2. SITE CHARACTERIZATION ACTIVITIES

This chapter presents a description of the Site characterization activities performed during the RI in accordance with EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1992), *Superfund Program Representative Sampling Guidance* (EPA 1995), the RI/FS work plans and TSWPs. These activities include:

- sampling and analysis of surface water and sediment from surface water bodies, (Sect. 2.1);
- sampling and analysis of surface soils, (Sect. 2.2);
- sampling and analysis of subsurface soils and installation of temporary overburden monitoring wells (Sect. 2.3);
- bedrock coring, discrete interval sampling, installation of bedrock monitoring wells, discrete interval sampling in select domestic wells, diffusion bag groundwater sampling and analysis, and conversion of select domestic wells to dual-completion monitoring wells (Sect. 2.4);
- in situ hydraulic conductivity testing (Sect. 2.5);
- site-wide baseline sampling of groundwater monitoring wells, including inspection and redevelopment of pre-RI monitoring wells and development of newly installed wells (Sect. 2.6);
- sampling of surface and near-surface soils from off-Site locations (i.e., background sampling) (Sect. 2.7); and
- geophysical survey to locate any buried metals and to assist in the identification of unknown "disturbed areas" (Sect. 2.8).

Overall, the intent of this investigation was to implement a phased approach to sampling. Surface soil sampling locations were selected based on the results of the gamma survey (SAIC 2003a). Subsurface soil sampling locations were based on the need to obtain representative data in all AOCs. Available surface soil analysis results, qualitative VOC depth profiles obtained at multiple locations using a membrane interface probe (MIP), and plume delineation models generated during previous investigations (Plates 3 and 5 of LBG 2002b) were also considered in locating subsurface soil samples. Groundwater target constituents for laboratory analyses were selected based on surface and subsurface soil analytical data from previous studies and quick-turnaround field-screening data obtained from the on-going RI.

2.1 SURFACE WATER AND SEDIMENT SAMPLING

The surface water bodies in the vicinity of the Hematite Site which may have been impacted by historical Site operations are the Site Pond, the Site Creek, Joachim Creek, and the Northeast Site Creek (see Fig. 1.3). The Site Pond and Site Creek receive NPDES-permitted discharge water from sanitary sewage and stormwater systems at Outfalls #1 and #3. The Site Pond is also fed by a natural spring located on the north tip of the Site Pond. The Site Creek merges with the Lake Virginia tributary, and the combined stream discharges to Joachim Creek. The Northeast Site Creek does not directly receive wastewater discharge from the Hematite Facility, but it may have been impacted by surface water runoff and groundwater discharge from the Burial Pit Area. Joachim Creek maybe have been impacted by historical Site operations through surface water flow from the Site Creek and the Northeast Site Creek, as

well as shallow groundwater flowing downgradient from the Hematite Site and discharging into Joachim Creek, surface water runoff from impacted Site soils, and flooding. Some discharge of contaminants is allowed by the NPDES permit for the Facility, and has been monitored according to NPDES permit requirements.

The TSWP *Surface Water and Sediment Investigation* (SAIC 2004a) served as guidance for this portion of the field investigation, along with EPA guidance document *Superfund Program Representative Sampling Guidance Volume 5: Water and Sediment* (EPA 1995).

2.1.1 Surface Water Level Measurements

Staff gauges were installed at the Site Pond, Site Creek, Joachim Creek, Northeast Site Creek, and East Lake; specific locations are shown on Fig. 2.1. Elevations of the staff gauges were surveyed by a professional land surveyor. Surface water levels were measured monthly from June 2004 through January 2005 to assess the hydraulic relationship between these surface water bodies and local groundwater.

2.1.2 Surface Water Sampling

Surface water samples (Fig. 2.2) were collected from the Site Pond (US-03-SW and SW-01-SW), Northeast Site Creek (US-01-SW and SW-09-SW), East Lake Tributary (US-04-SW), and Joachim Creek (US-05-SW, SW-16-SW, SW-08-SW, SW-14-SW, SW-02-SW, SW-15-SW) (Fig. 2.2). One upstream surface water sample (US-02-SW, Fig. 2.2) was also collected from the Lake Virginia Tributary, which merges with the waters of Site Creek prior to discharging to Joachim Creek. Samples from the creeks were collected as grab samples at mid-depth in moving water at the main flow line of the creeks and were considered to represent the entire creek cross-section. Surface water samples collected from Site Pond (SW-01-SW) and an upstream spring location (US-03-SW) were vertical composites from the deepest points in the pond, except for the samples for VOC analyses which were collected as grab samples.

Prior to sample collection, field parameters [i.e., dissolved oxygen (DO), pH, temperature, and specific conductivity] were measured using a water quality meter at each surface water sampling location (SAIC FTP-880). Surface water samples from the Site Creek and Northeast Site Creek were collected using a dipper (SAIC FTP-577), while Joachim Creek and Site Pond were sampled with a bomb sampler due to the deeper water profiles. Downstream samples were collected first, then the remaining samples were collected in an upstream direction to minimize disturbance. Samples for VOC analysis were collected first, with special attention to minimize headspace, followed by the collection of samples for any remaining constituents. At locations where water and sediment samples were collocated, water samples were collected before the sediment samples, and upstream from any imprint made in the streambed. Sampling equipment and tools were decontaminated between sampling locations (SAIC FTP-405). Immediately upon collection, the samples were containerized, labeled, and placed on ice. Surface water samples were shipped to an off-site laboratory and analyzed for RCOPCs and CCOPCs using methods shown in Table 2.1. Quality control (QC) samples [i.e., field duplicates, matrix spikes (MSs), and matrix spike duplicates (MSDs)] were collected at a rate of 1 for every 12 sample locations. Rinsate blanks were collected daily from the decontaminated sampling equipment and analyzed for the full suite of constituents sampled that day. Trip blanks for VOC analysis and temperature blanks were included in each shipping container. A summary of analytical results for the surface water samples are presented and discussed in Chapter 4 of this report.

2.1.3 Sediment Sampling

Sediment (streambed) samples from the Site Creek/Lake Virginia Tributary (SW-04-SS and SW-03-SS), Site Pond (SW-05-SS, SW-07-SS, SW-06-SS, SW-01-SS), Northeast Site Creek/East Lake Tributary

(SW-11-SS, SW-12-SS, SW-13-SS, SW-10-SS, US-04-SS), and Joachim Creek (US-05-SW, SW-16-SS, SW-08-SS, SW-14-SS, SW-02-SS, SW-15-SS) were collected as grab samples (Fig. 2.3). The samples were collected in depositional areas along the main flow line of the water body because particle-reactive contaminants tend to concentrate in the fine-grained sediments in depositional zones. Sediment samples from the Site Pond were collected at the deepest points in the pond at the upper and lower ends.

Streambed and pond sediment samples were collected using stainless steel trowels, shovels, and augers depending on field conditions at the time of sampling. Upon collection, the sample was extracted from the sampling device and placed immediately in appropriate laboratory containers. Samples for VOC analysis were collected first, with special attention to minimize headspace, followed by the collection of samples for any remaining constituents. Sample containers were labeled and placed on ice (SAIC FTP-650). Sediment samples were shipped to an off-site laboratory and analyzed for RCOPCs and CCOPCs (Table 2.2). QC samples (i.e., field duplicates, MSs, and MSDs) were collected at a rate of 1 per 17 sample locations. Sampling equipment was decontaminated between sampling locations (SAIC FTP-405). Rinsate blanks were collected daily from the decontaminated sampling equipment and analyzed for the full suite of constituents sampled that day. Trip blanks for VOC analysis and temperature blanks were included in each shipping container. A summary of analytical results for the sediment samples are presented and discussed in Chapter 4 of this report.

2.2 SURFACE SOIL SAMPLING

Surface soil samples were collected at 12 AOCs (note that some of the AOCs do not include surface soil media, e.g., AOC #1 Groundwater), at other sampling locations identified during the gamma survey (SAIC 2003a), and along east-west and north-south transect lines across the Hematite Site to aid in the evaluation of potential impacts due to deposition from air emissions or contamination from surface activities. Surface soil samples were collected at 115 locations (Figs. 2.4a and b). The *Surface Soil Investigation* TSWP (SAIC 2004b), as well as the EPA document *Superfund Program: Representative Sampling Guidance, Volume 1: Soil* (EPA 1995), served as guidance for this portion of the field investigation. Sample locations and frequencies varied from the initial location/frequencies detailed in the RI/FS Work Plan (LBG 2003) based on data gathered during the gamma survey (SAIC 2003a).

Soil samples were collected from a depth of 0 to 0.5 ft below ground surface (BGS) using stainless steel spades or trowels (SAIC FTP-550). Sample locations covered by asphalt or concrete were relocated to the nearest unpaved area. After collection, samples were placed in stainless steel bowls for radiological screening and classification by a field geologist according to the Unified Soil Classification System (USCS).

Surface soil samples were screened for beta-gamma activity using portable radiation monitoring equipment: Geiger-Mueller (GM) for beta/gamma and a sodium iodide (NaI) for gamma activity (SAIC FTP 451). Relative background count rates (in air) were obtained at each sampling location prior to screening samples. The relative background count rates were used for comparison with count rates from screening the soil core as an indication of the soil core's activity. In addition, prior to final selection of each surface soil sampling location, the general area surrounding the planned location was scanned with a 2 × 2-in. NaI gamma radiation detector. If activities within an area around the planned sampling location did not exhibit elevated activity, then the sample was collected at the planned location. If an area of elevated activity was located during the general area scan, then the location with elevated activity was selected for sampling.

After the soil samples were logged and surveyed, they were containerized, labeled, placed on ice, and shipped to an off-site laboratory (SAIC FTP-650) for radiological and chemical analysis (Table 2.3). Samples

for VOC analyses were collected first, with special attention to minimize headspace. The remaining soils were homogenized in stainless steel bowls. QC samples were collected at a rate of 1 per 19 for field duplicates and 1 per 29 for MS/MSD samples. Rinsate blanks were collected daily and analyzed for the full suite of constituents sampled that day. Trip blanks for VOC analysis and temperature blanks were included in each shipping container. Analytical results for the surface soil samples are presented and discussed in Chapter 4 of this report.

Samples of the spent limestone were collected from approximately ten locations within each of the three limestone storage/fill areas (Figure 1.3) and composited for laboratory analysis. Approximately 50% of the samples within each limestone pile/area were collected at the surface (i.e., within the top 6 inches) and the remaining samples were collected at various depths. The ten samples from each limestone pile/area were then composited in accordance with SAIC FTP-691, Composite Procedures, and sent to the analytical laboratory for the same analyses performed for surface soil samples (see Table 2.3) with the exception of isotopic uranium and thorium analyses. Analytical results for the limestone pile composite samples (LS-01 through LS-03, see Figure 2.4b) are analyzed together with the rest of the surface soil sample results in Chapter 4 of this report.

2.3 SUBSURFACE SOIL SAMPLING AND INSTALLATION OF OVERBURDEN MONITORING WELLS

The Hematite RI TSWP, *Subsurface Soil Investigation and Overburden Monitoring Well Installation and Development* (SAIC 2004c), and associated field changes served as guidance for this portion of the field investigation. Potential soil sampling locations were initially screened using a MIP advanced through the subsurface to bedrock or refusal using direct-push technology (DPT). The focus of the MIP and DPT investigations was VOC detection and plume delineation. These locations were selected in accordance with the AOCs (Sect. 1.6); in many instances, locations were also selected due to elevated radiological activity detected during the gamma survey (SAIC 2003a). If real-time screening data provided by the MIP indicated the presence of VOCs, soil samples were then collected at the same location for VOC analysis. Rotary drilling was used to obtain overburden soil samples in locations where bedrock coring was performed. Details regarding subsurface soil screening, soil sampling, and installation of temporary monitoring wells in the DPT boreholes are described in the following subsections.

2.3.1 Field Screening Using the MIP

The MIP is a recently developed field-screening tool that enables rapid assessment at depth where VOC contamination is likely to be found. As the probe is advanced into the subsurface, VOCs diffuse through a membrane into the heated probe and are swept into gas-phase detectors located on the ground surface. The MIP detectors include a flame ionization detector (FID), an electron capture detector (ECD), and a photoionization detector (PID). Elevated responses from these detectors for a given probe depth indicate the potential presence of VOCs. The MIP is also equipped with instruments that measure soil conductivity, probe depth, and temperature.

If the MIP detector logs indicated the presence of VOCs, a separate borehole for soil sampling was advanced within close proximity of the MIP hole. The MIP logs (i.e., detector response versus depth) were used to select depth intervals within a soil core for qualitative headspace screening and quantitative VOC analysis (Sect. 2.3.2). In some cases, the MIP was used to verify clean soil to verify VOC plume boundaries in subsurface soil. A total of 93 locations were investigated with the MIP; MIP logs can be found in Appendix B.

2.3.2 Subsurface Soil Sampling via Direct-Push Technology

DPT using hydraulic pressure was used to advance Macro-Core® samplers to obtain soil cores. When necessary, a vibratory hammer was used in combination with hydraulics to reach the target depth. Upon setup, 1-min fixed radiological measurements were taken at the sampling locations. The boreholes were advanced to refusal, which was assumed to correspond to bedrock depth. The soil was sampled continuously using 4-ft-long Macro-Core® samplers fitted with acetate liners. This approach allowed for logging of the entire soil profile. Upon removal of the liner from the sampling equipment, it was cut open and representative sections were immediately placed in sealable plastic bags for headspace analysis and labeled with the corresponding depths. The remaining soil cores were scanned for radiological contamination with NaI (gamma) and GM (beta/gamma) hand-held meters (SAIC FTP 451). A 1-min fixed-point measurement was performed at the core section, which exhibited the highest reading noted during the scan. If no elevated scan readings were identified, the fixed reading was performed at the approximate mid-point of the sampling interval. The zone within each sampling interval having the highest readings was selected for radiological sample collection and laboratory analysis. If elevated radiological readings were not detected along the soil core, soil samples for radiological analyses were collected within the same zones as those for the chemical constituents.

Immediately after being scanned and logged, up to 2-ft segments of soil core were placed in separate plastic bags. After a period of 10 min, a headspace analysis was performed by inserting the tip of a hand-held PID inside the bag to measure VOC vapor concentrations (SAIC FTP-750). Field measurements are recorded in the boring logs (Appendix C). Sample locations were selected based on the intervals having the highest headspace readings and a comparison to the MIP logs. If the readings were essentially homogeneous across the entire length of the boring, samples were collected within the approximate center of each lithologic unit with the samples representative of a maximum 10-ft interval. If the soil core was homogeneous with respect to headspace readings but a depth of concern was identified with the MIP, that area of the soil core was selected for sampling. In general, at least three samples were collected for each boring: above the water table, at the top of the saturated zone, and at the bottom of the boring. Additional samples, if collected, were selected due to notable lithologic changes. After the headspace analysis was completed, the selected samples were containerized, labeled, packed on ice, and shipped to an off-site laboratory (SAIC FTP-650) for radiological and chemical analysis (Table 2.4). Soil-sampling equipment was decontaminated between soil-sample intervals and locations (SAIC FTP-400 and FTP-405).

A total of 381 subsurface soil samples were collected from 109 sampling locations (Figs. 2.5a and b) and analyzed for contaminants of concern (Table 2.4). QC samples were collected at a rate of 1 per 16 for field duplicates and 1 per 29 for MS/MSD samples. Rinsate blanks were collected daily and analyzed for the full suite of constituents sampled that day. Trip blanks for VOC analysis and temperature blanks were included in each shipping container.

Boring logs for the overburden boreholes can be found in Appendix C, and are discussed in Chapter 3. A summary of analytical results for the soil samples are presented and discussed in Chaps. 4 and 5.

2.3.3 Installation of Temporary Groundwater Monitoring Wells in Direct-Push Technology Boreholes

Based on information gathered through the MIP detector logs (Sect. 2.3.1, Appendix B) and headspace VOC screening (Sect. 2.3.2), temporary monitoring wells were installed at selected DPT boring locations. Temporary groundwater monitoring well locations are shown on Figs. 2.6a and b, while logs and well construction data can be found in Appendices C and D, respectively. Boreholes not completed as temporary wells were backfilled with a tremied bentonite slurry.

The temporary monitoring wells were installed as follows in accordance with MDNR Well Construction Rules, 10 CSR 23-4.060, *Construction Standards for Monitoring Wells*. Upon completion of soil sampling (Sect. 2.3.2), a 3-in. outer diameter (O.D.) steel casing was driven into the open hole to the desired well screen depth. In general, the well screen depth was selected such that the screen bottom was approximately at the overburden/bedrock interface. At four locations where perched water is suspected (Fig. 2.5b, BP-20, EP-18, BP-22, and NB-57), a second monitoring well was installed and screened at least 10 ft above the overburden/bedrock interface. A well assembly composed of 1-in. inner diameter Schedule 40 polyvinyl chloride (PVC) pipe fitted with a 2.5-in. O.D. pre-packed well screen was then lowered into the 3-in. casing. Once the well assembly was in place, the 3-in. casing was retracted to a point situated just above the screen. A 1- to 2-ft sand barrier was then installed directly above the well screen through a tremie pipe that delivered sand to the desired depth and was advanced upward as the borehole annulus was filled with sand. The secondary filter pack serves as a barrier that prevents the bentonite slurry used for an annular seal from entering the screen interval. After installing the secondary filter pack, the annular region between the well and the borehole was grouted up to the ground surface with a high solids bentonite slurry grout (at least 20% solids) delivered via the tremie method. The annular seal was installed in one continuous operation. Upon grouting the annulus to ground surface, the 3-in casing was removed and additional slurry added to restore the grout level to ground surface, if necessary. The use of a bentonite slurry grout as opposed to chipped or pelletized bentonite will aid in the abandonment process. Screen lengths and depths were selected based on lithologic units, the appearance of saturated soils, static water levels, and field screening measurements (MIP and DPT data). In some cases, if transmissive zones were separated by less to non-transmissive zones of minimal thickness, the wells were designed to capture both transmissive zones.

Temporary monitoring wells were not developed after installation due to the nature of the pre-pack construction. However, three well volumes were removed prior to sampling activities. Groundwater samples for the site-wide groundwater monitoring event were not collected until 2 weeks after completion of the temporary wells to ensure that a return to stable conditions had occurred.

Preliminary groundwater samples were collected after installation of temporary wells to aid in determining the extent of groundwater contamination in the overburden and to ensure that sufficient wells were installed prior to demobilization. These groundwater samples were analyzed at an on-site analytical laboratory for VOCs only (EPA SW-846 8260M); results for the on-site analysis are presented in Chapter 4. Based on the on-site mobile laboratory analyses, a subset of these temporary groundwater monitoring wells was selected for inclusion in the site-wide baseline groundwater sampling event (Sect. 2.6). Additionally, several samples were collected from select wells installed around the Evaporation Ponds and submitted to the off-site laboratory for isotopic uranium, isotopic thorium, and ^{99}Tc analysis. Analytical results from on-site and off-site analyses can be found in Appendix I; off-site analyses are also tabulated in Appendix H.

Surface protection was not installed for any temporary well immediately after installation. Some of these monitoring wells will be converted to permanent monitoring wells with the installation of surface protection, while the rest of the wells will be abandoned following MDNR Well Construction Rules, 10 CSR 23-4.080, *Plugging of Monitoring Wells*.

2.3.4 Subsurface Soil Sampling via Rotary Drilling

In locations associated with planned bedrock monitoring wells near Joachim Creek [NB-62 (BR-06-OB), NB-29 (BR-08-OB), and NB-76 (BR-10-OB); Fig. 2.5a), subsurface soil sampling and installation of overburden monitoring wells (Sect. 2.3.5 below) were performed using rotary drilling in anticipation of large, gravel-size particles in the overburden materials located in Joachim Creek's flood plain. Subsurface soil samples were collected at 2-ft intervals by advancing a 3-in. diameter split spoon. After each 2-ft

sample interval, 3.75-in. inside diameter (ID) hollow-stem augers (HSAs) were advanced to the bottom of the sample interval. The augers were flooded with water once below the water table, and a center-bit was used to prevent or minimize heaving sands. Upon removal, the soil cores/samples were placed on a table, and representative sections were immediately placed in sealable plastic bags for headspace analysis and labeled with the corresponding depths. The remainder of the core was scanned with portable radiological instrumentation, and logged by a field geologist, as previously described (Sect. 2.3.2). After a minimum period of 10 min had passed, the bagged samples were subjected to headspace analysis and intervals selected based on this analysis were containerized as previously described (Sect. 2.3.2). Field measurements are shown in the boring logs (Appendix C). Soil samples were sent to an off-site laboratory for analysis using methods shown in Table 2.4.

2.3.5 Installation and Development of Permanent Overburden Monitoring Wells in Rotary Drilled Boreholes

At NB-62 (BR-06-OB), NB-29 (BR-08-OB), and NB-76 (BR-10-OB), permanent overburden monitoring wells were installed as follows in accordance with MDNR Well Construction Rules, 10 CSR 23-4.060, *Construction Standards for Monitoring Wells*. A 4.25-in. ID HSA with wooden knockout plugs (to prevent soil from entering the augers) was advanced to refusal (assumed to be bedrock). Upon reaching the bottom depth, the plug was removed, and a 2-in nominal diameter PVC riser with a 10-ft PVC screen (0.010-in. slot) was lowered through the augers to the bottom of the boring. Screen lengths were selected based on lithologic units (coarse sands and gravels) and placed at the top of bedrock.

Once the screen and riser materials were lowered to the bottom of the auger string, primary filter pack material (10/20-mesh sand) was placed inside the augers around the well screen. When possible, the placement of the sand and removal of the augers was performed simultaneously to prevent excess backfill materials from building up inside the augers, and to prevent the collapse of the natural formation around the screen interval. The primary filter pack was extended 1.7 to 2.5 ft above the screen and covered by a 1- to 2-ft-thick secondary filter pack composed of 100-mesh sand. Both filter packs were tremied in place to prevent bridging. An approximate 3-ft-thick bentonite seal of 0.25-in. coated bentonite pellets was placed above the secondary filter pack by gravity methods and allowed to hydrate for a minimum of 1 hour. The remainder of the borehole was tremied with a bentonite grout (minimum 20% solids) to ground surface inside the augers in one event. Once the grout reached the surface, the augers were removed and additional bentonite grout added to account for the volume of the augers. Prior to completion of the surface protection, additional grout was added to make up for any settling that may have occurred.

Surface protection was completed by the installation of a 4-in. square aluminum protective casing and a 2- × 2-ft concrete pad sloped to shed water. Steel bollards were installed around the well locations to provide added protection. Metallic tags stamped with the well numbers were permanently affixed to the protective casings. Well construction details are given in Appendix D, while completion diagrams are located in Appendix E.

Permanent overburden monitoring wells (BR-06-OB, BR-08-OB, and BR-10-OB) were developed using 0.75-in. high-density polyethylene (HDPE) tubing with a foot valve and surge block manipulated by mechanical means in 1- to 2-ft increments while pumping until stable water quality parameters (pH, temperature, specific conductivity, and turbidity) were achieved. Initially, the uppermost part of the well screen was surged while the water quality parameters were stabilized. The tubing and surge block were then lowered to the bottom of the well and held stationary until the water quality parameters stabilized. The tubing and surge block were then raised to the bottom of the previously surged zone and the process repeated until the entire screen interval was developed.

After a minimum of three well volumes was removed, water quality parameters were measured in 5-min increments until stable in three successive readings. The criteria for stability were: (1) pH varied less than or equal to 0.1 standard unit (s.u.), (2) temperature varied less than or equal to 0.5°C, (3) conductivity varied less than or equal to 3%, and (4) turbidity less than or equal to 10 nephelometric turbidity units (NTUs). Although a goal of 10 NTU was set for turbidity, in certain instances that goal could not be met due to the natural characteristics of the groundwater. If 10 NTU could not be reached in three attempts, development was considered complete when the water was clear to the unaided eye and the turbidity varied by less than or equal to 10%. It should be noted that natural turbidity levels in groundwater may exceed 10 NTUs and that turbidity is always the last indicator parameter to stabilize (USACE 1998).

All three permanent overburden monitoring wells collocated with bedrock monitoring wells (BR-06-OB, BR-08-OB, and BR-10-OB) were included in the site-wide baseline groundwater sampling event (Sect. 2.6).

Overburden monitoring wells were not installed in all the bedrock monitoring locations for the following reasons: (1) BR-05, BR-09, BR-11, and BR-12 were beyond the extent of overburden contamination delineated by MIP and field analysis of groundwater samples from temporary monitoring wells installed via DPT (Sect. 2.3.3); and (2) only 3 ft of overburden was present at BR-07.

2.4 BEDROCK CORING, DISCRETE INTERVAL GROUNDWATER SAMPLING, AND INSTALLATION OF BEDROCK MONITORING WELLS

One of the objectives of this RI is to assess the nature and determine the horizontal and vertical extent of contamination in bedrock formations where contaminants have been detected during previous investigations. To achieve this objective, bedrock monitoring wells were installed as part of this RI in eight locations (BR-05, BR-06, BR-07, BR-08, BR-09, BR-10, BR-11, and BR-12) (Fig. 2.6a). In addition, a monitoring well screened in the shallower Jefferson City-Cotter formation was installed at BR-03 where bedrock coring and a groundwater monitoring well screened within the Roubidoux formation (BR-03-RB) had been installed during previous investigations (LBG 2002b). The WEC-Hematite RI TSWP, *Subsurface Soil Investigation and Packer Isolation and Discrete Groundwater Sampling and Bedrock Monitoring Well Installation and Development* (SAIC 2004d), and associated field changes served as guidance for this portion of the field investigation. This effort consisted of bedrock coring and associated discrete interval groundwater sampling and monitoring well installations.

2.4.1 Bedrock Coring, Discrete Interval Sampling, and Diffusion Bag Sampling

Bedrock coring at locations shown on Fig. 2.6a (BR-05 through BR-12) proceeded as follows. A 3.75-in. ID HSA was advanced through the overburden to refusal (presumed to be bedrock). The first ~20-ft of bedrock was cored with an NQ-size wireline system. The rock core was boxed and logged by a field geologist. The 3.75-in. ID HSA was then removed and a 10.25-in. ID HSA was drilled to refusal. A 10-in. air rotary bit was advanced to the bottom of the cored interval and a 6-in. steel isolation casing set and tremie-grouted in place. The depth of the isolation casing was determined based on the depth of competent bedrock as observed in rock cores taken from the first 20-ft of bedrock. This isolation casing was installed to prevent the potential downward migration of contaminants from the overburden through the coreholes to the bedrock. After the cement grout around the isolation casing was allowed to harden, coring was continued using an NQ-wireline system at 5- to 10-ft intervals. Boring logs for these bedrock boreholes can be found in Appendix C, and are discussed in Chapter 3.

Discrete interval groundwater sampling was performed as the coring was advanced through the bedrock. Upon completion of a core interval, the core rod string was raised approximately 2 ft above the cored interval. The cored interval was then isolated by lowering a single-stage inflatable packer to the bottom of the core rod string; the bottom of the corehole was used as the lower barrier. A bladder pump was positioned below the packers and adjusted so that it was in the vertical center of the isolated interval.

Following inflation of the single-stage packer with compressed gas, the isolated interval was purged by removing a minimum of three volumes of the isolated interval prior to monitoring for water quality parameters. Stabilization was considered to have been achieved when the water quality parameters were stable for a minimum of three successive readings at 5-min intervals at a purge rate not exceeding 300 milliliters per minute (mL/min). The criteria for stability were: (1) pH varied less than or equal to 0.1 s.u., (2) temperature varied less than or equal to 0.5°C, and (3) conductivity varied less than or equal to 3%. Once these criteria were met, the purge rate was reduced to 100 mL/min for collection of a sample of groundwater for VOC analysis. Immediately upon collection, the groundwater samples were labeled, packed on ice, and transported, along with completed chain-of-custody (COC) forms, to the on-site analytical laboratory for expedited analysis via EPA SW-846 8260M. Purging continued until an additional three volumes had been removed or until the on-site laboratory analytical results were returned. At this time, water quality parameters were monitored and stabilized as above, and another groundwater sample for VOC analysis was collected to verify the results of the initial sample. Duplicate groundwater samples were collected at a rate of 1 in 20 and analyzed at either the on- or off-site laboratory. Results from on-site and off-site analyses can be found in Appendix I; off-site analyses results are also tabulated in Appendix H.

An attempt was made to determine the importance of removing three well volumes prior to testing for parameter stability by collecting and analyzing samples after one and two volumes had been removed. However, due to the absence of contaminated zones encountered after the implementation of this study, the results were inconclusive.

It was not uncommon for non-transmissive zones to be encountered during discrete interval sampling. Non-transmissive zones were indicated by purge flow rates that substantially decreased or dropped to zero, likely because groundwater flow into the isolated interval could not keep up with the purge flow rate. Field checks were made to verify the non-transmissive conditions by releasing the air from the packers and monitoring the purge flow rate as the column of water standing above the packer was allowed to drain into the previously isolated interval. In all cases, after the packers were released, the purge flow rate returned to maximum capacity. This process, involving releasing and re-inflating the packers, was repeated approximately three times to verify the isolated interval was non-transmissive. In these cases, no groundwater sample was collected and coring continued and the next interval was isolated and tested.

During bedrock coring, precautionary measures were implemented to prevent vertical cross-contamination within a borehole. At BR-09 and BR-10, coring was terminated when contamination was detected in discrete interval samples at concentrations greater than a screening level [e.g., drinking water standards (i.e., 5 ppb for TCE)]. After coring was terminated, these boreholes were reamed using a 5.625-in rotary bit, and wells screened within the contaminated intervals were subsequently installed (BR-09-JC, BR-10-JC, see Sect. 2.4.2 on procedures for well installation). At BR-08, coring was suspended when a contaminated depth interval was first encountered, and an isolation casing was installed in the borehole to prevent downward contaminant migration into deeper bedrock when coring resumed. After installation of the isolation casing, coring and packer testing continued until a positive identification of the Roubidoux formation was made. The borehole was then reamed using a 5.625-in rotary bit and a bedrock monitoring well was installed. A second borehole located within a few feet of the first borehole was then drilled to install a monitoring well (BR-08-JC) screened within the contaminated

depth interval identified during the discrete interval sampling at the first borehole. The second borehole was drilled using a 10.25-in HSA through the overburden to refusal, followed by NQ-size wireline coring through the first 20-ft of bedrock. The depth of competent bedrock was determined from the 20-ft rock core, after which a 10-in air rotary bit was drilled to this depth. A 6-in isolation casing was then lowered into the hole and set in place via tremie grouting. Coring and discrete interval sampling was conducted following the same procedure used in the first borehole. Coring in the second borehole was terminated when VOCs were detected in the discrete interval samples. The borehole was then reamed using a 5.25-in air rotary bit prior to installation of BR-08-JC.

At BR-05, BR-06, BR-07, BR-11 and BR-12, coring and packer testing were continued until a positive identification of the Roubidoux formation was made. No VOC levels were detected above 5 ppb during packer testing at these locations.

Core water was recirculated to the maximum extent possible to reduce the amount of investigation-derived waste (IDW) generated. Clean water was added on occasion to remove accumulated sediments inside the core rod string and barrel. Although no quantitative measurements were made regarding the volumes of core water used and lost during the coring process, visual estimations were made. Factors other than loss into the formation were deemed to play major roles in this determination (i.e., loss around augers prior to casing installation and pump and piping leakages); therefore, it is concluded that water loss to the formation did not appreciably dilute collected discrete groundwater samples.

Diffusion bag sampling was performed in BR-05 to confirm the results of the discrete interval sampling. Polyethylene bags were filled with deionized water, sealed, and suspended within the open borehole on 20-ft centers throughout the water column and left in place for a minimum of 2 weeks. The bags were then removed and samples collected for VOC analysis at the on-site laboratory. On-site analysis results for the diffusion bag samples can be found in Appendix I.

2.4.2 Bedrock Monitoring Well Installation

Bedrock monitoring wells (2-in diameter) were installed in accordance with MDNR Well Construction Rules, 10 CSR 23-4.060, *Construction Standards for Monitoring Wells*. The wells were installed either in boreholes drilled for coring and discrete interval sampling (drilling procedures described previously in Sect. 2.4.1), or boreholes that were drilled solely for well installation. For monitoring wells installed in the boreholes that had been used for coring and discrete interval sampling, the boreholes were reamed with a 5.25-in air rotary bit to the desired well depth prior to well installation. For wells installed in new borings (e.g., in locations where wells at two depths were installed, such as BR-05, BR-07, BR-08, BR-10, and BR-12), 10.25-in. ID HSAs were advanced through the overburden to refusal. The first ~20-ft of bedrock was cored with an NQ-size wireline system. A 10-in. air rotary bit was then advanced to a depth corresponding to competent bedrock based on the 20-ft rock core, and a 6-in. steel isolation casing set and tremie-grouted in place. This isolation casing was installed to prevent the downward migration of contaminants from the overburden through the coreholes to the bedrock. A 5.625-in. air rotary bit was then used to drill through the isolation casing down to the desired depth of the well.

After the borehole had been drilled or reamed to the desired well depth, the well string was lowered to the bottom of the borehole. The primary filter pack was installed by tremie method to a position 2 to 5 ft above the screen. A secondary filter pack consisting of clean fine sand was placed by tremie method 1 to 2 ft above the primary filter pack. The purpose of the secondary filter pack was to ensure that grout used for the annular seal did not infiltrate into the primary filter pack. A 3- to 5-ft-thick bentonite seal of pelletized bentonite designed to fall through water without hydrating was placed above the secondary filter pack and allowed to hydrate for 1 hr.

Upon completion of the bentonite seal, the annular seal was installed by emplacing a bentonite slurry grout to a position equivalent to the proposed location of the base of the protective cover. The high solids sodium bentonite slurry, at least 20 % by weight solids, was tremie-grouted from the bottom to the top of the annular space in one continual operation. The grout was allowed to cure for a minimum of 24 hours. After this time, additional grout was added to rectify any settling that may have occurred to restore the grout level to the desired depth.

After completion of the annular seal, a protective cover was installed around the riser pipe and completed per the above-referenced MDNR Well Construction Rules. A concrete pad approximately 2×2 ft was constructed around the protective cover and sloped to drain to prevent ponding around the well. Bollards were also installed around bedrock wells to protect the wellhead from damage by vehicles. Metallic tags stamped with the well numbers were permanently affixed to the protective casings. Well construction data are provided in Appendix D, while well completion diagrams are located in Appendix E. Well construction details can also be found in Appendix C, where they are shown in the associated borings logs.

2.4.3 Video logging and Discrete Interval Groundwater Sampling in Domestic Wells

A number of residential wells southeast of the Facility across Joachim Creek were video-logged to verify the characteristics of the wells in public records (e.g., depth of casing, total depth, etc.). The information obtained from the video logging is provided in Appendix B.

Based on the historical knowledge that VOCs were present in a number of residential wells to the east and southeast of the site, discrete interval sampling was performed on residential wells PW-3 and PW-19 (Fig. 1.2 for domestic well locations).

A dual-stage packer system attached to 2-in. nominal diameter steel pipe capable of isolating zones up to 40 ft was lowered into the open domestic well. A variable-speed submersible pump was positioned inside the steel pipe near the bottom of the isolated zone. Packer-isolation intervals were maintained at 40 ft throughout the initial investigation of PW-19 until the entire well was sampled. At this time, the isolation intervals were reduced to 10 or 20 ft for more specific determination of the vertical extent of contamination. Intervals were maintained at 20 ft throughout the entire investigation of PW-3.

Purging began at 5 gpm or the maximum obtainable pumping rate, whichever was less, with the intent of determining general hydraulic characteristics of the isolated portion of the aquifer. During purging, water levels were monitored inside and outside of the drop pipe. If the interval was not pumped dry prior to the removal of three volumes, the depth to water inside the drop pipe was recorded upon removal of each volume, and the parameter stabilization and sample process initiated (Sect. 2.4.1).

If the interval was pumped dry prior to the removal of three volumes, pumping was stopped and the water level allowed to recover to the approximate midpoint of the isolated interval. Water levels inside the drop pipe were again measured periodically and recorded with elapsed time to determine recovery rates. Once the water level had reached the midpoint of the isolated interval, pumping was resumed with the attempt to equalize the pumping rate to the recharge rate of the aquifer followed by parameter stabilization and sample collection. If the interval did not recharge to the midpoint within 90 min, a sufficient volume of water was allowed to accumulate within the isolated zone and low-flow sampling was initiated without parameter stabilization. This approach was implemented to obtain a basic understanding of, the hydraulic properties of the aquifers. Duplicate samples were collected at the rate of 1 in 20 and analyzed at the on-site laboratory. Select samples were also sent to the off-site laboratory for VOC analysis. A comparison of the on- and off-site laboratory data can be found in Chapter 4. Analytical results from the on-site laboratory can be found in Appendix I.

2.4.4 Diffusion Bag Sampling and Analysis in Domestic Wells

Diffusion bag sampling was performed at PW-19 to validate packer test results prior to installation of the wells, and at PW-16 in place of packer testing. Analytical results from the on-site laboratory can be found in Appendix I. Polyethylene bags were filled with deionized water, sealed, and suspended within the open boreholes on 20-ft centers throughout the water column and left in place for a minimum of 2 weeks. The bags were then removed and samples collected for VOC analysis at the on-site laboratory. Further discussion of the results and comparison to packer test data can be found in Chapter 5.

2.4.5 Conversion of Domestic Wells to Dual-Completion Monitoring Wells

As part of the investigation of the extent of groundwater contamination outside the Facility, domestic wells PW-06, PW-16, and PW-19 (Fig. 2.6a) were converted to dual-completion monitoring wells. These wells were reamed with a tri-cone roller bit to their existing total depth and chlorinated to eliminate any potential bacterial populations. Within the same borehole, two 2-in. PVC monitoring wells were installed: one in the Roubidoux formation and a second within the Jefferson City-Cotter formation. Screened intervals in the Jefferson City-Cotter formation were selected based on results obtained during discrete interval groundwater sampling and diffusion bag sampling (PW-16 and PW-19). The contaminated zones at BR-08, BR-09, and BR-10 appeared to be on a plane with strike and dip directions that are consistent with the known bedding plane orientation at the Hematite Site. The screened intervals at PW-16, PW-19, and PW-06 within the Jefferson City-Cotter Formation were also roughly on the same plane as the contaminated zones identified during packer testing of BR-08, BR-09, and BR-10. The bottom of the screened intervals in the Roubidoux Formation were set at or within 5 ft of the bottom of the original well boreholes.

The dual-completion monitoring wells were installed as described in Sect. 2.3.3, with the exception that bentonite grout was placed above the Roubidoux and below the Jefferson City-Cotter wells. Upon completion of the Roubidoux well, a portion of the borehole was grouted with high-solids bentonite grout to a position near the proposed location of the Jefferson City well and allowed to cure. If necessary, the remainder of the borehole was filled with chipped or pelletized bentonite to the desired location for the Jefferson City well. The upper well was then completed. To ensure that a competent seal was formed between the wells, pumping tests were performed on the Roubidoux well while monitoring the water levels within the Jefferson City well. The pump test results provided by the well installers can be found in Appendix I. Wells were installed in accordance with MDNR Well Construction Rules, 10 CSR 23-4.060, *Construction Standards for Monitoring Wells*. Well construction details are provided in Appendix D, while completion diagrams are located in Appendix E.

2.5 IN-SITU HYDRAULIC CONDUCTIVITY TESTING

In situ hydraulic conductivity tests (slug tests) were performed on selected overburden wells (BR-06-OB, BR-08-OB, BR-10-OB, NB-73, and NB-84), and in the following bedrock wells (BR-07-JC, BR-08-JC, BR-10-JC, BR-11-JC, BR-12-JC, PW-06-JC, PW-19-JC, PZ-03, PZ-04, WS-30, WS-31, BR-01-RB, BR-02-RB, BR-06-RB, BR-07-RB, BR-08-RB, BR-10-RB, BR-12-RB, and PW-06-RB) to supplement data from previous investigations. Testing was performed in accordance with SAIC FTP-376, *Aquifer Analysis by Slug Test Method*, and other approved industry standards. The overburden locations were chosen to provide representative hydraulic conductivities of the overburden near the Facility (terrace deposits) and near Joachim Creek (floodplain deposits; detailed discussion of overburden lithology is presented in Chapter 3). The bedrock locations were selected to provide representative hydraulic conductivities of the Jefferson City–Cotter Formation and Roubidoux Formation across the entire Hematite Site.

The slug tests were performed using a standard technique of pressurizing the well casing with air (a pneumatic slug), which displaces water out of the well thus releasing the pressure, then monitoring the recovery of the water level in the well. During the slug tests, water levels were measured using a pressure transducer that was connected to a data logger capable of recording data every 1 sec. The pneumatic slug assembly was positioned on top of the well casing, all gauges zeroed and all relief valves closed. Prior to insertion into the well, the pressure transducer was programmed with specific well information, and the static water level and total depth were manually recorded. The transducer was then lowered into the well through the pneumatic slug assembly to a position approximately 10 to 15 ft below the static water level, and an airtight fitting was tightened around the transducer cable to seal the connection. Air was introduced into the well via a small portable air compressor until the desired displacement had been achieved. At that point, the relief valve was opened and the test performed as a "rising head" test. A data logger was used to record pressure transducer response from the beginning of pressurization through complete recovery to the static water level. Due to the need to set recording times at such a short interval (every 1 sec), direct observation of the data was not possible in some of the wells tested. After a period of approximately 5 min, the transducer was stopped and the data reviewed to ensure static conditions had been achieved. Additional tests were run routinely to provide replicate recovery data for a given well.

Due to the low conductivities experienced in BR-7-JC, a sufficient water displacement using a pneumatic slug in the well was difficult to achieve. Thus, a traditional "slug" constructed of PVC pipe was used to create displacement and a "falling head" conductivity test was performed. Direct reading of the pressure transducer allowed for the correction of an error common to pneumatic slug testing in aquifers with lower conductivities. In these instances, the transducer reads the pressure inside the well and not the displacement of the water column. By using the direct-read function of the transducer, air was continually applied, thus resulting in a "rise" in the water level. This was monitored until the level had returned to static. At this time, the relief valve was opened and a subsequent lowering of the water level occurred, and the levels routinely monitored until true static conditions were achieved.

2.6 SITE-WIDE GROUNDWATER INVESTIGATION

The purpose of this investigation was to determine baseline groundwater conditions and to assess the presence and/or extent of groundwater contamination for applicable RCOPCs and CCOPCs. This investigation included inspection of the existing (i.e., pre-RI) groundwater monitoring network (Sect. 2.6.1), redevelopment of some of the pre-RI monitoring wells (Sect. 2.6.2,) and sampling of the existing monitoring well network and a select number of wells that were installed as part of the RI (Sect. 2.6.3). The WEC-Hematite RI TSWP, *Site-Wide Groundwater Well Assessment and Baseline Sampling* (SAIC 2004f), served as guidance for this portion of the field investigation.

2.6.1 Monitoring Well Inspection/Assessment

Existing monitoring wells and piezometers (prior to those installed as part of the RI) were visually inspected for compliance with current MDNR Well Construction Rules (MDNR 1996) to determine whether rehabilitation or maintenance was required. Criteria for the assessment included the following:

- Proximity to other sample points.
- Construction methods/materials.
- Availability of construction information (i.e., well installation diagrams).
- Existing conditions:
  - Surface seal.
  - Riser diameter.

- Screen length and interval.
- Recharge rate.

Existing wells selected for sampling with unknown construction details (WS-07, WS-08, WS-09, WS-14, WS-15, and WS-16) were subjected to video examination to determine screen lengths. All wells had static water levels and total depths recorded manually in accordance with established field protocols (SAIC FTP-370). Visual inspection also included a description of the condition of the surface protection, the condition of the visible portion of the well, and the protective casing and riser height above ground surface, if applicable.

Downhole video camera inspections were performed with a 2-in. downhole view or 4-in. dual-view camera run from the top to the bottom of the monitoring well to record structural and/or mechanical damage and the presence of screen plugging and/or biofouling. Continuous footage of the inspection was recorded on a vertical helical scan tape. Overall, it was found that the monitoring wells inspected were in good condition; due to their age, the wells installed prior to LBG 2002b were subjected to redevelopment (next subsection). The results of the well assessment were summarized in *Baseline Groundwater Well Assessment Well Inspection Report* (SAIC 2004g) which is included in Appendix F of this report.

2.6.2 Monitoring Well Redevelopment

Redevelopment of monitoring wells that were installed prior to 2002 (LBG 2002b) was performed with the use of a surge block affixed to 0.75-in. HDPE tubing. In addition to creating a surging effect, the tubing was fitted with a foot valve used to pump the well while surging. The tubing was raised and lowered in approximately 1-ft increments beginning at the bottom of the screen and proceeding upward until the entire screen was surged and pumped.

Redevelopment was considered to have been achieved when the water quality parameters (pH, temperature, specific conductivity, and turbidity) were stable for a minimum of three readings at 5-min intervals.

2.6.3 Groundwater Sampling

Groundwater sampling was conducted following established protocols (WEC-FTP-01, WEC-FTP-02). Details regarding the sampling equipment and depth are as follows:

- Sampling pumps: Permanent monitoring wells and piezometers were sampled using dedicated sampling tubes attached to non-dedicated bladder pumps. Temporary monitoring wells were sampled using dedicated sampling tubes attached to a peristaltic pump. The peristaltic pumps were equipped with an in-line sampling trap when collecting water samples for VOC analysis. Use of the in-line trap allowed sample collection prior to entry into the pump head to minimize VOC volatilization.

- Pump intake depth: For wells installed prior to the RI, the pump intake depth was generally set at the approximate middle of the screened interval. However, deeper pump intake depths were used in wells for which historical data indicated water levels were below the screen mid-point. For overburden wells installed during the RI, the pump intake depth was set at the middle of the screens. For bedrock wells installed during the RI, the pump intake depth was set at the zone of highest contamination based on initial packer test sampling. For bedrock wells with screened intervals that did not exhibit any contamination during the packer testing, the pump intake depth was set at the middle of the screen length.

Groundwater sampling proceeded as follows. After setting up the sampling pump, purging was initiated by adjusting the flow rate to 300 mL/min or less and allowing at least 300 mL to flow through the sampling port. Purge water was allowed to run through the water quality meter to remove any trapped air pockets. Upon removal of the calculated purge volume required for micropurging (low-flow purging and sampling, Puls 1996), field parameters (i.e., specific conductivity, pH, temperature, and turbidity) measurements were recorded. Purging continued and a minimum of two additional parameter measurements were taken in successive 5-min intervals until stability was reached. The criteria for stability were the same as those used in discrete interval sampling from the bedrock boreholes (Sect. 2.4.1). Water levels were monitored periodically during purging to observe any drawdown. The pumping rate was reduced or halted if the water level in the well approached the top of the screened interval. Wells in which drawdown to the top of the screened interval occurred while purging at a rate of 80 mL/min or less were assumed to pump dry. Aside from providing more representative groundwater samples (Puls 1996), the low-flow purging and sampling technique resulted in a reduction of IDW generated during the site-wide sampling event.

Upon stabilization of the water quality parameters, purging was suspended by turning off the pump control box, the discharge tubing was removed from the flow-through cell, and sample collection was initiated. In accordance with EPA recommendations for the order of sample collection (EPA 1992), VOC samples were collected first at a flow rate of 100 mL/min or less. After VOC sample collection was complete, the flow rate was increased up to 300 mL/min, or the maximum allowable pumping rate to correspond to slower recharge rates, whichever was less.

Wells that were pumped dry after parameter stabilization and prior to the completion of sample collection were allowed to remain undisturbed for a minimum of 24 hours and sample collection was then resumed without parameter stabilization. Due to poor recharge, the complete set of analyses intended for the groundwater samples was not collected at BD-22B (no filtered parameters) and BD-07 (no radiologic parameters). Monitoring wells BD-15, EP-14, EP-18A, EP-18B, and WS-09 were not sampled due to poor recharge. The inability to sample from these wells did not impact the assessment of groundwater contamination at the Site since there was still a sufficient number of surrounding wells that provided adequate areal coverage at the Site (refer to Chapter 4 for a complete assessment of groundwater data).

After collection, all samples requiring storage at 4° C were placed in a cooler with ice. COC forms were completed and the samples and appropriate COC forms submitted for shipment to an off-site laboratory. QC samples were collected at a rate of 1 per 16 for field duplicates and 1 per 57 for MS/MSD samples. Rinsate blanks were collected daily from each non-dedicated sampling device and analyzed for the full suite of constituents sampled that day. Trip blanks for VOC analysis and temperature blanks were included in each shipping container.

With the exception of BD-22B, BD-07, PW-06, PW-16 and PW-19, groundwater samples from all monitoring wells were analyzed for gross alpha/beta, isotopic uranium, isotopic thorium, ^{99}Tc, VOCs, metals, chloride, nitrate, and sulfate. As mentioned previously, filtered groundwater samples were not collected from BD-22B, radiological parameters were not collected at BD-07, and groundwater samples from the dual-completion wells (PW-06, PW-16, and PW-19) were sampled for VOCs alone based on historical data that had been collected from the private wells.

Groundwater samples for transuranic [americium-241 (^{241}Am), Neptunium-237 (^{237}Np) and plutonium isotopes] analysis were collected from 30 monitoring wells, 20 of which were selected randomly while the remaining 10 were selected to ensure that the sample set adequately represented AOCs. Groundwater samples for SVOC analysis were collected from wells in the vicinity of paved areas, based on low levels of SVOCs detected in surface and subsurface soil samples generally located near asphalt parking areas or driveways. The presence of dioxins was noted in soil samples from the

Cistern/Burn Pit (Chapter 4). For this reason, dioxin analysis was performed on a groundwater sample from monitoring well CB-02. Groundwater samples from eight monitoring wells located along a north/south transect and eight monitoring wells located along an east/west transect were analyzed for isotopic radium, pesticides, and PCBs. At these 16 transect monitoring well locations, both filtered (0.45 μm) and unfiltered samples were collected for metals and radiological parameters. Fluoride analysis was not performed on groundwater samples due to results in subsurface soil samples that were generally below the reporting limit (~7 mg/kg) except for a few locations within the Evaporation Ponds, under the buildings, and near Deul's Mountain. However, even the highest fluoride level (190 mg/kg in EP-13-06-SL, see Sect. 4.2.5.2) in the subsurface soil is below the geometric mean of regional values (270 mg/kg) reported by Tidball (1984). At all other well locations, only unfiltered samples were collected for metals and radiological parameters. Analysis methods used to determine the target analytes are shown in Table 2.5.

Water quality parameters were measured using field techniques in all the groundwater samples. The water quality parameters include pH, alkalinity, specific conductance, turbidity, DO, oxidation-reduction potential (ORP), sulfide, iron, and temperature. pH, specific conductance, DO, ORP, and temperature were measured using parameter-specific probes or instruments, while alkalinity, sulfide, and iron were measured using colorimetric test kits.

A list of the monitoring wells included in the site-wide sampling event can be found in Appendix D, while the results of the groundwater sample analyses are presented in Chapter 4 of this report.

To assess groundwater potentiometric conditions at the Hematite Site, water levels were measured in 1 day (December 3, 2004) at all monitoring wells included in the site-wide groundwater sampling event. Potentiometric surfaces based on this round of water level measurements are presented in Chapter 3.

2.7 OFF-SITE/BACKGROUND SAMPLING

The purpose of this investigation was to measure off-site/background concentrations of applicable RCOPCs and CCOPCs in surface and subsurface soil, surface water, groundwater and sediment to be used for evaluating contaminant analysis results relative to background conditions (Chapter 4). The Hematite RI TSWP, *Background Sampling* (SAIC 2004e), the *Multi-Agency Radiation Survey and Site Investigation Manual*, Revision 1, August (EPA 2000) and *Establishing Background Levels*, EPA/540/F-94/030, (EPA 1995) served as guidance for this portion of the field investigation. The collection of surface water and sediment samples at locations upgradient of the Hematite Site are discussed in Sect. 2.1. The collection of off-Site soil samples is described in the following paragraphs.

Thirty soil samples were collected from two off-Site locations, split between terrace and alluvial strata (Chapter 3 contains a description of these strata and their distribution in and around the Hematite Site). The terrace strata samples were collected approximately 2.5 miles west of the Hematite Site along Highway P. The alluvial strata samples were collected at the U.S. National Guard Armory Site, located approximately 1 mile to the northeast of the Hematite Site near the junction of State Road P and State Road A (see Fig. 2.7). The soil samples were collected from 0 to 0.5 ft BGS (discrete) and 1 to 4 ft BGS (composite) at each location (EPA 2000). The VOC sample collected from 1 to 4 ft BGS was a discrete sample. Consistent with sampling in impacted areas of the Hematite Site, the soil samples were scanned with GM and NaI detectors to provide background count rate information (SAIC FTP-451). Samples were collected regardless of scanning results so that background radionuclide concentrations were not biased to elevated readings. Soil samples were collected using stainless steel trowels or hand augers in accordance with established field protocols (SAIC FTP-525 and FTP-550). The soils were logged by a field geologist according to the USCS.

After the soil samples were logged and surveyed, they were containerized, labeled, placed on ice, and shipped to an off-site laboratory for radiological and chemical analysis (Table 2.6). QC samples (i.e., field duplicates, MSs, MSDs) were collected at a rate of 1 per 15 samples. Rinsate blanks were collected daily and analyzed for the full suite of constituents sampled that day. Trip blanks for VOC analysis and temperature blanks were included in each shipping container. Results of the off-Site sampling are given in Chapter 4 of this report. Additional information relative to calculations of appropriate background concentrations and analyte screening are provided in Appendix J.

2.8 GEOPHYSICAL SURVEY

A geophysical survey was conducted by Geophex, Ltd (Geophex, 2005) to collect surface magnetic data to assist in the identification of unknown "disturbed areas," which were originally presented on Plate 25 of the RI/FS WP (LBG 2003). These areas encompass locations adjacent to Site Pond and the Tile Barn, southwest of the railroad tracks, north and south of the Joachim Creek Bridge AOC, east of the Burial Pits AOC, and a few locations in the floodplain area. The scope of this geophysical survey did not encompass the Burial Pits AOC, as geophysical surveys have been conducted previously within that portion of the Facility (LBG 1999). Electromagnetic (EM) data was also collected to confirm any anomalies identified with the magnetic data. This EM data provided information about soil electrical conductivity and assisted in the identification of any areas that may have been trenched or filled with non-ferrous items.

Fieldwork was conducted from January 31 to February 4, 2005, within 13 grid areas totaling 5.76 acres. A Geometrics G-858 vertical gradient magnetometer and a Geophex GEM-2 EM induction sensor were walked over tracklines spaced at 5-ft intervals. All data were rectified using differentially corrected GPS to Missouri East State Plane coordinates and placed on Facility drawings.

Geophysical data found that most of the grid areas contained no evidence of buried metallic objects. Only one grid near the dairy barn highlights a number of magnetic anomalies and what appears on the EM data to be rectangular conductivity anomalies. Note that this area corresponds to the Red Room Roof AOC. Other than the Burial Pits, this is the only area where there is evidence of subsurface excavation or burial of objects that may have been trenched and/or filled at some time. Another anomaly rich area exists immediately north and south of the bridge over Joachim Creek. However, the majority of these anomalies are visible surface metal scrap and it is not suspected that any of the buried anomalies infer any organized trenched and/or filled area. These areas appear as ad hoc household dumping areas.

2.9 DATA QUALITY AND DATA VALIDATION

Laboratory analyses of samples collected for the RI were performed in accordance with the *Quality Assurance Project Plan, Hematite Remedial Investigation/Feasibility Study, Final Draft, Revision 1.1,* (QAPP, Appendix A of LBG 2003). The QAPP identified laboratory methods that represent the current state of practice for analysis of samples to measure identified parameters. Quality Control samples were used by the laboratory during the analyses according to the appropriate methodology. These samples included calibration verification samples, calibration blanks, laboratory control samples (LCS), and laboratory method blanks. Quality Assessment samples were also collected to confirm the quality of the data. These samples included field duplicates, matrix spikes (MS), matrix spike duplicates (MSD), trip blanks, and equipment rinsate blanks. Additionally, the laboratory methodology included the analysis of samples to which known concentrations of compounds (surrogates) have been added (spiked) to assess the performance (i.e. recovery) of the analyses.

Level IV data packages were provided by the laboratory. These data packages included the raw data and data summary forms for the primary field samples as well as all supporting QA/QC samples. The RI data were reported to the method detection limit (MDL), in that if a compound was identified below the reporting limit (RL) it was assigned a "J" qualifier to indicate that the concentration is estimated. The laboratory data generated during the RI are tabulated in Appendix H and also provided as electronic files in Appendix I. A data validation technical review was performed on 10% of the laboratory data. This review was performed in accordance with the *EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review, EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review,* and the *Laboratory Data Validation Guidelines for Evaluating Radionuclide Analyses and Radiochemical Data Verification and Validation.* The analyses were evaluated against criteria established in the related analytical procedures and the Westinghouse data quality requirements. Sixty-nine samples with a total of 9,897 data points were validated. None of the data subjected to validation were rejected. Detailed results of the data validation technical review are presented in the Data Validation Report in Appendix H, while data quality as indicated by analysis of quality control and quality assessment samples are summarized below.

Field Duplicates. Field duplicates are collected concurrently with the primary environmental samples and equally represent the medium at a given time and location. Comparison of the primary sample results with the field duplicate results indicated acceptable precision. Review of the results from the analysis of field duplicates did not identify any significant data quality issues with regard to the RI data.

Matrix Spikes and Matrix Spike Duplicates. The MS/MSD samples are laboratory control samples that are collected from the various media at the Site to allow evaluation of potential interferences that may arise from within the media itself. These samples are "spiked" with a known concentration of a compound in the laboratory and submitted for laboratory analysis. The samples are run in duplicate to assess the reproducibility of the results. Evaluation of the results from the sample (MS/MSD) analysis can point to a bias (either high or low) in the data, and this bias should be taken into account when evaluating the data. Approximately 1 MS/MSD sample pair was collected for every 20 samples collected during surface and subsurface soil sampling. During groundwater sampling, the frequency of MS/MSD samples collected was less than 1 in 20 due to low yield of many of the DPT-installed monitoring wells. There is no evidence that collection of additional MS/MSD samples during groundwater sampling would have materially affected the conclusions regarding the data quality. Five (5) MS/MSD samples were collected and analyzed for groundwater during the overall groundwater sampling event. The data from analysis of those samples did not indicate a data bias (high or low), thus those results were not used to qualify the data. Matrix interferences may affect the ability of the analytical instrument to detect concentrations of a contaminant, particularly near the detection limit. In those cases where the detection limit is close to a screening value (i.e. potential cleanup criteria), this limitation could result in the low concentration of that compound not being detected. This issue is typically not a problem where a relatively higher concentration of a compound is reported, since that compound will typically drive the risk and associated remedial measures.

Surrogates. Surrogate compounds are typically similar in chemical composition to the target compounds, so that the recovery of these compounds can be measured and reported as percentage of the added (known) concentration. The surrogate recoveries are evaluated, such that the sample analysis (or batch) is acceptable if the recoveries fall within a specified range. If the recoveries fall outside of the acceptable range, the results are evaluated by the laboratory to determine if the issue materially affects the sample results. As part of the validation effort (Appendix H), only one sample, CB-01-00-SL-FD, was identified with low surrogate recovery in the PCB analysis. This low recovery did not affect analysis for other compounds (i.e. volatile organic compounds) and does not appear to indicate an overall problem with the data, thus the data was determined to be useable for the RI. Given the substantial amount of sample analysis performed and data generated to support the RI, it is not unusual that there were some instances

where the surrogate recoveries were outside the specified range and qualifiers were applied to the data by the laboratory.

Blanks. Trip blank samples consist of containers of organic-free reagent grade water that are kept with the field sample containers from the time these leave the laboratory until they are returned for analysis. The purpose of trip blanks is to determine whether samples are being contaminated from VOCs during transit or sample collection. One trip blank was placed into each cooler used to store and ship samples designated for volatile organic analysis. Equipment rinsate blanks were collected from the water rinsate collected from equipment decontamination activities. They were comprised of samples of analyte-free reagent grade water, which was rinsed over decontaminated sampling equipment. Equipment rinsate blanks are employed to assess the effectiveness of the decontamination process, the potential for cross contamination between sampling locations and incidental field contamination. Laboratory method blanks are non-contaminated samples of the matrix of interest (usually reagent grade water or silica sand) that is subjected to all of the sample preparation (i.e., digestion, distillation, extraction) and analytical methodology applied to the samples. The purpose of the method blank is to check for contamination from within the laboratory that might be introduced during sample preparation and analysis that would adversely affect analytical results. Qualifiers were applied to the primary sample results by the laboratory when compounds were detected in an associated blank. Blank contamination could potentially cause sample results to be biased high (a conservative situation). It should be noted that the first tier of screening within the Baseline Human Health Risk Assessment evaluated potential constituents of concern based on a comparison of the maximum detected concentration to the corresponding regulatory limit. If sample results were reported at levels higher than the regulatory limit (i.e, maximum contaminant level or MCL) a conservative bias would be inherent in the risk assessment process.

Tentatively Identified Compounds. The data validation process and associated report (Appendix H) does not address tentatively identified compounds (TICs). The QAPP (Appendix A of LBG 2003) and Work Plans anticipated use of Level III data, which do not typically include TICs. During execution of the RI, a decision was made by WEC to have sample analysis for the RI performed using Level IV protocols. The Level IV data is reported in a data quality package that can be validated, where Level III data is not. Standard Level IV protocols do not include reporting and evaluation of TICs. Since there was no commitment to identify TICs, the laboratory was not asked to report them, and this information was not included in the data reports that were prepared in support of the RI at this Site. It should be noted that if TICs are identified, the laboratory typically performs a library search to try to identify the compound and estimates the quantity by the analytical methodology. Since the TICs are not included on a target compound list, where the methodology is established, the identification and quantification are less certain than that of the known compounds. Furthermore, the TICs when identified are typically organic compounds that are not associated with a known risk and would not typically be a factor in a risk assessment. As discussed in Sections 4 and 5 of this report, the most predominant organic compounds measured in the RI samples were PCE and TCE, consistent with historical use of these chemicals at the Facility. It is therefore extremely unlikely that TICs, if present, would materially impact decisions regarding remediation at the Site. Furthermore, the Historical Site Assessment (HSA) did not identify a significant potential for the presence of compounds other than those already on the established target compound lists that were identified for the different groups of analytes that were assessed as part of the RI.

Laboratory Review. Laboratory data review typically includes assessment of other laboratory QC measures (i.e. calibration verification recoveries, calibration blanks, LCS recoveries, and laboratory method blanks). If the laboratory identifies issues with the data, it either applies data qualifiers or re-runs the sample, according to the laboratory methodology. These laboratory qualifiers are included in the tabulated data (Appendix H) and electronic data files (Appendix I).

In summary, the impacts of identified potential quality issues (i.e. low surrogate recovery or contaminated method blank) are minimal in that they only occurred in relatively few of the analysis performed as part of the overall data set. In that the data were provided as a result of analysis by different independent methods, one potential issue, such as that with the low PCB surrogate recovery, does not affect the other data obtained through other analysis methods. Overall, these issues did not indicate a systematic error and the data should be considered useable for unrestricted use.

CHAPTER 2 FIGURES

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PROPERTY BOUNDARY

Fig. 2.1. Surface water gauging stations.

PROPERTY BOUNDARY

Fig. 2.2. Surface water sampling locations.

PROPERTY BOUNDARY

Fig. 2.3. Sediment sampling locations.

PROPERTY BOUNDARY

Fig. 2.4a. Surface soil sampling locations.

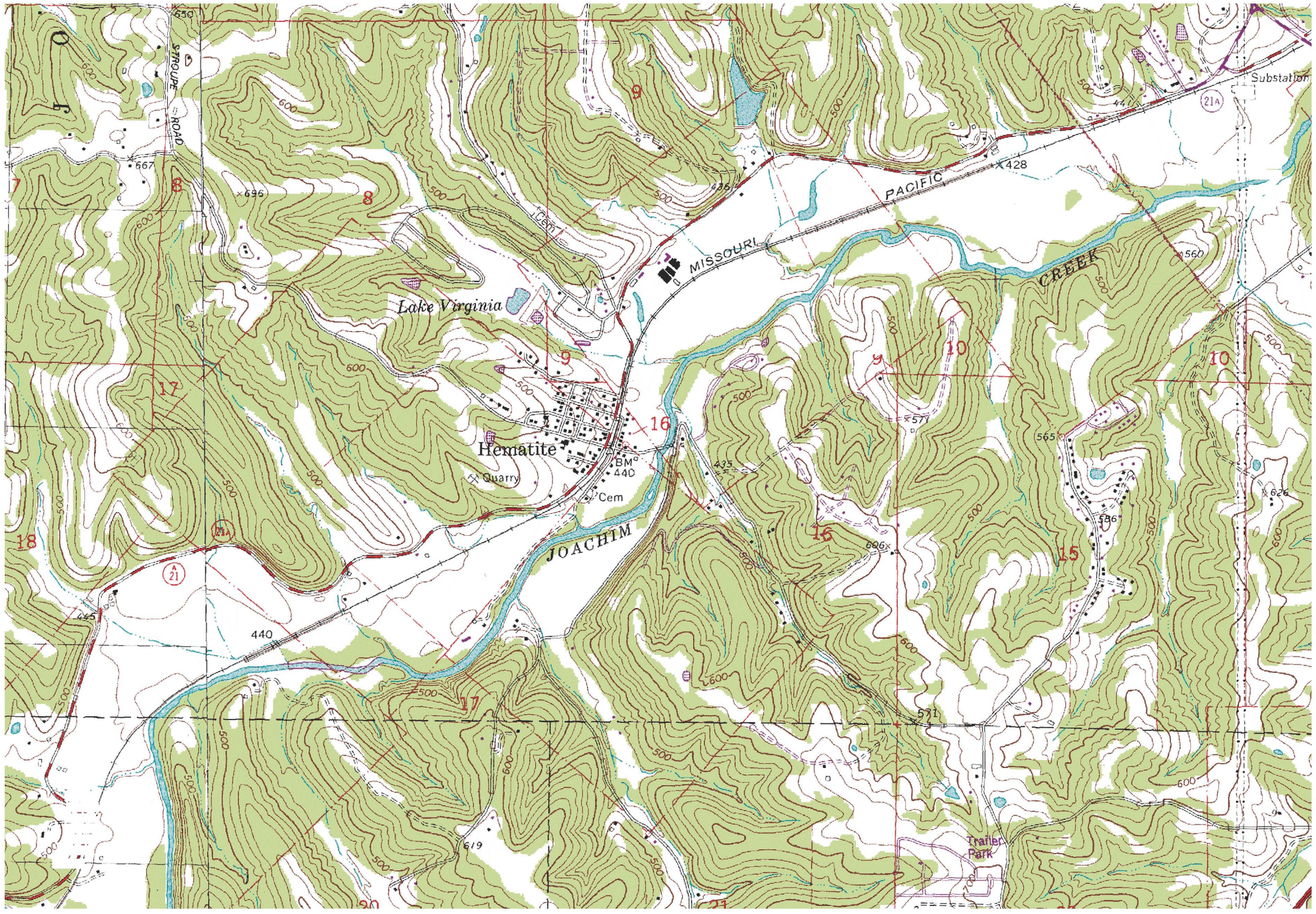
PROPERTY BOUNDARY

Fig. 2.5a. Subsurface soil sampling locations.

PROPERTY BOUNDARY

Fig. 2.5b. Subsurface soil sampling locations, Detail A.

Fig. 2.6b. Groundwater monitoring wells, Detail A.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Hematite
Quarry
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CHAPTER 2 TABLES

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Table 2.1. Analysis methods for surface water samples

Analysis	Analysis method
Gross alpha and beta	EPA 900: Gas-flow proportional counting.
^{228}Th, ^{230}Th, ^{232}Th	ASTM D3972-90M: Alpha spectrometry.
^{234}U, ^{235}U, ^{238}U	ASTM D3972-90M: Alpha spectrometry.
^{99}Tc	DOE RP 550: Liquid scintillation counting (analogous to ASTM C1387-98, which is a method for solid samples).
Volatile organic compounds	EPA SW-846 8260B: GC/MS.
Semivolatile organic compounds	GC/MS. EPA SW-846 8270C: GC/MS.
Organochlorine pesticides and PCBs	EPA SW-846 8081A: Gas chromatography/electron capture detection. EPA SW-846 8082: Gas chromatography/electron capture detection.
Fluoride	EPA 9214: Potentiometric determination with an ion-selective electrode.
Metals	EPA 6010B: Inductively coupled plasma-atomic emission spectrometry.
Mercury	EPA 7470A: Manual cold-vapor technique.
Total cyanide	EPA 9014: Titrimetric and manual spectrophotometry. (spectrophotometric method was used)

ASTM = American Society for Testing and Materials.
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency.
GC = gas chromatography.
MS = mass spectrometry.
PCB = polychlorinated biphenyl.
Tc = technetium.
Th = thorium.
U = uranium.

Table 2.2. Analysis methods for sediment samples

Analysis	Analysis method
Gamma-emitting radionuclides	EPA 901.1M: Gamma spectrometry.
^{228}Th, ^{230}Th, ^{232}Th[a]	ASTM D3972-90M: Alpha spectrometry.
^{234}U, ^{235}U, ^{238}U	ASTM D3972-90M: Alpha spectrometry.
Transuranics (Neptunium-237 (^{237}Np), Isotopic Plutonium (Pu))	ASTM D3972-90M: Alpha spectrometry.
^{99}Tc	ASTM C1387-98: Liquid scintillation counting.
VOCs	EPA SW-846 8260B: VOCs by GC/MS.
SVOCs	EPA SW-846 8270C: SVOCs by GC/MS.
Organochlorine pesticides and PCBs	EPA SW-846 8081A: Organochlorine pesticides by GC. EPA SW-846 8082: PCBs by GC.
Fluoride	EPA 9214: Potentiometric determination of fluoride in aqueous samples with ion-selective electrode (used on sediment extract).
Metals	EPA 6010B: Inductively coupled plasma-atomic emission spectrometry.
Mercury	EPA 7471A: Mercury in solid and semi-solid wastes (manual cold-vapor technique).
Total cyanide	EPA 9014: Titrimetric and manual spectrophotometric determinative methods for cyanide (spectrophotometric method was used)

[a]20% and 24% of sampling locations were selected for isotopic thorium and transuranics analysis (^{239}Pu, ^{240}Pu, and ^{237}Np, respectively).

ASTM = American Society for Testing and Materials.
EPA = U.S. Environmental Protection Agency.
GC = gas chromatography.
MS = mass spectrometry.
PCB = polychlorinated biphenyl.
SVOC = semivolatile organic compound.
Tc = technetium.
Th = thorium.
U = uranium.
VOC = volatile organic compound.

Table 2.3. Analysis methods for surface soil samples

Analysis	Analysis method
Gamma-emitting radionuclides	EPA 901.1M: Gamma spectrometry.
^{228}Th, ^{230}Th, ^{232}Th[a]	ASTM D3972-90M: Alpha spectrometry.
^{234}U, ^{235}U, ^{238}U[b]	ASTM D3972-90M: Alpha spectrometry.
^{99}Tc	ASTM C1387-98: Liquid scintillation counting.
Transuranics (^{237}N and Pu)[c]	ASTM D3972-90M: Alpha spectrometry.
Volatile organic compounds	EPA SW-846 8260B: GC/MS.
Semivolatile organic compounds	EPA SW-846 8270C: GC/MS.
Organochlorine pesticides and PCBs	EPA SW-846 8081A: GC/electron capture detection. EPA SW-846 8082: GC/electron capture detection.
Fluoride	EPA 9214: Potentiometric determination with an ion-selective electrode.
Metals	EPA 6010B: Inductively coupled plasma-atomic emission spectrometry.
Mercury	EPA 7471A: Manual cold-vapor technique.
Total cyanide	EPA 9014: Titrimetric and manual spectrophotometry.
Total petroleum hydrocarbons[d]	EPA 8015B: GC/flame ionization detection.
Dioxin[e]	EPA 8290: High-resolution GC/high-resolution MS.

[a]Isotopic thorium analysis was performed on 5% of the samples collected from areas of concern (AOCs) where Th-232 is a RCOPC.

[b]Isotopic uranium analysis was conducted on 5% of the samples.

[c]26% of samples were selected for transuranics analysis. Locations were randomly selected from samples greater than the minimum detectable concentrations but less than the derived concentration guidance levels and to ensure that AOCs were adequately represented.

[d]Conducted on samples collected at the Former Gasoline Station (AOC #10).

[e]Conducted on samples collected at the Cistern Burn Pit (AOC #14).

ASTM = American Society for Testing and Materials.
EPA = U.S. Environmental Protection Agency.
GC = gas chromatography.
MS = mass spectrometry.
Np = neptunium.
PCB = polychlorinated biphenyl.
Pu = plutonium.
Tc = technetium.
Th = thorium.
U = uranium.

Table 2.4. Analysis methods for subsurface soil samples

Analysis	Analysis method
Gamma-emitting radionuclides	EPA 901.1M: Gamma spectrometry.
^{228}Th, ^{230}Th, ^{232}Th[a]	ASTM D3972-90M: Alpha spectrometry.
^{234}U, ^{235}U, ^{238}U [b]	ASTM D3972-90M: Alpha spectrometry.
^{99}Tc	ASTM C1387-98: Liquid scintillation counting.
Transuranics (^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu)	ASTM D3972-90M: Alpha spectrometry.
Volatile organic compounds	EPA SW-846 8260B: GC/MS.
Semivolatile organic compounds	EPA SW-846 8270C: GC/MS.
Organochlorine pesticides and PCBs	EPA SW-846 8081A: GC/electron capture detection. EPA SW-846 8082: GC/electron capture detection.
Fluoride	EPA 9214: Potentiometric determination with an ion-selective electrode (used on sediment extract).
Metals	EPA 6010B: Inductively coupled plasma-atomic emission spectrometry.
Mercury	EPA 7471A: Manual cold-vapor technique.
Total cyanide	EPA 9014: Titrimetric and manual spectrophotometry.
Total petroleum hydrocarbons[c]	EPA 8105B: GC/flame ionization detection.
Dioxin[d]	EPA 8290: High-resolution GC/high-resolution MS.

[a]Isotopic thorium analysis was conducted on 5% of the samples collected from areas of concern (AOCs) where Th-232 is a radiological contaminant of potential concern.
[b]Isotopic uranium analysis was conducted on 5% of the samples.
[c]Total petroleum hydrocarbon analysis was conducted on samples collected at the Former Gasoline Station (AOC #10).
[d]Dioxin analysis was conducted on samples collected at the Cistern Burn Pit (AOC #14).
Am = americium.
ASTM = American Society for Testing and Materials.
EPA = U.S. Environmental Protection Agency.
GC = gas chromatography.
MS = mass spectrometry.
PCB = polychlorinated biphenyl.
Pu = plutonium
Tc = technetium.
Th = thorium.
U = uranium.

Table 2.5. Analysis methods for baseline groundwater samples

Analysis	Analysis method
Gross alpha and beta	EPA 900: Gas-flow proportional counting.
^{228}Th, ^{230}Th, ^{232}Th	ASTM D3972-90M: Alpha spectrometry.
^{234}U, ^{235}U, ^{238}U	ASTM D3972-90M: Alpha spectrometry.
Transuranics (^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu)[a]	ASTM D3972-90M: Alpha spectrometry.
^{99}Tc	DOE RP 550: Liquid scintillation counting (analogous to ASTM C1387-98 which is a method for solid samples).
Volatile organic compounds	EPA SW-846 8260B: GC/MS.
Semivolatile organic compounds[b]	EPA SW-846 8270C: GC/MS.
Organochlorine pesticides and PCB[c]	EPA SW-846 8081A: GC/electron capture detection. EPA SW-846 8082: GC.
^{226}Ra, ^{228}Ra[c]	EPA 903.1: Radon emanation technique.
Metals	EPA 6010B: Inductively coupled plasma-atomic emission spectrometry.
Mercury	EPA 7470A: Mercury in liquid waste (manual cold-vapor technique).
Nitrate, sulfate, and chloride	EPA 300.0: Determination of inorganic anions by ion chromatography.

[a]Conducted on samples from 30 monitoring wells, 20 of which were selected randomly while the remaining 10 were selected to ensure that the sample set adequately represented areas of concern.

[b]Conducted on groundwater samples collected from wells that are in the vicinity of paved areas. Semivolatile organic compounds were detected in surface and subsurface soil samples collected from this area (Chapter 4).

[c]Conducted on groundwater samples from eight monitoring wells located along a north/south transect and eight monitoring wells located along an east/west transect.

Note: Radiological constituents and metals were collected as filtered and unfiltered samples.

Am = americium.
ASTM = American Society for Testing and Materials.
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency.
GC = gas chromatography.
MS = mass spectrometry.
Np = neptunium.
PCB = polychlorinated biphenyl.
Pu = plutonium
R = radium.
Tc = technetium.
Th = thorium.
U = uranium.

Table 2.6. Analysis methods of off-Site soil samples

Analysis	Analysis method
Gamma-emitting radionuclides	EPA 901.1M: Gamma spectrometry.
^{228}Th, ^{230}Th, ^{232}Th	ASTM D3972-90M: Alpha spectrometry.
^{234}U, ^{235}U, ^{238}U	ASTM D3972-90M: Alpha spectrometry.
Transuranics (^{241}Am, ^{237}N, ^{238}Pu, $^{239/240}$Pu)	ASTM D3972-90M: Alpha spectrometry.
Volatile organic compounds	EPA SW-846 8260B: GC/MS.
Metals	EPA 6010B: Inductively coupled plasma-atomic emission spectrometry.
Mercury	EPA 7471A: Manual cold-vapor technique.

Am = americium.
ASTM = American Society for Testing and Materials.
EPA = U.S. Environmental Protection Agency.
GC = gas chromatography.
MS = mass spectrometry.
Np = neptunium.
Pu = plutonium
Th = thorium.
U = uranium.