Zn determined by microwave-assisted nitric acid digestion with ICP detection (RSKSOP-180 Rev.2), except for <2 µm As determined following 24 hour extraction with 1 N HCl at room temperature. NM = not measured. TOC = total carbon minus inorganic carbon determined using an UIC, Inc. Carbon Coulometer. S = total sulfur determined using an UIC, Inc. Sulfur Coulometer.

Table F.5. Geochemical data for pore water isolated from sediment samples. COND = specific conductivity, ALK = alkalinity, NM = not measured.

Sample ID	pH	COND µS/cm	ALK mg/L $CaCO_3$	Fe^{2+} mg/L	As µg/L
GHME12B	NM	688	18.4	7.9	674
GH2801	5.76	945	151.2	65.0	215
GH2901	8.62	537	17.6	4.5	540
HBHAW02B	7.14	1138	283.6	42.5	156

Table F.6. Concentrations of selected elements in surface sediments collected within the Well's G&H and the Hall's Brook Holding Area wetlands. Fe, As, Pb, Cr, and Zn determined by microwave-assisted nitric acid digestion with ICP detection (RSKSOP-180 Rev.2). ND = not detected. TOC = total carbon minus inorganic carbon determined using an UIC, Inc. Carbon Coulometer. S = total sulfur determined using an UIC, Inc. Sulfur Coulometer. Locational data (Massachusetts State Plane, NAD83 except HBHAW02B) for sediments are as follows (Sample ID; Northing, meters; Easting, meters): GHME12B, N 916167.941, E 230325.386; GH2801, N 916304.07332, E 230251.86080; GH2901, N 916085.94456; E 230310.01906; HBHAW02B, N 4708561.424, E 324278.5871 (UTM Z19 NAD83).

Sample ID	Fe wt%	S wt%	TOC wt%	As µg/gm	Pb µg/gm	Cr µg/gm	Zn µg/gm
GHME12B	4.6	1.6	20.0	1110	686	1450	1750
GH2801	5.0	0.9	37.6	1030	393	495	1520
GH2901	1.0	0.3	2.9	83	59	218	494
HBHAW02B	1.2	0.2	1.2	66	30	44	508

Table F.7. Summary of solution data from leaching experiments. Dried sediment split samples were leached either with surface water collected from NML-2 sampling location ('NML-2') or a synthetic solution ('SSPW') with a major inorganic element composition comparable to water from NML-2. No dissolved organic carbon was present in the SSPW solution. Values for 'Estimated As From Pore Water' were determined based on the volume of residual pore water and the measured pore water As concentration for each sediment split sample. The fraction of residual pore water contribution for each leaching experiment is shown in parentheses.

Sample ID	Elapsed Time (hour)	pH S.U.	COND µS/cm	ORP mV	As ppb	Estimated As From Pore Water ppb
GHME12B1 (SSPW)	0.25	7.31	1031	94	262	11 (4%)
	2.12	7.33	1006	150	319	
	3.70	7.33	993	156	316	
GHME12B2 (SSPW)	0.33	7.29	970	48	243	13 (4%)
	2.05	7.44	974	111	316	
	4.30	7.28	991	123	339	
GHME12B3 (NML-2)	0.33	6.71	964	48	260	14 (4%)
	2.00	6.84	955	97	336	
	4.00	6.82	964	120	369	
GH28011 (SSPW)	0.33	7.03	1002	102	87	21 (26%)
	2.08	7.02	996	107	90	
	4.58	6.95	1040	127	82	
GH28012 (SSPW)	0.33	6.79	993	67	89	19 (14%)
	1.67	6.9	973	63	103	
	3.58	7.01	959	83	141	
GH29011 (SSPW)	0.33	6.79	921	45	26	29 (126%)
	2	6.94	889	93	21	
	4.00	6.98	886	133	23	
HBHAW02B1 (SSPW)	0.33	6.69	947	-9	<33	13
	2	6.93	912	11	<33	
	4.00	7.06	899	33	<33	
HBHAW02B2 (NML-2)	0.33	6.42	908	-10	25	13 (108%)
	2.00	6.51	916	22	15	
	4	6.5	925	83	12	

Figure F.1. Photograph of shallow oxic sediments within the northern portion of the HBHA Pond near the Atlantic Avenue Drainway discharge. This photograph depicts the area of collection for sediment samples WI01, WI01-NEP, WI02, WI02-NEP and WI04. The orangish-red sediments are the product of rapid oxidation and precipitation of ferrous iron discharging into the HBHA Pond from shallow ground-water seeps. Photograph was taken August 24, 2000.

Appendix G

Summary of benzene and toluene concentrations for snap-shot and fixed (tubing wells) ground-water monitoring locations and surface-water locations within the HBHA Pond.

Table G.1. Summary of benzene and toluene concentrations measured in filtered ground-water samples collected from snap-shot monitoring locations. Explanation of abbreviations: ft bgs = feet below ground surface, BLQ = below limit of quantitation, ND = not detected, NM = not measured, NS = not sampled.

Location	Sampling Date	Screen Depth ft bgs	Benzene ppb [1]	Toluene ppb [2]
A01-1	10/14/1999	32.75	1.2	1.6
A01-2	10/15/1999	41.75	1.0	BLQ
A02-1	10/14/1999	12.00	2.1	ND
A03-1	10/15/1999	9.00	ND	ND
A03-2	10/15/1999	19.00	ND	ND
A04-1	10/15/1999	15.00	ND	ND
A04-2	10/15/1999	24.75	ND	ND
A04-3	10/15/1999	32.50	ND	ND
A05-1	10/15/1999	8.50	ND	ND
A06-1	10/18/1999	15.50	BLQ	ND
A06-2	10/18/1999	25.50	ND	ND
A07-1	10/18/1999	13.50	ND	ND
A07-2	10/18/1999	23.50	ND	ND
A08-1	10/19/1999	9.00	ND	ND
A08-2	10/19/1999	19.00	ND	ND
A08-3	10/19/1999	39.00	2580.0	23.3
A09-1	10/19/1999	12.50	6.9	BLQ
A09-2	10/19/1999	22.50	2.4	ND
A09-3	10/19/1999	43.00	1.1	ND
A10-1	10/20/1999	10.00	BLQ	ND
A10-2	10/20/1999	20.00	799.0	1.4
A10-3	10/20/1999	30.00	1130.0	1.7
A11-1	10/20/1999	10.50	3.2	ND
A11-2	10/20/1999	20.50	719.0	1520.0
A11-3	10/20/1999	30.50	4780.0	91.4
A12-1	10/20/1999	12.00	11.8	ND
A12-2	10/21/1999	22.00	4.1	ND
A12-3	10/21/1999	32.00	3.3	ND
A13-1	10/20/1999	7.50	6.6	ND
A13-2	10/20/1999	17.50	322.0	1970.0
A13-3	10/20/1999	34.50	NM	NM
A13-4	10/20/1999	45.00	NM	NM
A14-1	11/30/1999	10.00	ND	ND
A14-2	11/30/1999	15.00	ND	ND
A14-3	11/30/1999	30.00	BLQ	ND
A15-1	11/30/1999	11.8	NM	NM
A16-1	12/1/1999	7.00	ND	ND
A16-2	12/1/1999	12.00	171.0	13.5
A17-1	12/1/1999	7.00	ND	ND
A17-3	12/1/1999	17.00	4812.0	7.8
A18-1	12/2/1999	19.00	9.1	ND
A19-1	12/2/1999	8.50	1.7	ND
A20-1	3/28/2000	5.00	NS	NS
A20-2	3/28/2000	10.00	BLQ	2.0
A21-1	3/30/2000	5.50	BLQ	BLQ
A21-2	3/30/2000	13.50	ND	BLQ
A22-1	3/31/2000	9.75	BLQ	BLQ
A22-2	3/31/2000	14.75	BLQ	BLQ
A23-1	3/31/2000	9.75	5.0	2.0
A23-2	4/3/2000	16.75	2.0	1.0

[1] Detection Limit = 0.23 ppb; Quantitation Limit = 1.00 ppb
[2] Detection Limit = 0.22 ppb; Quantitation Limit = 1.00 ppb

Table G.2. Summary of benzene and toluene concentrations measured in filtered ground-water samples collected from fixed-point monitoring locations. Explanation of abbreviations: ft bgs = feet below ground surface, ft bws = feet below water surface, NA = not applicable, NM = not measured, ND = not detected, BLQ = below limit of quantitation.

Location	Sampling Date	Screen Depth ft bgs [1]	Benzene ppb [2]	Toluene ppb [3]
TW01	3/29/2000	9.00	4070.0	11.0
	5/17/2000	9.00	1745.0	67.0
	4/3/2001	9.00	2590.0	31.2
TW02	4/6/2000	14.00	728.0	9.0
	5/16/2000	14.00	865.5	1.9
	3/29/2001	14.00	782.0	3.8
TW03	3/29/2000	13.00	2.0	1.0
	5/16/2000	13.00	BLQ	BLQ
TW04	3/29/2000	14.00	5.5	BLQ
	5/16/2000	14.00	1.0	1.0
	3/29/2001	14.00	1.8	5.4
TW05	5/17/2000	11.00	10.5	BLQ
TW06-1	4/5/2000	12.25	1.0	BLQ
	5/16/2000	12.25	BLQ	BLQ
TW06-2	4/5/2000	17.50	BLQ	1.0
	5/16/2000	17.50	BLQ	BLQ
TW06-3	4/5/2000	22.50	1.0	1.0
	5/16/2000	22.50	BLQ	BLQ
TW07-1	4/4/2000	12.25	BLQ	1.0
	5/16/2000	12.25	BLQ	BLQ
	3/29/2001	12.25	BLQ	4.8
TW07-2	4/5/2000	15.00	BLQ	BLQ
	5/16/2000	15.00	BLQ	BLQ
	3/29/2001	15.00	BLQ	4.7
TW07-3	4/5/2000	20.00	BLQ	1.0
	5/16/2000	20.00	BLQ	BLQ
	3/29/2001	20.00	BLQ	5.6
TW08-1	4/6/2000	8.00	89.0	204.0
	5/17/2000	8.00	111.0	141.0
	4/3/2001	8.00	40.0	76.3
TW08-2	4/6/2000	13.00	BLQ	1.0
	5/17/2000	13.00	BLQ	BLQ
TW08-3	4/6/2000	17.50	4770.0	11.0
	5/17/2000	17.50	3750.0	14.3
	4/3/2001	17.50	2980.0	17.5
TW10-1	5/16/2000	10.58	3.6	BLQ
	4/2/2001	10.58	BLQ	2.5
TW10-2	5/16/2000	15.58	BLQ	BLQ
	4/2/2001	15.58	BLQ	2.9
TW10-3	5/16/2000	20.58	BLQ	BLQ
	4/2/2001	20.58	BLQ	2.4

[1] Fixed monitoring locations TW01, TW02, TW03, TW04, and TW05 are installed within the HBHA Pond. The depth indicated for is for feet below water surface.
[2] Quantitation Limit = 1.00 ppb
[3] Quantitation Limit = 1.00 ppb

Table G.3. Summary of benzene and toluene concentrations measured in filtered surface-water samples collected from within the HBHA Pond on November 30, 1999. The position of 'WN', 'WC', and 'WS' sampling locations is shown in Figure A.7 in Appendix A. Explanation of abbreviations: BLQ = below limit of quantitation, ND = not detected.

Location	Sampling Date	Depth Below Water Surface, ft	Benzene ppb [1]	Toluene ppb [2]
WN50	11/30/1999	1.64	BLQ	ND
WN100	11/30/1999	3.28	BLQ	ND
WN150	11/30/1999	4.92	1.9	ND
WN200	11/30/1999	6.56	6.4	ND
WN250	11/30/1999	8.20	293	BLQ
WC50	11/30/1999	1.64	2.3	ND
WC100	11/30/1999	3.28	1.7	ND
WC150	11/30/1999	4.92	1.2	ND
WC200	11/30/1999	6.56	14.8	ND
WC250	11/30/1999	8.20	105	BLQ
WS50	11/30/1999	1.64	1.7	ND
WS100	11/30/1999	3.28	BLQ	ND
WS150	11/30/1999	4.92	BLQ	ND
WS200	11/30/1999	6.56	32.9	BLQ
WS250	11/30/1999	8.20	106	BLQ
WS300	11/30/1999	9.84	187	BLQ

[1] Quantitation Limit = 1.00 ppb
[2] Detection Limit = 0.22 ppb; Quantitation Limit = 1.00 ppb

Table G.4. Summary of benzene and toluene concentrations measured in filtered suface-water samples collected from within the HBHA Pond on April 4, 2000. The position of 'WN', 'WC', and 'WS' sampling locations is shown in Figure A.7 in Appendix A. Explanation of abbreviations: BLQ = below limit of quantitation, ND = not detected.

Location	Sampling Date	Depth Below Water Surface, ft	Benzene ppb	Toluene ppb [1]
WN50	4/4/2000	1.64	1	BLQ
WN100	4/4/2000	3.28	1	BLQ
WN150	4/4/2000	4.92	2	BLQ
WN175	4/4/2000	5.74	1	BLQ
WN200	4/4/2000	6.56	1	BLQ
WN225	4/4/2000	7.38	2	BLQ
WN250	4/4/2000	8.20	136	1
WN300	4/4/2000	9.84	908	ND
WC50	4/4/2000	1.64	8	1
WC100	4/4/2000	3.28	4	BLQ
WC150	4/4/2000	4.92	3	BLQ
WC200	4/4/2000	6.56	8	1
WC250	4/4/2000	8.20	3	BLQ
WC275	4/4/2000	9.02	8	BLQ
WS50	4/4/2000	1.64	2	1
WS100	4/4/2000	3.28	2	1
WS150	4/4/2000	4.92	3	BLQ
WS200	4/4/2000	6.56	2	BLQ
WS250	4/4/2000	8.20	2	BLQ
WS300	4/4/2000	9.84	116	BLQ

[1] Detection Limit = 0.22 ppb; Quantitation Limit = 1.00 ppb

Table G.5. Summary of benzene and toluene concentrations measured in filtered surface-water samples collected from within the HBHA Pond on April 2-5, 2001. The position of 'WN', 'WC', and 'WS' sampling locations is shown in Figure A.7 in Appendix A. The position of the 'NML' sampling location is shown in Figure A.8 in Appendix A. Explanation of abbreviations: BLQ = below limit of quantitation, ND = not detected, NM = not measured.

Location	Sampling Date	Depth Below Water Surface, ft	Benzene ppb [1]	Toluene ppb [2]
WN50	4/2/2001	1.64	0.6	2.9
WN100	4/2/2001	3.28	8.1	2.6
WN150	4/2/2001	4.92	0.6	2.4
WN200	4/2/2001	6.56	0.6	2.2
WN250	4/2/2001	8.20	0.8	2.1
WN270	4/2/2001	8.86	0.7	2.3
WN310	4/2/2001	10.17	21.9	ND
WC50	4/2/2001	1.64	BLQ	2.5
WC100	4/2/2001	3.28	2.6	2.3
WC150	4/2/2001	4.92	NM	NM
WC200	4/2/2001	6.56	BLQ	2.2
WC250	4/2/2001	8.20	NM	NM
WC300	4/2/2001	9.84	0.9	2.1
WS50	4/2/2001	1.64	2.9	4.3
WS100	4/2/2001	3.28	BLQ	1.8
WS150	4/2/2001	4.92	0.8	3.8
WS200	4/2/2001	6.56	0.5	2.6
WS250	4/2/2001	8.20	0.5	1.8
WS300	4/2/2001	9.84	BLQ	1.9
NML-1	4/5/2001	2.26	NM	NM
NML-2	4/5/2001	3.90	1.1	2.7
NML-3	4/5/2001	5.54	NM	NM
NML-4	4/5/2001	7.19	NM	NM
NML-5	4/5/2001	8.83	NM	NM
NML-6	4/5/2001	10.47	0.5	0.5
NML-7	4/5/2001	12.11	NM	NM
NML-8	4/5/2001	13.75	1830	13.9

[1] Quantitation Limit = 1.00 ppb
[2] Detection Limit = 0.22 ppb

January 26, 2004

MEMORANDUM

FROM: Robert Ford, EPA/ORD

TO: Joseph LeMay, EPA/Region 1

Attached are concentration data for benzene and toluene detected in the HBHA Pond during three sampling trips. Depth and concentration data are shown in Tables 1-3. The positions of sampling locations within the HBHA Pond are shown in Figure 1. Determination of benzene and toluene concentrations was performed using Purge and Trap Gas Chromatography according to RSKSOP-122 Rev.3.

Figure 1. Position of north (WN), central (WC), south (WS), and NML surface water sampling locations within the HBHA Pond. Contour lines show the depth from water surface to sediment. Image was derived from April 2001 aerial photograph obtained from MassGIS.

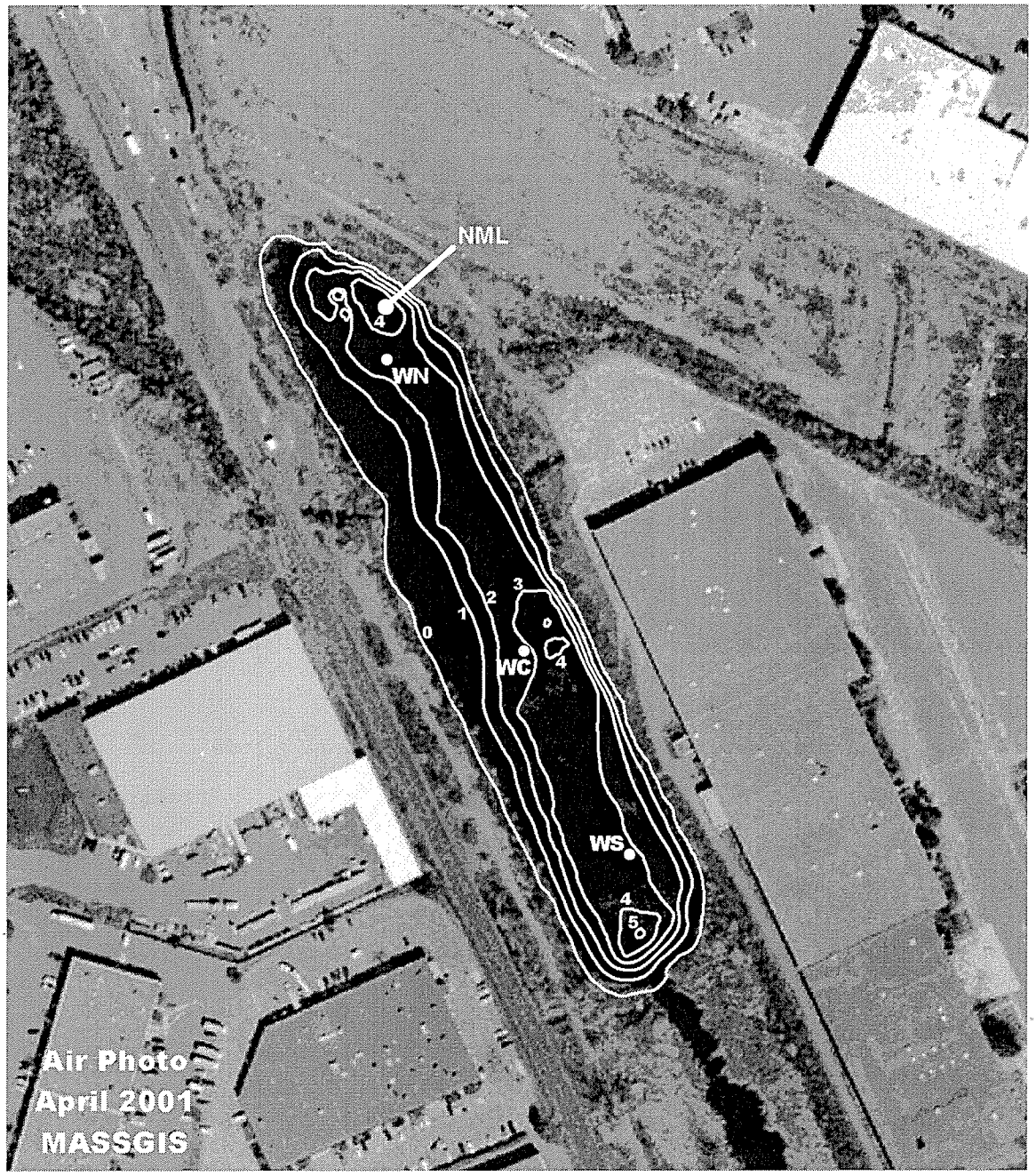


Table 1. Concentrations of benzene and toluene measured in water samples collected at various depths within the HBHA Pond on November 30, 1999.

Location	Depth Below Water Surface, cm	Benzene ppb [a]	Toluene ppb [b]
WN50	50	BLQ	ND
WN100	100	BLQ	ND
WN150	150	1.9	ND
WN200	200	6.4	ND
WN250	250	293	BLQ
WC50	50	2.3	ND
WC100	100	1.7	ND
WC150	150	1.2	ND
WC200	200	14.8	ND
WC250	250	105	BLQ
WS50	50	1.7	ND
WS100	100	BLQ	ND
WS150	150	BLQ	ND
WS200	200	32.9	BLQ
WS250	250	106	BLQ
WS300	300	187	BLQ

[a] BLQ = Below Limit of Quantitation; Quantitation Limit = 1.00 ppb
[b] ND = not detected, Detection Limit = 0.22 ppb; Quantitation Limit = 1.00 ppb

Table 2. Concentrations of benzene and toluene measured in water samples collected at various depths within the HBHA Pond on April 4, 2000.

Location	Depth Below Water Surface, cm	Benzene ppb	Toluene ppb [a]
WN50	50	1	BLQ
WN100	100	1	BLQ
WN150	150	2	BLQ
WN175	175	1	BLQ
WN200	200	1	BLQ
WN225	225	2	BLQ
WN250	250	136	1
WN300	300	908	ND
WC50	50	8	1
WC100	100	4	BLQ
WC150	150	3	BLQ
WC200	200	8	1
WC250	250	3	BLQ
WC275	275	8	BLQ
WS50	50	2	1
WS100	100	2	1
WS150	150	3	BLQ
WS200	200	2	BLQ
WS250	250	2	BLQ
WS300	300	116	BLQ

[a] BLQ = Below Limit of Quantitation, Quantitation Limit = 1.00 ppb; ND = not detected, , Detection Limit = 0.22 ppb

Table 3. Concentrations of benzene and toluene measured in water samples collected at various depths within the HBHA Pond on April 2-5, 2001; NM = not measured.

Location	Depth Below Water Surface, cm	Benzene ppb [a]	Toluene ppb [b]
WN50	50	0.6	2.9
WN100	100	8.1	2.6
WN150	150	0.6	2.4
WN200	200	0.6	2.2
WN250	250	0.8	2.1
WN270	270	0.7	2.3
WN310	310	21.9	ND
WC50	50	BLQ	2.5
WC100	100	2.6	2.3
WC150	150	NM	NM
WC200	200	BLQ	2.2
WC250	250	NM	NM
WC300	300	0.9	2.1
WS50	50	2.9	4.3
WS100	100	BLQ	1.8
WS150	150	0.8	3.8
WS200	200	0.5	2.6
WS250	250	0.5	1.8
WS300	300	BLQ	1.9
NML-1	69	NM	NM
NML-2	119	1.1	2.7
NML-3	169	NM	NM
NML-4	219	NM	NM
NML-5	269	NM	NM
NML-6	319	0.5	0.5
NML-7	369	NM	NM
NML-8	419	1830	13.9

[a] BLQ = Below Limit of Quantitation; Quantitation Limit = 1.00 ppb
[b] ND = not detected, Detection Limit = 0.22 ppb

Table 3. Concentrations of benzene and toluene measured in water samples collected at various depths within the HBHA Pond on September 20-21, 2004.

Location	Depth Below Water Surface, cm	Benzene ppb [a]	Toluene ppb [b]
WS50	50	ND	ND
WS100	100	ND	ND
WS150	150	ND	ND
WS200	200	2.88	ND
WS300	300	ND	ND
WS350	350	ND	ND
WS400	400	68.8	1.03
WS450	450	75.2	BLQ
NML-6	319	1210	2.69
NML-7	369	1830	4.91
NML-8	419	2530	3.31

[a] ND = not detected, Detection Limit = 0.29 ppb

[b] BLQ = Below Limit of Quantitation, Quantitation Limit = 1.00 ppb; Detection Limit = 0.22 ppb