1. INTRODUCTION

This Report presents the results of the remedial investigation (RI) conducted at a former fuel cycle facility that is located within 228 acres of property in Hematite, Missouri, and is currently owned by the Westinghouse Electric Company, LLC (WEC). WEC ceased facility operations in June 2001 and is proceeding with Site characterization, remediation, and facility decommissioning. This Report was prepared by Science Applications International Corporation (SAIC) under contract to WEC.

As used throughout this document, the "Hematite Facility" refers to the central portion of the property, encompassing the historic primary operations area, Site Pond and burial pits, while the "Hematite Site" refers to the "Hematite Facility," and other areas that were the focus of this investigation based on potential impacts by previous Facility operations. "Property" refers to the 228 acres of land owned by Westinghouse.

1.1 GOALS AND OBJECTIVES OF THE REMEDIAL INVESTIGATION

The overall goals of the RI are to characterize the nature and extent of contamination resulting from previous operations at the Hematite Facility and to reasonably predict contaminant fate and transport (F&T) in the surface and subsurface environment. Characterization data collected during the RI are being used in risk assessment studies that will quantify the impact of contamination associated with previous operations on human health and the ecological environment. The results of the RI will also be used in subsequent feasibility studies (FSs) to determine suitable remedial alternatives for the Hematite Site.

To achieve the goals of the RI, characterization and modeling activities were designed with the following specific objectives:

- To establish a conceptual model for hydrogeologic conditions at the Hematite Site that will be used as a framework for assessing contaminant migration pathways.

- To obtain information necessary for developing a conceptual site model (CSM), including lithologic characteristics and hydraulic conductivities for the overburden and bedrock formations, potentiometric surfaces in the overburden and bedrock groundwater, hydraulic gradients between hydrogeologic units, and interactions between groundwater and surface water features at the Hematite Site.

- To determine whether historic operations have impacted surface water and sediment, and whether contaminants are migrating off-Site through surface water and sediment migration pathways.

- To assess the impact of historic operations on surface and subsurface soils, including the identification of potential sources for groundwater and surface water contamination.

- To define the sources of contamination and characteristics of these source areas that are important to the evaluation of remedial alternatives.

- To assess the nature and extent of contamination in the shallow (i.e., overburden) groundwater, and to determine potential contaminant migration pathways from possible source areas within the Hematite Facility to surface water and deeper (i.e., bedrock) groundwater.

- 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 develop a groundwater and contaminant transport model for the Hematite Site that can be used to predict long-term fate of contaminants, to guide future sampling programs, and to evaluate remedial alternatives.

- To address data gaps identified during previous investigations.

A technical approach for achieving the goals and objectives of the RI was presented in a RI/FS Work Plan (LBG 2003) submitted by WEC to the Missouri Department of Natural Resources (MDNR) in May 2003. In response to the conditional approval of the RI/FS Work Plan (MDNR 2003), a series of task-specific work plans (TSWPs) were prepared and submitted to MDNR. The TSWPs, which were reviewed but not formally approved by MDNR, were aligned with the aforementioned RI objectives and provided additional details regarding the following field activities:

- Sampling and analysis of Site and upstream (background) surface water and sediment for radiological contaminants of potential concern (RCOPCs) and chemical contaminants of potential concern (CCOPCs), including the installation of surface water gauging stations (SAIC 2004a).

- Sampling and analysis of surface soil for RCOPCs and CCOPCs (SAIC 2004b).

- Sampling and analysis of subsurface overburden soil, including the installation of temporary monitoring wells that enabled sampling and analysis of overburden groundwater for volatile organic compound (VOC) and radiological contamination detected during previous investigations (SAIC 2004c).

- Drilling and installation of bedrock wells to supplement the pre-RI monitoring network, including (1) discrete interval sampling and analysis of groundwater for VOCs in the new bedrock boreholes and select domestic supply wells, and (2) slug testing at selected wells to measure hydraulic conductivities of the overburden and bedrock formations (SAIC 2004d).

- Sampling and analysis of surface and near-surface soil for RCOPCs and CCOPCs in locations remote from the Hematite Site (SAIC 2004e) to obtain characteristics of soil not likely to have been impacted by previous operations (i.e., local background).

- Baseline groundwater sampling and analysis for RCOPCs, CCOPCs, and basic water quality parameters at pre-RI, newly installed bedrock and temporary overburden groundwater monitoring wells at the Hematite Site, including groundwater level measurements at these wells (SAIC 2004f).

As a result of a detailed review of the RI/FS Work Plan, modifications were made to the original technical approach. These modifications and the technical basis for making these changes were presented in the TSWPs and were based on input from the RI Contractor (SAIC and its subcontractors), WEC, and MDNR.

1.2 SCOPE AND ORGANIZATION OF THE REPORT

This Report presents the results of RI field activities performed from April 2004 through January 2005 in accordance with the aforementioned RI/FS Work Plan and TSWPs. It also provides a summary of the results of the gamma survey conducted in April 2003 and sampling and analyses conducted in December 2003 of soils underneath buildings at the Hematite Facility (SAIC 2003a).

Following the RI field activities, the data were integrated with available information from previous investigations to develop:

- a CSM,
- an evaluation of the nature and extent of environmental contamination associated with historical operations, and
- an assessment and prediction of contaminant F&T in the vicinity of the Hematite Site.

The Report is organized as follows:

- The remainder of Chapter 1 contains a history of operations at the Hematite Facility, descriptions of the various buildings and areas on the Hematite Facility, a summary of previous investigations conducted at the Hematite Site, and the areas of concern (AOCs) identified during these previous studies.
- Chapter 2 describes Site characterization activities performed during the RI.
- Chapter 3 presents the physical characteristics of the Hematite Site, including geology and hydrogeology.
- Chapter 4 discusses the chemical characteristics of the Hematite Site, including nature and extent of contamination.
- Chapter 5 describes likely sources of contamination, possible mechanisms for migration of contaminants, a summary of groundwater and contaminant transport modeling results, and a screening level assessment of monitored natural attenuation.
- Chapter 6 concludes the Report with a summary of major RI findings relevant to future feasibility studies, remedial design and implementation, as well as long-term monitoring of surface water and groundwater conditions in and around the Hematite Site.
- Appendices A through L provide supplemental and supporting information.

The groundwater and contaminant transport modeling conducted as part of the RI is described in more detail in a separate report entitled *Groundwater and Contaminant Transport Modeling for the WEC Hematite Site* (SAIC 2007); the full report is included in Appendix A of this report. Baseline health and ecological risk assessment studies also will be covered in a separate document not included in this report.

1.3 FACILITY LOCATION AND HISTORY OF OPERATIONS

The Hematite Facility is located at 3300 Missouri State Road P in Jefferson County, Missouri, near the town of Hematite (Fig. 1.1). The Westinghouse Hematite Property consists of 228 acres of land with primary operations historically being conducted within the central portion of the property. Figure 1.2 shows the approximate boundary of the Hematite Facility, encompassing the historic primary operations area, Site Pond and burial pits.

Nuclear-related operations at the Hematite Facility began with the purchase of the Property (then consisting of farmlands) by Mallinckrodt Chemical Works in 1955. The Hematite Facility became operational in July 1956, producing uranium metals for the nuclear fuel program of the U.S. Navy.

Mallinckrodt Chemical Works and related entities operated the Hematite Facility until 1961, when ownership was transferred to a joint venture called United Nuclear Corporation (UNC). UNC continued to produce uranium products for the Federal government. In 1971, UNC and Gulf Oil Corporation (Gulf) entered into a joint venture forming the Gulf United Nuclear Fuels Corporation, which owned and managed the Hematite Facility until January 1974. General Atomic Company (GAC), a partnership involving Gulf, owned the Hematite Facility from January 1974 through May 1974, when Combustion Engineering Inc. (CE) purchased the Hematite Facility from GAC. Asea Brown Boveri (ABB) purchased the stock of CE in 1989, and CE began operating the Hematite Facility as ABB Combustion Engineering. In April of 2000, WEC purchased the nuclear operations of ABB, which included the Hematite Facility. WEC ceased operations in June 2001 and is proceeding with Site investigation activities in preparation for Site remediation, including decommissioning.

Throughout its history, the manufacture of uranium metal and compounds from natural and enriched uranium was the primary activity at the Hematite Facility (Section 2.2, page 4 of LBG 2003). Operations included the conversion of uranium hexafluoride (UF_6) gas of various ^{235}U enrichments to uranium oxide, uranium carbide, uranium dioxide pellets, and uranium metal. During the period prior to the purchase of the Property in 1971 by Gulf United Nuclear Fuels Corporation, classified government projects dominated Hematite Facility operations. As such, specific details regarding the exact nature of production processes prior to 1974 are not known. The following are examples of known projects during this time (Section 2.2, page 4 of LBG 2003):

- production of uranium metal for use in the U.S. Navy's nuclear-powered submarines and destroyers;
- production of specialized uranium oxides for use in the U.S. Army's Army Package Power Reactor;
- production of highly enriched uranium oxides for a General Atomics gas-cooled reactor;
- production of highly enriched uranium metal for materials test reactors utilized by the U.S. Navy;
- production of uranium-beryllium pellets for use in the SL-1, an experimental U.S. military nuclear power reactor that was part of the Army Nuclear Power Program;
- production of high-enrichment uranium zirconia pellets for a naval reactor; and
- production of highly enriched oxides for use in General Atomics nuclear rocket projects.

Although uranium material production was the primary function at the Hematite Facility, records indicate secondary activities such as uranium scrap recovery and a limited amount of work with thorium compounds as part of early research into the use of thorium in the fuel cycle.

A detailed list of radioactive feed materials historically used for production is not available. However, previous investigators have compiled a list of chemicals (Table 1.1) used at the Hematite Facility during active operations (Section 3.2.6.2, page 26-27 of LBG 2003).

1.4 DESCRIPTION OF THE WESTINGHOUSE HEMATITE FACILITY AND SITE

The Hematite Site and Facility contain features shown on Figs 1.2 and 1.3, respectively, and briefly described below (based on Section 3.2, pages 20-31 of LBG 2003). The "fence line" as used in this Report refers to the "old" fence line, and not the new security fence installed in 2004. The old fence line is shown on all the figures in this report.

- **Buildings.** Several buildings were used for various production operations and material storage. Brief descriptions of the buildings, including historical and current use (as of the date this Report was published), are given in Table 1.2, while building locations are shown on Fig. 1.3. In September 2004, WEC prepared an Engineering Evaluation/Cost Analysis (EE/CA, WEC 2004a) to evaluate potential removal action alternatives for buildings and equipment at the Hematite Facility. The focus of this EE/CA was on buildings that are radioactively contaminated or that can interfere with the future characterization and, if necessary, remediation of impacted soil and/or groundwater beneath the buildings.A Non-Time Critical Action Memorandum was issued in October 2005 documenting the selection of equipement removal and building demplition as the preferred alternative for remediation.

  In advance of building demolition, the former process and storage buildings have been emptied of equipment and materials involved in nuclear fuel production. The removed equipment and materials have been packaged for shipment and sent off-Site for disposal or for metals reclamation. At the conclusion of the equipment removal operations, Westinghouse conducted a final cleaning of the buildings as needed to remove loose dust, dirt, and debris. This cleaning was performed by vacuuming with units fitted with HEPA filtration systems. Following the cleaning, building surfaces were surveyed and, a chemical fixative (“lock down” agent) was applied to the interior surfaces of the radioactively contaminated buildings.

- **Spent Limestone Pile and Fill Areas.** Hydrogen fluoride gas, a byproduct in the UF_6 conversion process, was captured in limestone scrubbers during part of the plant history. Spent limestone was generated from 1968 through 1998, when the limestone scrubbers were replaced with a more efficient wet absorber system. Currently, the spent limestone is stored in surface piles within the fenced area of the Hematite Facility. The spent limestone was also used as fill in at least two areas, one near the Site Spring and the other northeast of the Burial Pits. The spent limestone was also used historically as fill for building and road foundations. Figure 1.3 shows known locations of spent limestone pile and fill areas.

- **Deul’s Mountain.** An outdoor pile of potentially radiologically contaminated soil was located southeast of Building 256 (Fig. 1.3). The pile of soil, referred to as Deul’s Mountain, came from excavations during construction of Building 256. An EE/CA for removal alternatives was prepared for this material in August 2004 (WEC 2004b) and approved by MDNR in January 2005. A Non-Time Critical Action Memorandum approving excavation and off-Site disposal was signed in June 2005, and the material has been removed from the Facility.

- **“Red Room” Roof Burial Area.** The roof of the “Red Room” of Building 240 was buried in an area located south of Building 101 (the Tile Barn, Fig. 1.3). As noted in Table 1.2, Building 240 was used for UF_6 conversion and the “Red Room” within this building was used for processing highly enriched uranium. Soil contamination was discovered in 1993 during renovations to the Tile Barn and was thought to be from use of this area for temporary scrap storage (Section 3.2.8, page 29 of LBG 2003). Results of a geophysical survey performed in February 2005 detected magnetic and conductivity anomalies in this area, indicative of a trenched or filled area. Details of the investigation can be found in the document *Geophysical Survey at the Westinghouse Hematite Facility, Festus, MO* (Geophex 2005), and the results are summarized in Sect. 2.8 of this RI report.

- **Cistern Burn Pit Area.** The Cistern Burn Pit Area, also located south of Building 101 (Fig. 1.3), was historically used to burn contaminated wood and pallets. Radiological contamination within the cistern was reportedly removed in 1993 (Section 3.2.15, page 31 of LBG 2003) to less than 30 pCi/g of uranium.

- **Burial Pit Area.** The Burial Pit Area is located to the east-northeast of the Hematite Facility (Figs. 1.2 and 1.3). Unlined pits were actively used by previous owners from 1965 to 1970 for disposal of uranium-contaminated materials and other wastes. Other undocumented excavations prior to 1965 may exist. Burial pit logbooks contain entries recorded during the operational period from July 16, 1965 to August 24, 1970 (Section 1.3, page 8 of WEC 2006). According to the logbook, 40 pits were created and filled between 1965 and 1970. The primary waste types disposed of on-site included various solids such as trash, empty bottles, floor tile, rags, drums, bottles, glass wool, lab glassware, acid insolubles, and filters. Chemical wastes were also disposed of in the pits including hydrochloric acid, hydrofluoric acid, potassium hydroxide (KOH), trichloroethene (TCE), alcohols, oils, and wastewater. Based upon the logbook, the mass of uranium disposed in each pit varied, ranging from 178.08 grams to 801.8 grams.

- **Evaporation Ponds.** The Evaporation Ponds are located on the southeast side of the Hematite Facility, south of the process buildings and directly adjacent to and west of the Limestone Storage Pile within the security area on the Site (Fig. 1.3). The ponds were historically used for the disposal of water from cylinder washing potentially contaminated with TCE and technetium-99 (^{99}Tc) (Section 2.6.2, page 15 of LBG 2003). These ponds also received effluent streams for the wet conversion processes being performed in Building 240 (Section 3.2.6.1, page 23 of LBG 2003). Based on aerial photography review, the Evaporation Ponds were constructed sometime after 1966 and before 1971. In 1992, soil was removed from the Evaporation Pond Area as described in Sect. 1.5.3.

- **Sanitary Sewage and Stormwater Systems, including the Former Leach Field.** The current sanitary system (Fig. 1.3) consists of drain lines from buildings, a sewage treatment plant, and a pipeline that carries treated water from the sewage treatment plant to a permitted discharge point into the Site Creek immediately below the Site Pond (Outfall No. 1, Fig. 1.3). The discharge is authorized under a National Pollutant Discharge Elimination System (NPDES) permit issued by MDNR. Sewage sludge is routinely dewatered and disposed of at the Envirocare of Utah low-level waste disposal facility. Due to reduced operations at the Facility, sewage sludge has not accumulated significantly and removal has not been necessary for quite some time. The sanitary system receives water from sinks, toilets, showers, and drinking fountains. It also received pre-treated laundry water, wastewater from a process water demineralization system, and water from laboratory sinks when the Facility was operating. Prior to 1977, wastewater from the sewer pipelines drained into a septic tank and leach field (see Fig. 1.3 for location); the latter is no longer in use since the new sanitary treatment plant was installed. The stormwater system consists of lines that collect water from the roof and ground surface drains and then channel the collected water to a NPDES-permitted discharge point upstream of the Site Pond dam (Outfall No. 3, Fig. 1.3). The Site Pond dam is considered as Outfall No. 2 in the Hematite Facility's NPDES permit.

- **Site Pond and Site Creek.** The Site Pond and Site Creek are located west and southwest of the Hematite Facility and receive NPDES-permitted discharge water from sanitary sewage and storm-water systems (Fig. 1.3). The Site Pond is also fed by a natural spring located on the north tip of the Site Pond (Fig. 1.2). The Site Creek merges with the Lake Virginia tributary, and the combined stream discharges to Joachim Creek (Fig. 1.3).

- **Northeast Site Creek.** This is an intermittent stream that runs parallel to the northeast boundary of the Hematite Facility (Fig. 1.2).

- **Former Gas Station.** This abandoned gas station is within the Hematite Site Property boundary located approximately 1500 ft east of the Hematite Facility along Missouri State Road P (see Fig. 1.2). A 550-gallon single-walled steel underground storage tank was removed in May 2003 (Civil and

Environmental Consultants, Inc. 2003). No associated soil removal was required based on analytical results being below MDNR cleanup guidelines for benzene, toluene, xylene, methyl-t-butyl ether, and total petroleum hydrocarbons. No groundwater was encountered during excavation.

- **Railroad and Gas Pipeline.** Railroad tracks and a high-pressure gas pipeline (approximately 4 to 5 ft deep) cut through the Hematite Site southeast of the Hematite Facility. It has been suggested that the pipeline may be acting as a conduit for contamination transport in the subsurface. During the RI field investigation, excavations to expose the pipeline indicated that the pipeline was not buried in a gravel bed. The materials surrounding the pipeline consisted of native soil. The pipeline depth ranged for 3 to 5 ft below ground surface (BGS).

- **Joachim Creek and Bridge.** This perennial stream runs approximately 800 ft southeast of the Hematite Facility (Figs. 1.1 and 1.2) and eventually discharges into the Mississippi River near the city of Herculaneum, approximately 9 to 10 miles from the Hematite Facility. There were verbal reports of third-party waste disposal activities in the vicinity of Joachim Creek Bridge (Section 3.2.16, page 31 of LBG 2003).

1.5 PREVIOUS ENVIRONMENTAL INVESTIGATIONS AND ONGOING MONITORING PROGRAMS

Brief descriptions of previous investigations are given below, while more details can be found in the referenced reports. Note that additional investigations may have been conducted previously at the Hematite Site. However, reports are only available for the investigations described in the following sections. Comparisons are made between the results of these previous studies and the RI in Chaps. 3 through 5 of this report.

1.5.1 Radiological Survey of the Combustion Engineering Burial Site, July 1983

Radiation Management Corporation, under contract to the Nuclear Regulatory Commission, conducted a radiological survey of the Burial Pits in the spring and summer of 1982 (RMC 1983). External radiation levels were measured and samples were collected to determine radionuclide concentrations in air, groundwater, and surface water. Results of the external radiation surveys indicated detectable levels above background in the northwest corner of the Burial Pit Area adjacent to the old security fence. It was determined that these levels were due to containers of UF_6 routinely stored in an area next to the fence line rather than buried material. Results of surface soil sampling indicated low-level surface contamination that may have resulted from past burial activities or from airborne (i.e., stack) releases. Activities for ^{234}U ranged from 2 to 47 pCi/g, as estimated from ^{238}U activity that ranged from 1.7 to 4.9 pCi/g, and assuming an activity ratio of 10. The activity ratio was estimated from a 4% average enrichment in five samples that were analyzed for isotopic uranium using alpha spectroscopy. Results of subsurface soil sampling (deepest sample at 13 ft) showed the highest ^{234}U activity in the Burial Pits was approximately 400 pCi/g, as estimated from measured ^{238}U activity of 38 pCi/g and a ^{234}U/^{238}U activity ratio of 10. In the groundwater and surface water samples, only one groundwater sample collected from a borehole showed gross alpha activity exceeding 15 pCi/L (the drinking water limit at the time). Gross beta activity exceeding 50 pCi/L was found in 5 of the 22 samples, 3 of which came from a borehole near the Evaporation Ponds. High volume air samples collected in the vicinity of the Burial Pits showed no unusual or elevated levels.

1.5.2 Preliminary Assessment Hematite Radioactive Site, Hematite, Jefferson County, Missouri, Ecology and Environment, Inc., April 1990

Ecology and Environment, Inc. prepared a report for Region 7 of the U.S. Environmental Protection Agency (EPA) that discusses the Hematite Site's physical characteristics, potential waste sources, surrounding residential areas and water sources, and groundwater and surface water characteristics (Ecology and Environment 1990). The groundwater assessment was based on regional data and no new field studies were conducted in preparation of this report.

1.5.3 Removal Action: Former Evaporation Ponds

Quadrex performed a radiological characterization of the former Evaporation Ponds in 1992 (Bicehouse 1992). Information gathered from this study was used to develop a source term for risk evaluation. Because of the residual contamination present in the ponds, CE decided to remove soil from the Evaporation Pond area. The material from the retention ponds was disposed at a low-level waste disposal facility.

1.5.4 Investigation to Determine the Source of Technetium-99 in Groundwater Monitoring Wells WS-17 and WS-17B, September 1996

Gateway Environmental Associates, Inc. conducted an investigation to determine the source of ^{99}Tc in overburden monitoring wells WS-17 and WS-17B (GEA 1996). Prior to this investigation, WS-17 had been abandoned due to concerns that the well had a poor surface seal. WS-17B was installed in its place, and subsequent groundwater sampling showed ^{99}Tc activities to be consistent with activities measured in WS-17.

A previous assessment had identified the Evaporation Ponds as a potential source of ^{99}Tc contamination in WS-17 and WS-17B. However, updated groundwater contour maps showed groundwater flow directions that were inconsistent with this hypothesis, and that the more likely source would be located north of WS-17 and WS-17B. Potential sources in this area were the spent limestone pile, the uranium recovery area, and a former ring storage area (located immediately east-northeast of Building 252, refer to Fig. 1.3). Twelve probe holes were drilled to approximately 15 ft deep in the vicinity of these suspected sources. Subsurface soil samples from the probe holes and co-located surface samples were analyzed for gross beta activity. Temporary groundwater monitoring wells were installed in the probe holes, which enabled groundwater level measurements and the collection of groundwater samples for gross beta and ^{99}Tc analysis via liquid scintillation counting. These monitoring wells were abandoned upon completion of the field investigation. Slug tests were conducted in WS-7 and WS-17B to measure hydraulic conductivities.

Soil encountered in all the boreholes (approximately 15 ft deep) consisted of clayey silt overlying silty clay. A highly plastic clay was encountered at the bottom of a few of the boreholes. Hydraulic conductivities were measured at 0.33 ft/day (11.5×10^{-5} cm/sec) in WS-17B, and 0.06 ft/day (2.2×10^{-5} cm/sec) in WS-7. The field hydrogeologist performing the slug test noted the presence of a more conductive discrete zone within WS-17B at 8 to 10 ft BGS.

Based on the groundwater contour map constructed from water levels in the temporary wells, Gateway Environmental Associates concluded that the ^{99}Tc may have entered the groundwater system within the former ring storage area and traveled downgradient toward WS-17/WS-17B. The distribution of gross beta activity in the temporary wells generally supported this hypothesis, with gross beta activity being highest directly underneath the former ring storage area. Gross beta activity in a few surface soil samples from this area were also elevated; however, gross beta activity in the subsurface soil samples could not be distinguished from the established background. The spent limestone pile and uranium recovery area (area where uranium was extracted from cuno filters; exact location not clear from the report) were deemed to be unlikely sources of ^{99}Tc.

1.5.5 Exploratory Probe-hole Investigation for the Evaporation Ponds at the ABB Combustion Engineering Hematite Facility, April 1997

Gateway Environmental Associates, Inc. conducted a probe-hole investigation in the Evaporation Pond Area (GEA 1997). Seven shallow probe holes (4 ft deep) were advanced within the berm area of the ponds primarily to determine the thickness of the gravel/crushed limestone surface layer. Four deeper probe holes (20 ft deep) were drilled immediately adjacent to the Evaporation Ponds to determine gross alpha and total uranium levels in soil. Soil encountered was generally clayey silt overlying silty clay. A sandy silt layer was encountered at the bottom of one of the probe holes. A gravel layer was encountered in only two of the seven boreholes and was less than 1 ft thick.

Gross alpha activities, which were elevated relative to background, were detected in some of the samples, ranging from 90 to 744 pCi/g. All the samples with elevated gross alpha activities were taken at depths of 5 ft BGS or less. Total uranium activity was detected in some of the samples, ranging from 5 to 534 pCi/g. As in the gross alpha measurements, all the samples with detectable total uranium activity were from depths less than 5 ft BGS.

1.5.6 Hydrogeologic Investigation and Groundwater, Soil and Stream Characterization, March 1999

Leggette, Brashears & Graham, Inc. (LBG), under contract to CE, conducted a hydrogeologic investigation at the Hematite Site in 1998 (LBG 1999). Specific activities included: (1) a geophysical study to delineate the areal extent of the Burial Pit Area; (2) drilling of 17 borings, which were subsequently completed as monitoring wells or piezometers (see Fig. 1.2 for locations of monitoring wells completed as part of this LBG study); (3) physical and chemical analyses of soil and groundwater samples collected from the boreholes and monitoring wells, respectively; and (4) slug testing in selected wells. All of the wells installed during this investigation were located within the vicinity of Hematite Facility (Fig. 1.2). Most were completed in the overburden, while two piezometers and two monitoring wells were installed in bedrock (60 ft BGS depth).

The geophysical study showed numerous disposal trenches detected as anomalies in the geophysical data. The study also indicated that all disposal trenches detected by the instruments contained ferrous materials. Areas where no anomalies were detected could indicate the absence of disposal trenches, or that the geophysical instruments used could not distinguish between the buried materials in these areas and the surrounding soil. A high percentage of the buried ferrous material is present within 10 ft of the surface.

LBG identified five hydrostratigraphic units (HSU) based on the borehole logs and physical tests on soil samples. These units were: (1) a near surface silt/silty clay (NSSSC), which consisted of a brown/gray firm and friable silt that typically graded to a moderate yellowish-brown silty clay; (2) a fat clay, which consisted of a firm to very firm, gray/olive-gray plastic soil; (3) a deeper silty clay/clay (DSCC), which consisted of a slightly firm, slightly plastic, olive gray/gray soil; (4) a clayey/silty/sandy gravel; and (5) the Jefferson City Formation (the first bedrock formation encountered at the Site, refer to Chapter 3 for more detailed discussion of Site geology). The fat clay layer (6 to 10 ft thick) separated the near-surface and deeper silty clay layers but appeared discontinuous because it was not encountered in all the boreholes drilled for this investigation. Atterberg Limit tests confirmed the high plasticity of the fat clay layer; however, tests on some of the samples from the deeper silty clay also indicated high plasticity. These results suggest the gradation between the fat clay layer into the deeper silty clay layer may be gradual, or the potential presence of fat clay lenses in the deeper silty clay layer. LBG concluded that the fat clay layer could not be considered an aquitard because of its discontinuous nature. The clayey/silty/sandy gravel unit was encountered (thickness ranging from 4 to 6 ft) in all boreholes that were drilled to refusal or auger-drilled to bedrock. Note that all of these boreholes were drilled outside the old fenced area of the Hematite Facility (see Fig. 1.2). Visual examination of the core from one of the boreholes (WS-31, see Fig. 1.2 for location) drilled through shallow bedrock showed gray/tan, fine-grained dolomite. No vertical fractures or joints were intersected by this borehole and bedding planes appeared to be well-sealed. LBG concluded that storativity and transmissivity of the dolomite was from bedding planes and fractures rather than the matrix. A potentiometric surface constructed for the deeper silty clay/sandy-gravel layer indicated a groundwater flow direction generally toward Joachim Creek. A separate potentiometric surface was developed for the near-surface silty clay layer, which indicated multiple groundwater flow directions depending on location within the Hematite Facility.

Average hydraulic conductivities measured in the different HSUs were: (1) 3×10^{-5} cm/sec for the near-surface silty clay, (2) 80×10^{-5} cm/sec for the deeper silty clay layer, (3) 600×10^{-5} cm/sec for the sandy gravel layer (result from one well), (4) 1×10^{-5} cm/sec for unfractured bedrock, and (5) 80×10^{-5} cm/sec for fractured bedrock.

With the exception of one blind duplicate sample, results of VOC analyses in soil samples showed concentrations of perchloroethylene (PCE) that were near the detection limit (5 μg/kg). TCE was not detected in any of the soil samples. The inconsistency between the duplicate samples (the blind duplicate exhibited elevated levels of TCE and PCE) was attributed to sample heterogeneity or laboratory error. In groundwater, TCE and PCE were detected at levels above 50 μg/L in one bedrock well (WS-30, 430 and 350 μg/L, respectively; the piezometer wells were not sampled), and in one well screened within the deeper silty clay and sandy gravel layers (WS-32, 20,000 and 4,400 μg/L, respectively). TCE and PCE in the rest of the groundwater samples were either below the detection limit of 5 μg/L or were less than 50 μg/L. The measured radiological activities were deemed to be approximately at background levels, although a statistical analysis of the data was not conducted. VOCs were below the quantitation limit (4 μg/kg) and radionuclide activity was not detected at levels above background in stream sediment samples collected from two locations (one from the Site Creek downstream of the Site Pond dam and the other from the Northeast Site Creek). PCE was detected near the detection limit (5 μg/L) in the surface water sample collected from the Site Creek. VOCs were not detected in the other surface water samples collected from Joachim Creek and the Northeast Site Creek. Polychlorinated biphenyls (PCBs) were not detected in any of the surface water samples. The surface water samples did not exhibit levels of alpha, beta, or gamma activities above background.

1.5.7 Interim Hydrogeologic Investigation to Support the Engineering Evaluation and Cost Analysis for Response Actions for Off-Site Groundwater Quality, November 2002

In the summer of 2002, WEC retained LBG to perform an interim hydrogeologic investigation (LBG 2002b) to address the detection of VOCs in a number of private water wells near the Hematite Site. Contamination in these private wells was detected in December 2001, when the Missouri Department of Health and Senior Services, upon request from MDNR, added VOCs to the suite of radiological analytes that were normally included in their annual radiological monitoring program. The purpose of the interim hydrogeologic investigation was to evaluate the extent and degree of impacted groundwater on an expedited basis. The results of the study were used to evaluate and, ultimately, select a time-critical removal action to address the detection of VOCs in nearby private domestic water supply wells. The investigation also addressed monitoring for future off-Site and vertical contaminant migration by installing sentry wells.

Bedrock cores were collected from the formations underlying the Hematite Site including the Jefferson City-Cotter Formation, the Roubidoux Formation, and the top of the Gasconade Formation (in order of increasing depth, more details regarding Site geology are presented in Chapter 3). The bedrock borehole locations (BR-01 through BR-04) are shown in Fig. 1.2. The geology and hydrogeologic properties of the bedrock underlying the Site were evaluated through various geophysical tests and video-logging. Vertical profiling of groundwater quality was accomplished by collecting discrete groundwater samples from packer-isolated intervals within the bedrock boreholes. In addition, two overburden boreholes were drilled at two locations along the natural gas pipeline (OB-01 and OB-02) to address concerns that this pipeline was acting as a conduit for off-Site contaminant migration. Monitoring wells were installed in the overburden borehole locations (OB-01 and OB-02) and in BR-03, where analysis by a mobile laboratory indicated the presence of PCE in an overburden soil sample from this location. Wells screened in the Jefferson City-Cotter and the Roubidoux Formations were installed in the bedrock borehole locations; bedrock wells were not installed in the Gasconade Formation because contamination was not detected in any of the groundwater samples collected during sampling of packer-isolated intervals. Bedrock monitoring wells were installed in the Jefferson City-Cotter Formation at BR-01, BR-02, and BR-04. Bedrock monitoring wells were installed in the Roubidoux Formation at BR-01 through BR-04 (see Appendix D for well construction data for all wells installed at the site). Potentiometric maps were prepared from water level measurements in the newly installed bedrock wells.

The geologic character of the overburden was consistent with the previous investigation (Section 4.2, pages 9-13 of LBG 1999). An anomalously deep overburden/bedrock interface was noted in BR-04 (~50-ft depth, compared to 30 to 35 ft within the Hematite Facility). Rock quality and permeability showed a wide range of results even within the same formation; no consistent trends or patterns were noted. Based on potentiometric maps developed for the Jefferson City and Roubidoux Formations, groundwater flow was predominantly to the east. Calculated hydraulic conductivities from the slug tests were reported, although some of these values are suspect due to problems with the drawdown analysis or with the drawdown data (see Chapter 3).

VOC analyses by a mobile laboratory indicated low levels (approximately 4 μg/L of TCE, approximately 12 μg/L of PCE) in groundwater from the overburden well at BR-03. TCE and PCE were not detected in the other overburden wells (OB-01 and OB-02) and in an overburden groundwater sample collected from BR-04. During groundwater sampling from packer-isolated intervals in bedrock at BR-01 through BR-04, VOC contamination was only detected in BR-04 at the 95- to 105-ft-BGS depth interval (within the Jefferson City-Cotter Formation). This was confirmed by analysis of a groundwater sample collected from the bedrock monitoring well subsequently installed and screened within this interval. Contamination in the deeper Roubidoux and Gasconade Formations was not detected in any of the bedrock borehole locations during this study.

Gross alpha and gross beta activities were measured in soil samples collected from the overburden. The data were presented but not discussed due to the lack of information regarding background activities. Gross alpha, gross beta, total U, and ^{99}Tc activities were measured in groundwater samples from the overburden and bedrock. Technetium-99 was below detection limits (approximately 2 pCi/L) in all groundwater samples. Maximum gross alpha, gross beta, and total uranium activities in filtered groundwater samples were 64.7, 118, and 28.7 pCi/L, respectively.

1.5.8 Gamma Walkover Survey, April 2003

A gamma walkover survey (SAIC 2003a) over the entire Hematite Facility and large areas within the Hematite Site was conducted in April 2003 by SAIC. Areas with elevated gamma count rates were consistent with AOCs that had been previously identified (Section 3.2, pages 20-31 in LBG 2003, and Sect. 1.6 of this report). Thus, the survey did not reveal any new surficial sources of radiological contamination. The gamma walkover survey results were used to locate surface sample locations for the RI; a comparison between the areas with elevated gamma count rates and radiological analyses of surface samples is presented in Chapter 4 of this RI report.

1.5.9 Determination of Distribution Coefficients for Radionuclides of Concern at the Westinghouse Hematite Facility, July 2003

In July 2003, SAIC conducted a study to measure site-specific distribution coefficients for uranium and ^{99}Tc using soil collected from the Hematite Site (SAIC 2003c). A total of 18 soil samples were collected from 6 borings that were advanced to refusal (assumed to be bedrock). Soil physical properties, as well as isotopic uranium and ^{99}Tc activities, were measured in the soil samples prior to conducting the distribution coefficient tests. The soil samples tested in the laboratory were representative of the brown silty clay typically found in the shallow overburden at the Hematite Site. Uranium activities were detected at elevated levels in samples from the restricted areas adjacent to the process buildings (>200 pCi/g total uranium) and the shallowest sample collected from the Tile Barn/Cistern Burn Area (>34 pCi/g total uranium). Except for one sample from the restricted areas, ^{99}Tc was not detected at concentrations greater than the laboratory reporting limits in the samples collected for the study. Results of this investigation are described in *Determination of Distribution Coefficients for Radionuclides of Concern at the Westinghouse Hematite Facility* (SAIC 2003c).

1.5.10 Wetlands and Surface Water Assessment

In preparation for the RI, a wetland and surface water assessment was conducted in November 2003 to delineate and classify potentially jurisdictional wetlands and surface water bodies at the Hematite Site (SAIC 2004a). The assessment was conducted to identify potential impacts of Site investigation activities (i.e., well installation and road building) with regard to compliance with requirements of Sects. 401/404 of the Clean Water Act. The single potential wetland identified at the Hematite Facility is located in a small depression south of the Hematite Facility between the railroad berm and a gravel road that goes from the vicinity of the Hematite Facility to the south towards Joachim Creek. The wetland is a small isolated forested/scrub shrub wetland that is confined to the south and southwest by the gravel road and to the north by the railroad berm. There were no inputs or outputs at the wetland and hydrology appears to be the result of precipitation, which ponds between the road and railroad. A field survey of surface water bodies within the Property was also conducted, and detailed descriptions of the intermittent streams were performed. Based on the wetland and surface water survey, it was concluded that Site investigation activities can be implemented without significant impact to wetlands and surface water bodies.

1.5.11 Ongoing Environmental Monitoring Programs

Since 2002, quarterly groundwater monitoring samples have been collected from bedrock wells BR-01-RB, BR-02-RB, BR-03-RB, BR-04-RB, and BR-04-JC (see Fig. 1.2 for well locations) and analyzed for VOCs and radiological contaminants. Groundwater samples have also been collected periodically at private wells near the Hematite Facility; these private wells are shown in Figure 1.2 (labels begin with "PW"). A discussion of these monitoring results is provided in Chapter 4 of this RI report.

As mentioned previously, the stormwater and sewer water outfalls that discharge into the Site Pond and Site Creek, respectively (Outfalls 1 and 3, see Fig. 1.3), are permitted under NPDES. As part of permitting requirements, both of these outfalls and the surface water at Site Pond Dam (Outfall No. 2, see Fig. 1.3) are monitored regularly for parameters required under the NPDES permit.

The Hematite Facility operates under a Special Nuclear Materials (SNM-33) license from the Nuclear Regulatory Committee (NRC). Following NRC license requirements, samples are routinely