APPENDIX A

PHYSICAL SETTING, SCOPES, AND METHODS

1. PHYSICAL SETTING

The following sections summarize the physical setting for the Laboratory for Energy-related Health Research (LEHR)/Old Campus Landfill Superfund Site (Site) (Figure A1), located at the University of California, Davis (UC Davis), including a summary of the Site's geology, hydrogeology, surface water, and storm water drainage. Additional information can be found in the *Draft Data Summary and Data Gaps Report and Remedial Investigation/ Feasibility Study Work Plan Addendum* (MWH, 2002) and the *Final Remedial Investigation Report, LEHR/SCDS Environmental Restoration* (Geomatrix, 2004).

1.1 Geology and Soils

Subsurface geology below the Site consists of two units: (1) the Pleistocene-Holocene Putah Creek Fan and (2) the Pliocene-Pleistocene Tehama Formation. The Putah Creek Fan primarily consists of silt and clay, with coarse-grained sediments occurring locally. The Tehama Formation, which lies beneath the Putah Creek Fan, primarily consists of clayey silt to silty clay, with deeper coarse-grained sand and gravel (Figure A2).

1.2 Hydrogeology

This section describes the hydrologic model of the Site.

1.2.1 Surface Water

There are no surface water bodies located on the Site. The nearest surface water body is the South Fork of Putah Creek (Putah Creek), an east-flowing, engineered channel that lies 250 feet from the southern boundary of the Site and is separated from the Site by a levee that was constructed during the 1940s and 1950s (Figure A1). This levee is approximately 30 feet high, forms the southern boundary of the Site, and is used as a road for vehicular traffic. The southern levee of the creek is located several hundred feet south of the Site. The creek flow rate is regulated by releases from the Monticello Dam and the Putah Creek Diversion Dam. Putah Creek receives a minimum annual water flow of 31,000 acre-feet during non-dry years, as required in the agreement between the Solano County Water Agency (and other Solano parties) and the Putah Creek Council (and other Yolo parties; Blasland, Bouck, & Lee, Inc, 2006). The UC Davis wastewater treatment plant (WWTP) discharges on average 4.9 acre-feet per day of treated wastewater to Putah Creek at a location just west of the Old Davis Road Bridge (Figure A1) (RWQCB, 2003; 2009). Putah Creek is a losing stream that recharges shallow groundwater in hydrostratigraphic unit 1 (HSU-1). The Creek and its surroundings serve as habitat for many aquatic and riparian biota, including amphibians, fish, birds, mammals and benthic invertebrates (Geomatrix, 2004; Water Resources Association of Yolo County, 2007).

1.2.2 Storm Water Drainage

Runoff at the Site occurs at three storm water sampling locations (Figure A1):

- Lift Station No. 1 storm water runoff sampling location (LS-01);
- Landfill Unit (LFU) No. 1 storm water runoff sampling location (LF-01); and
- LFU No. 3 storm water runoff sampling location (LF-03).

Water flows into these areas only after moderate to heavy winter storms. The three surface water sampling locations represent different size drainage areas and varying surface conditions at the Site. For example, most of the area that drains to location LS-01 is paved with asphalt, while locations LF-01 and LF-03 represent mostly unpaved areas near the landfill units. Location LS-01 captures runoff from buildings and parking lots; when runoff is present, it is pumped to a drainage swale along Old Davis Road. The occasional runoff from the other two surface drainages (LF-01 and LF-03) eventually flows through discharge pipes into Putah Creek. It is estimated that the pipe from location LF-01 discharges an average of eight days per year into Putah Creek; discharges from LF-03 occur less frequently (Geomatrix, 2004). Observations at LF-01 and LF-03 in 2013, 2014, and 2015 showed no discharge in these drought years. A concrete-lined drainage channel runs through the eastern portion of location LFU-3 (Figure A1).

1.2.3 Groundwater

The HSUs at the Site include, in order of increasing depth below ground surface: HSU-1, HSU-2, HSU-3, HSU-4, and an unnamed aquitard. The HSUs have been defined based on geologic and geophysical data collected at the Site since 1987. HSU-1 and HSU-2 form the upper and lower units, respectively, of the Putah Creek Fan; HSU-3, HSU-4, and the unnamed aquitard form the upper, intermediate, and lower units, respectively, of the Tehama Formation (Figure A2). HSU-2 and HSU-4 are the most permeable of these HSUs, predominantly consisting of sand and gravel deposits. HSU-1, HSU-3, and the unnamed aquitard are generally composed of silt and clay and are markedly less permeable than HSU-2 and HSU-4. Hydraulic conductivity is estimated to be between 2 and 11 feet per day (7×10^{-4} to 4×10^{-3} centimeters per second) in HSU-1, and the horizontal seepage velocity is estimated to be approximately 4 feet (1.2 meters) per year. HSU-2 is estimated to have a hydraulic conductivity of approximately 1,020 feet per day (0.36 centimeters per second) and a horizontal seepage velocity of 1,500 feet per year (Geomatrix, 2004).

More recently, an upper HSU-2 sub-unit has been identified based on well log and hydropunch data. The sub-unit is present in the vicinity of the chromium pilot test wells (Figure A1, Inset B) and is approximately 10 feet thick at that location. The upper HSU-2 sub-unit is composed of finer sand with interbeds of clayey silt and is less permeable than the underlying portions of HSU-2 (Weiss, 2013a).

2. SCOPE AND METHODS

Field measurements, sampling, and analytical procedures were performed in accordance with the following documents:

- *Final Revised Field Sampling Plan, LEHR/SCDS Environmental Restoration* (FSP) (Dames & Moore, 1998);
- *Quality Assurance Project Plan Revisions for the Laboratory for Energy-related Health Research/South Campus Disposal Site, University of California, Davis* (QAPP) (Weiss, 2008);
- *Storm Water Pollution Prevention Plan for the University of California, Davis Inactive Landfill, Waste Discharge Identification 5S57I002687* (SWPPP; UC Davis, 2008);
- *2007 Comprehensive Annual Water Monitoring Report, LEHR/SCDS Environmental Restoration* (B&C, 2008);
- *2009 Comprehensive Annual Water Monitoring Report for the Laboratory for Energy-related Health Research/South Campus Disposal Site, University of California, Davis* (Weiss, 2011a);
- *Revised Request to Modify Groundwater Treatment Interim Removal Action System, Laboratory for Energy-related Health Research/South Campus Disposal Site* (UC Davis, 2009), which modified the sampling frequency and was approved by the United States Environmental Protection Agency (USEPA) at the August 6, 2009 LEHR Team Meeting (LEHR Team Meeting Minutes, 2009);
- *Final Pilot Test Work Plan for in Situ Reduction of Chromium for Laboratory for Energy-related Health Research/South Campus Disposal Site, University of California, Davis* (Weiss, 2010a);
- Letter to David Stensby, USEPA, regarding Revised Groundwater Monitoring Plan for Chromium Remediation Pilot Study for Energy-related Health Research/South Campus Disposal Site, University of California, Davis (Weiss, 2010c);
- *Final Work Plan for 2010 Well Monitoring, Laboratory for Energy-related Health Research/South Campus Disposal Site, University of California, Davis* (Weiss, 2010b);
- *Project Health and Safety Plan for DOE Areas at the Former Laboratory for Energy-Related Health Research Federal Facility*, University of California, Davis, December 29, Rev. 0. (Weiss 2010d);
- *Project Health and Safety Plan for the Laboratory for Energy-Related Health Research, University of California, Davis, Rev 2, November 18.* (Weiss, 2011c);
- *Quality Assurance Project Plan for the Laboratory for Energy-Related Health Research, University of California, Davis* (DOE, 2012);

- *Remedial Design/Remedial Action Work Plan for the Former Laboratory for Energy-Related Health Research Federal Facility, University of California, Davis* (RD/RAWP) (DOE, 2010);
- *Groundwater Extraction and Treatment System Pilot Study Work Plan at the Energy-related Health Research/Old Campus Landfill Superfund Site, University of California, Davis* (Weiss, 2013a), and
- *Final Multi-Year Water Sampling Plan for the Laboratory for Energy-related Health Research/Old Campus Landfill Superfund Site, University of California, Davis* (Weiss, 2013c).

2.1 Groundwater Monitoring

Groundwater monitoring during 2016 included the measurement of water levels and field parameters and collection of water samples for laboratory analysis from a subset of the network of on-site groundwater monitoring wells. Figure A1 shows the monitoring wells relative to the U.S. Department of Energy (DOE) and UC Davis areas. Groundwater monitoring was performed by Weiss personnel.

2.1.1 Field Sampling Methods and Analyses

Field measurements were documented during sampling events, including recording depth-to-water in the well casings and sampling purge water for electrical conductivity (EC), pH, dissolved oxygen (DO) concentration, and oxidation-reduction potential (ORP).

Monitoring well sampling at the Site is primarily conducted by purging and sampling wells using dedicated pumps and tubing. However, not all Site monitoring wells currently have dedicated pumps. For these wells, a fully decontaminated portable pump was used, which was decontaminated between wells. The use of a dedicated or portable pump was recorded on the well sampling sheets (see Appendix B). Both the dedicated and portable systems consist of variable speed submersible pumps and bladder pumps. All DOE wells have dedicated bladder pumps, as do UC Davis wells installed subsequent to monitoring well UCD2-074. Purging and sampling procedures are described in Standard Operating Procedure 2.0 of the FSP (Dames & Moore, 1998) and consist of using either low-flow sampling or a three-volume purging technique, as described below. Low-flow regimes were employed at DOE wells, the recently installed HSU-2 wells, and wells associated with the chromium pilot test.

The low-flow technique consisted of collecting a sample by:

- Collecting field measurements every 3- to 5-minutes during pumping;
- Pumping at a flow rate between 0.1 and 0.5 liter/minute, allowing no more than 0.33 foot of drawdown, until measurements of pH stabilize to within ±0.1 pH units of the previous reading and EC, and ORP measurements stabilize to within 10 percent of the previous reading; and
- Collecting a water sample by using a pump at a target flow rate of between 0.1 and 0.5 liters/minute (0.026 to 0.13 gallons per minute).

When not using the low-flow technique, samples were collected after purging each well until:

- Three to five well casing volumes of water were removed from the well; and
- The field measurements of pH, temperature, and EC stabilized to within 10 percent of the previous reading.

Well purging was used for wells equipped with dedicated submersible pumps. Electrical submersible pumps are currently installed in 27 HSU-1 wells, 19 HSU-2 wells, and all five HSU-4 wells. These pumps remain in use as a cost savings when compared to replacing with new bladder pumps. Sample quality and loss of volatiles is minimized when sampling from the dedicated submersible pumps by adjusting the flow rate of the pump using the check-valve on the discharge line so that water will flow smoothly and without agitation into the sample bottles. Furthermore, during sampling, the discharge is allowed to flow gently down the inside of the sample bottle, minimizing aeration of the sample. Beginning in the fourth quarter of 2015, purging of three to five well volumes in wells with dedicated pumps was discontinued and replaced with the low-flow technique (Puls and Barcelona, 1996), which can be employed for both bladder pumps and electric submersible pumps.

Groundwater samples collected for analysis of metals and selected inorganic compounds were filtered and preserved in the field according to laboratory instructions. Samples were refrigerated and packaged with ice for shipment to the analytical laboratory, except for those slated for radiological analyses. Each sample was collected in a laboratory-prepared container and shipped under appropriate chain-of-custody. Groundwater samples were analyzed by the following laboratories:

- Eurofins Calscience Environmental Laboratories, Inc. (Eurofins), Garden Grove, California[1] – hardness, dissolved and suspended solids, 1,4-dioxane, nitrate (as nitrogen), and other anions, metals, hexavalent chromium Cr(VI), and volatile organic compounds (VOCs);
- Ozark Underground Laboratory, Protem, Missouri – tracer dyes;
- TestAmerica, North Canton, Ohio – formaldehyde;
- TestAmerica, Earth City, Missouri – radiological constituents; and
- GEL Laboratories, Charleston, South Carolina – radiological constituents for DOE.

A storm water sample was collected at one of three points, LS-01, where flow was observed in the 2016 calendar year. No storm water flow was observed in the other two points (LF-1 and LF-3). Chain-of-custody forms for groundwater samples are presented in Appendices E, F, and G.

2.1.2 Scope: Site-Wide Sampling

Groundwater monitoring was performed to satisfy the scope of the regulatory agency-approved documents listed in this section. For 2016 monitoring, the following activities were performed:

- Quarterly water level measurements were taken at 138 locations, including 54 HSU-1 wells (of which 12 are DOE wells), 33 HSU-2 wells, five HSU-4 wells, 18 density-driven convection (DDC) wells (six locations of three nested wells each), 15 DDC piezometers (five locations of three nested piezometers each),

[1] Calscience Environmental Laboratories was acquired by Eurofins Scientific in May 2014

10 extraction wells, and three UC Davis WWTP wells. Quarterly water level measurements were made Site-wide on February 4, April 15, August 11, and December 22, 2016.

- Selected wells were sampled and analyzed for up to six Site-wide target constituents and EC. These constituents include VOCs, chromium, nitrate, carbon-14, 1,4-dioxane, and 1,2,3-trichloropropane (1,2,3-TCP). The 2016 sampling included 35 HSU-1 wells, 24 HSU-2 wells, effluent from the Interim Removal Action (IRA) extraction well, 6 Groundwater Extraction and Treatment-Pilot Study (GWETS-PS) wells, eight DDC wells (four locations of two nested), and 5 chromium pilot test monitoring wells. Sampling of HSU-1 and HSU-2 wells occurred during two mobilizations that occurred in November and December 2016. Sampling of DDC wells occurred on April 21, 2016. Effluent from the IRA extraction well was sampled quarterly. GWETS-PS effluent sampling occurred in January, February, and December 2016. Groundwater samples specific to the DOE Areas were collected in March, April, and December 2016.
- Water level pressure transducers with built-in data loggers were operated and maintained in three HSU-1 monitoring wells (UCD1-054, UCD1-071, and UCD1-073), eight GWETS-PS extraction wells (EW1-02 through EW1-09) and GWETS monitoring well GMW-1C. The data loggers continuously record water level changes at the Site. Data from the data loggers were used to calculate water levels for the wells at each measured interval.

2.1.3 Scope: Chromium Pilot Test Sampling

The *Draft Implementation and Performance Monitoring Report for in situ Reduction of Hexavalent Chromium* (Weiss, 2011b) details the chromium field pilot test and discusses the results from the first 16 months of monitoring (through June 2011). Additional results are documented in the 2011, 2012, 2013, 2014 and 2015 *Comprehensive Annual Water Monitoring Reports* (Weiss, 2013b; 2016a, 2016b, 2016c). Groundwater monitoring of chromium pilot test wells was performed to further assess the results of the pilot test. For 2016 monitoring, the following activities were performed:

- Two HSU-1 pilot test monitoring wells (CrPMW1-025i and CrPMW1-025d) and three upper HSU-2 monitoring wells (CrPMW1-040a, CrPMW1-040b and CrPMW1-040c) were sampled in 2016 (February and November/December).
- Existing monitoring wells UCD1-028 and UCD1-029 were sampled once each during the first and fourth quarter of 2016.

2.1.4 Scope: DOE Area Sampling

In general, groundwater samples were collected to satisfy the scope of the RD/RAWP (DOE, 2010) for constituents of concern (COCs), monitoring-only constituents (MOCs), and new well constituents (NWCs).

A summary of groundwater monitoring activities performed in 2016 is presented below:

- Groundwater sampling took place on March 9-10, 2016.
- Quarterly water level measurements were obtained on February 4, April 15, August 8, and December 22, 2016, as part of the Site-wide water level monitoring event.
- Water level pressure transducers and data loggers were operated and maintained in monitoring wells UCD1-054, UCD1-071, and UCD1-073 throughout 2016 to evaluate groundwater elevation and gradient near the northwest corner of the Site.

2.2 Density-Driven Convection System

In December 2000, an initial DDC pilot test system began operation to assess the effectiveness of this technology in removing the source of VOCs in shallow groundwater. The results for the initial phase of the pilot test are documented in the May 7, 2001 Letter Report, *Groundwater Source Removal Pilot Test* (URS, 2001). Based on these results, the system was expanded in 2002. The expanded DDC groundwater treatment system began operation on December 5, 2002.

The objective of the DDC system, which consists of wells DDC-1 through DDC-6 (Figure A1), is to provide *in situ* treatment of groundwater near the suspected chloroform source area in HSU-1. Six nested DDC wells monitor three zones (A, B, C) each. The zones are represented by wells DDC-1A, DDC-1B, and DDC-1C through DDC-6A, DDC-6B, and DDC-6C, and are not intended to represent different hydrogeologic sub-units of HSU 1. Five nested temporary piezometers (TP-1A, TP-1B, and TP-1C through TP-5A, TP-5B, and TP-5C) also monitor the three depth zones.

Compressed air is injected into the lower portion of the casing of each open DDC well to strip chloroform from water inside the casing, and to induce density-driven flow from the bottom well screen to the top well screen. To minimize carbonate scale in the wells, a solution of 1 percent hydrochloric acid is continuously injected into each pumping DDC well. A detailed description of the design, construction, and technology for the DDC system is presented in the *Expanded Groundwater Source Removal Pilot Test System Summary Report* (B&C, 2004).

The *2007 Comprehensive Annual Water Monitoring Report* (B&C, 2008) established that the DDC wells are to be sampled semi-annually for VOCs. In 2016, samples were collected by lowering a disposable bailer down each piezometer completed within a sand pack interval of each nested DDC well while the DDC system was in operation. Because the samples were collected while the system was in operation, water in the wells was not static. As a result, 10 bailer volumes were purged prior to sampling rather than removing standard purge volumes. Purging and field instrument measurements were recorded on the well sampling sheets (Appendix B).

In 2016, Weiss performed operations and maintenance (O&M) of the DDC system every two weeks. O&M activities consisted of measuring air flow rates and pressures in the air injection hoses and piping, recording system run time readings, measuring water levels and pH in groundwater for each open DDC well, and servicing the air compressor, acid tank, and feed pump. Kaeser Compressors performed maintenance on the DDC air compressor in February 2016.

Typically, sampling of the system is performed concurrently with groundwater monitoring well sampling at the Site. Wells DDC-3, DDC-4, DDC-5, and DDC-6 were operational during 2016.

The B and C piezometers from wells DDC-3, DDC-4, DDC-5, and DDC-6 were sampled on April 21, 2016. No VOC samples were collected during the second half of 2016 due to the DDC system remaining off as a result of low water levels.

2.3 Interim Removal Action System

The IRA began full-scale operation on May 11, 1998. The primary objective of this system is to minimize the off-Site migration of chloroform and other VOCs in HSU-2. Originally, the IRA system operated by pumping water from extraction well EW2-01, located 800 feet to the east of the DDC remediation area (Figure A1), and treating the water using an air stripper. Prior to 2005, the treated water was injected into injection well IW2-01 (Figure A1). Due to the eventual failure of the injection well, the process was replaced with the discharge of treated water to the UC Davis WWTP or irrigation of nearby horse pastures. In the summer of 2009, UC Davis, in coordination with the USEPA, the Department of Toxic Substances Control (DTSC), and the Regional Water Quality Control Board (RWQCB) ceased operation of the air stripper and terminated the use of treated IRA water for irrigation. Presently, water pumped from extraction well EW2-01 is discharged directly to the UC Davis WWTP (UC Davis, 2009).

The objectives of IRA monitoring are to assess the efficacy of the system in controlling VOC migration in HSU-2 and to ensure treated water satisfies the UC Davis WWTP discharge requirements. Weiss operates and regularly maintains the IRA system. O&M activities consist of recording flow quantities, system run times, and pipe pressure readings; servicing the treatment system pumps; checking alarm indicators; and collecting quarterly effluent samples of the combined IRA-GWETS-PS flow. The sampling frequency of extraction well EW2-01 was changed from quarterly to annually in 2016. During the 2016 monitoring, IRA effluent samples were analyzed by Eurofins.

2.4 Groundwater Extraction and Treatment System

In January 2012, the USEPA, Central Valley RWQCB, DTSC, and UC Davis representatives agreed that uncertainties regarding the remediation of Cr(VI)) in Site groundwater necessitated a treatability study prior to preparation of the FS – Volume 2. To address these uncertainties, the parties agreed that a treatability study of groundwater extraction should be conducted. This proposed approach was described in detail in UC Davis's January 26, 2012 letter to the USEPA, which requested approval for the proposed approach (UC Davis, 2012); the USEPA approved the approach in a letter dated April 30, 2012 (USEPA, 2012).

The goal of the GWET-PS is to construct a groundwater extraction system that will convey Cr(VI) contaminated groundwater from the Site to the UC Davis WWTP for treatment (Figure A3). The system will be monitored for two years and data collected incorporated into the FS – Volume 2 to assess system viability for Site remediation.

The GWET-PS includes the following:

- Nine groundwater extraction wells equipped with electric submersible pumps;
- Seven new and nine existing groundwater monitoring wells;
- Plastic, double-contained pressure pipe to convey water from the extraction wells to the existing IRA treatment building;

- Modification in the IRA treatment building to use the existing influent tank and discharge pump, bag filters (two), and sewer discharge piping;
- Electrical and control upgrades within the IRA treatment building to facilitate relay control of the electrical submersible pumps;
- Installation of a leak detection system on the double-contained pressure pipe with capability of system shut-down;
- Flow and pressure indicating devices;
- Integration of existing extraction well EW2-01 operation with the new GWET-PS; and
- Improvements to the EW2-01 well head allowing for shut down of EW2-01 under specific alarm conditions at the GWET-PS.

The *Groundwater Extraction and Treatment System Pilot Study Work Plan* (Weiss, 2013a) follows current Site groundwater monitoring practices. As described in this report, a full round of baseline sampling was conducted for the 16 GWETS-PS monitoring wells and nine extraction wells after the new wells were developed and prior to commencement of groundwater extraction. Baseline groundwater samples were collected in April 2014 and analyzed for dissolved metals, nitrate, sulfate, and VOCs, as well as field parameters. However, the system did not begin operation until January 23, 2015 due to low water levels in HSU-1. O&M activities consist of recording flow quantities, system run times, and pipe pressure readings; servicing the treatment system pumps; checking alarm indicators; and collecting quarterly effluent samples. During the 2016 monitoring, GWETS-PS effluent samples were analyzed by Eurofins.

2.5 Storm Water Monitoring

Storm water monitoring consists of sampling storm water at three locations: LS-01, LF-01, and LF-03 (Figure A1). Samples from locations LF-01 and LF-03 are used to evaluate potential discharges from LFU-1 and LFU-3, respectively. Samples from LS-01 are used to evaluate runoff from the DOE Areas near Old Davis Road.

Storm water monitoring is normally conducted twice each year during the rainy season (October through April). For the 2016 rainy seasons, one storm water sample was collected on October 23 at LS-01. No spring sample was collected from this point, nor were any samples collected at LF-01 and LF-03 because precipitation was not intense enough to produce flow at these discharge locations.

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FIGURES

Weiss Associates

Figure A1. 2016 Water Sampling Locations, Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

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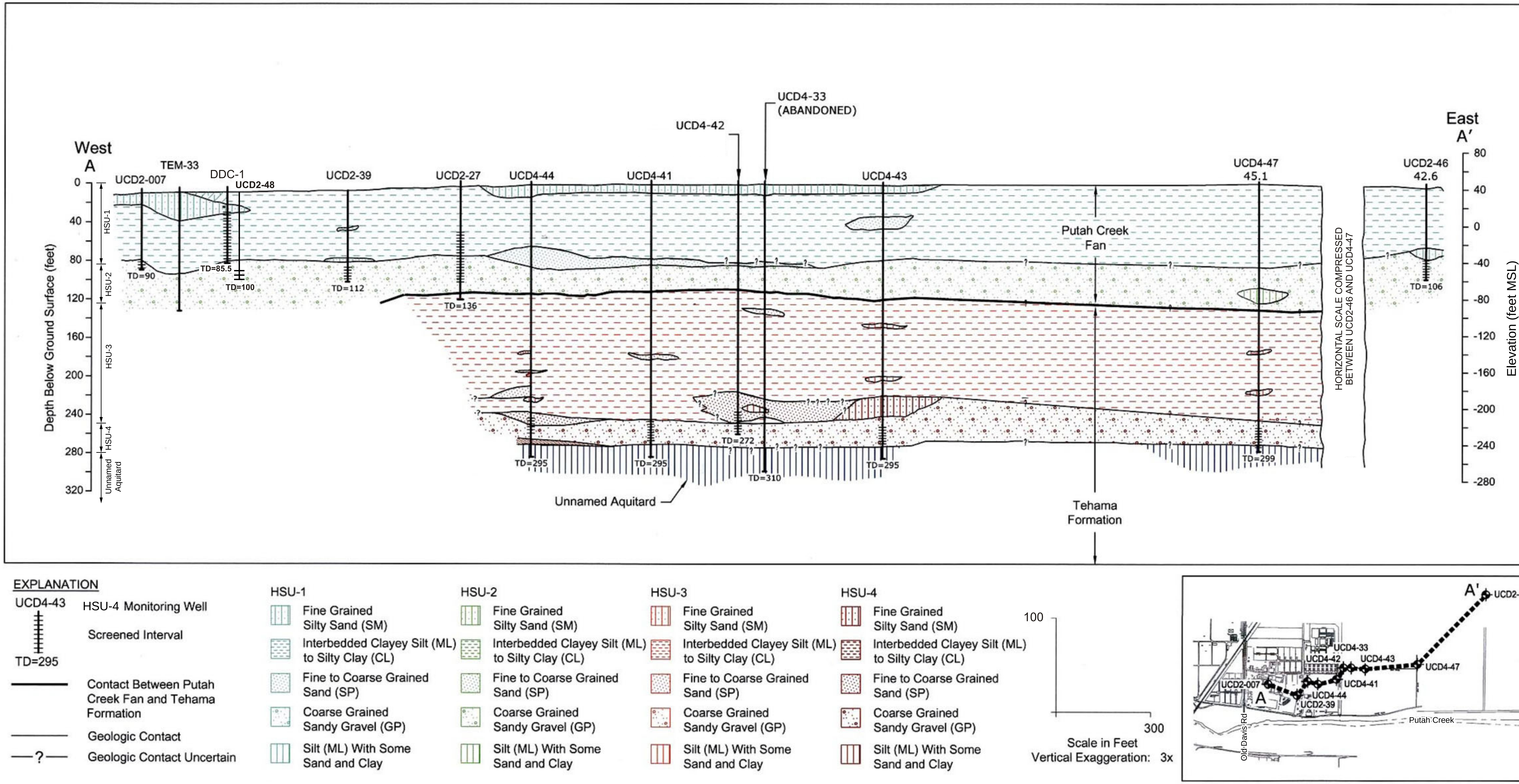
3/20/2017



Abbreviations:
HSU - hydrostratigraphic unit
MSL - feet above mean sea level
TD - total depth

Source: Draft Screening of Alternatives for the Feasibility Study, LEHR/SCDS Environmental Restoration (Brown & Caldwell, October 2006).

Figure A2. Generalized Hydrogeological Cross-Section, Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

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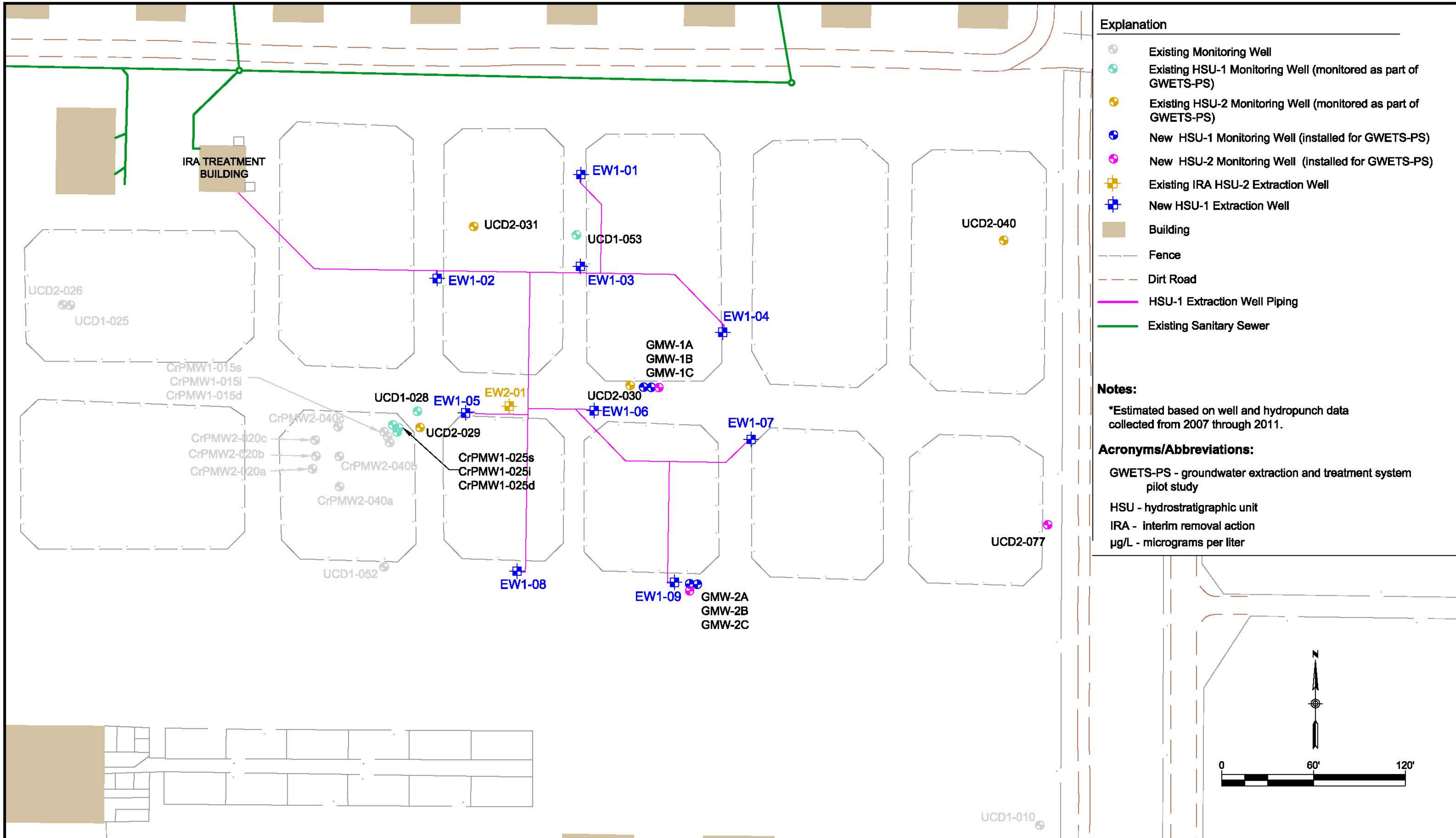

Figure A3. Groundwater Extraction and Treatment System Pilot Study Well Field Site Plan, Laboratory for Energy-related Health Research/Old Campus Landfill, University of California, Davis

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