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JUN 18 2012

PPPO-02-1482766-12

Mr. Wm. Turpin Ballard
Remedial Project Manager
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, Georgia 30303

Mr. Todd Mullins, FFA Manager
Kentucky Department for Environmental Protection
Division of Waste Management
200 Fair Oaks Lane, 2nd Floor
Frankfort, Kentucky 40601

Dear Mr. Ballard and Mr. Mullins:

TRANSMITTAL OF REMEDIAL DESIGN REPORT, CERTIFIED FOR CONSTRUCTION DESIGN DRAWINGS AND TECHNICAL SPECIFICATIONS PACKAGE, FOR THE GROUNDWATER OPERABLE UNIT FOR THE PHASE IIA VOLATILE ORGANIC COMPOUND CONTAMINATION AT THE C-400 CLEANING BUILDING AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY (DOE/LX/07-1272&D2)

References:

1. Letter from W. Ballard to R. Knerr, Untitled [Subject: EPA comments on the Remedial Design Report, Certified for Construction Design Drawings and Technical Specifications Package for the Groundwater Operable Unit (OU19) at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah Kentucky (DOE/LX/07-1272&D1)], dated April 19, 2012
2. Letter from A. Webb to R. Knerr, "Submittal of Comments to the Remedial Design Report, Certified for Construction Design Drawings and Technical Specifications Package, for the Groundwater Operable Unit for the Phase IIa Volatile Organic Compound Contamination at the C-400 Cleaning Building (DOE/LX/07-1272&D1), Paducah Gaseous Diffusion Plant, Paducah, McCracken County, Kentucky, KY8-890-008-982," dated April 9, 2012

Please find enclosed the certified *Remedial Design Report, Certified for Construction Design Drawings and Technical Specifications Package, for the Groundwater Operable Unit for the Phase IIa Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-1272&D2, (RDR) for your review and approval. The enclosed RDR incorporates comments received from the Kentucky Department for Environmental Protection (KDEP) and the U.S. Environmental Protection Agency (EPA) on April 9, 2012, and April 19, 2012, respectively. Design enhancements also made to the subject document, as discussed in the May 17, 2012, Federal Facility Managers' meeting, include the following:

- Vapor extraction well casing changed from 3 inch to 4 inch to increase radius of capture and reduce material cost;
- The use of a two smaller blowers running in parallel instead of one large blower to reduce cost and increase the availability of replacement parts; and
- The optimization of well field pipe header layout to reduce pressure requirements for the vacuum blowers.

Details associated with these design enhancements can be found in the enclosed unsolicited comment response summary and subject revised document.

This RDR documents the design necessary to implement the Electrical Resistance Heating technology for Phase IIa (Upper Continental Recharge System/upper Regional Gravel Aquifer action) in the C-400 southeast treatment area. This RDR revision does not address the implementation of Phase IIb (lower Regional Gravel Aquifer action).

A redline version of the RDR and comment response summaries also are provided to assist with your review.

If you have any questions or require additional information, please contact David Dollins at (270) 441-6819.

Sincerely,

Reinhard Knerr
Paducah Site Lead
Portsmouth/Paducah Project Office

Enclosures:
1. Clean version of the C-400 Phase IIa RDR
2. Redline version of the C-400 Phase IIa RDR
3. EPA Comment Response Summary
4. KDEP Comment Response Summary
5. Unsolicited Change Summary
6. Certification Page

e-copy w/enclosures:
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CERTIFICATION

Document Identification: ***Remedial Design Report, Certified for Construction Design Drawings and Technical Specifications Package, for the Groundwater Operable Unit for the Phase IIa Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE/LX/07-1272&D2)**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

LATA Environmental Services of Kentucky, LLC

Mark J. Duff, Paducah Project Manager

6-18-12
Date Signed

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

U.S. Department of Energy (DOE)

Reinhard Knerr, Paducah Site Lead
Portsmouth/Paducah Project Office

6/18/12
Date Signed

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DOE/LX/07-1272&D2
Primary Document

Remedial Design Report, Certified for Construction Design Drawings and Technical Specifications Package, for the Groundwater Operable Unit for the Phase IIa Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—June 2012

Prepared for the
U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
LATA ENVIRONMENTAL SERVICES OF KENTUCKY, LLC
managing the
Environmental Remediation Activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-10CC40020

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ACRONYMS

bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	conceptual site model
digiTAM	digital temperature acquisition module
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
ECD	electron capture detector
ERH	electrical resistance heating
ET-DSP™	Electro-Thermal Dynamic Stripping Process
FID	flame ionization detector
GAC	granular activated carbon
IPS	Inter Phase Synchronization
IRA	interim remedial action
KAR	*Kentucky Administrative Regulations*
KPDES	Kentucky Pollutant Discharge Elimination System
Mc^2	McMillan-McGee Corp.
MIP	membrane interface probe
mS/m	milliSiemens/meter
MW	monitoring well
mWh	megawatt hour
O&M	operations and maintenance
PDS	Power Delivery System
PGDP	Paducah Gaseous Diffusion Plant
pH	potential of hydrogen
PID	photoionization detector
PM	performance metric
POE	point of exposure
ppb	parts per billion
ppmv	parts per million by volume
psig	pounds per square inch gauge
RAWP	Remedial Action Work Plan
RDR	Remedial Design Report
RDSI	remedial design support investigation
RGA	Regional Gravel Aquifer
RI	remedial investigation
ROC	radius of capture
ROD	Record of Decision
scfm	standard cubic feet per minute
SVE	soil vapor extraction
TCE	trichloroethene
TDC	Time Distributed Control
UCRS	Upper Continental Recharge System
VOC	volatile organic compound
VR	vapor recovery
VX	vapor extraction
WAG	waste area grouping
WCS	water circulation system
XE	vapor extraction wells

1,1-DCE	1,1-dichloroethene
Tc-99	technetium-99
μV	microvolts
2-D	two-dimensional

EXECUTIVE SUMMARY

The response action selected in the *Record of Decision for Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (ROD), DOE/OR/07-2150&D2/R2, (DOE 2005a) for the source area comprised of trichloroethene (TCE) and other volatile organic compounds (VOCs) found at the C-400 Cleaning Building area is necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances, pollutants, or contaminants from these areas that may present an imminent and substantial endangerment to public health and welfare. Releases over a number of years have resulted in a subsurface source zone of TCE and other VOCs at the south end of the C-400 Cleaning Building Area.

This Remedial Design Report (RDR) has been prepared for the C-400 Cleaning Building Interim Remedial Action (IRA) at the Paducah Gaseous Diffusion Plant (PGDP). The IRA selected in the ROD is electrical resistance heating (ERH) technology. A phased deployment of ERH is being implemented. The first phase (Phase I), completed in December 2010, implemented the base design in the southwest and east treatment areas of the C-400 Cleaning Building. In addition to removing VOCs from these areas, another important objective of Phase I was to evaluate the heating performance of the base design through the Regional Gravel Aquifer (RGA) down to the McNairy Formation interface in the southwest treatment area.

Based on the evaluation of the lessons learned from the Phase I operations and performance, it has been determined that, with minor adjustments to the base design, ERH will be utilized to remove contaminants in the UCRS and upper RGA. Lessons learned, however, indicate that without extensive changes to the base design, ERH would not be effective in the lower RGA. Based on these conclusions, Phase II has been divided into two separate actions: (1) a UCRS/upper RGA action (Phase IIa) and (2) a lower RGA action (Phase IIb). This RDR revision addresses changes in the Phase I base design necessary to implement the ERH technology for Phase IIa in the C-400 southeast treatment area. This RDR revision does not address the implementation of Phase IIb.

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1. INTRODUCTION

The Paducah Gaseous Diffusion Plant (PGDP), located approximately 16.1 km (10 miles) west of Paducah, Kentucky, and 5.6 km (3.5 miles) south of the Ohio River in the western part of McCracken County, is an active uranium enrichment facility owned by the U.S. Department of Energy (DOE). Bordering the PGDP to the northeast, between the plant and the Ohio River, is the Tennessee Valley Authority Shawnee Steam Plant.

The C-400 Cleaning Building is located inside the plant secured area, near the center of the industrial section of PGDP. The building is bound by 10^{th} and 11^{th} Streets to the west and east, respectively, and by Virginia and Tennessee Avenues to the north and south, respectively.

The C-400 Cleaning Building Interim Remedial Action (IRA) is being conducted near the southeast and southwest corners of the C-400 Cleaning Building area of PGDP in the areas identified as the southwest treatment area, southeast treatment area, and east treatment area on Figure 1. These areas have been identified as the major sources of groundwater contamination by trichloroethene (TCE) and other volatile organic compounds (VOCs) at PGDP.

This Remedial Design Report (RDR) revision has been prepared for the C-400 Cleaning Building IRA at PGDP, owned by DOE. The IRA was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and is the response action selected in the *Record of Decision for Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (ROD), DOE/OR/07-2150&D2/R2 (DOE 2005a).

The technology selected in the ROD is electrical resistance heating (ERH). A phased deployment of ERH is being implemented at C-400. The first phase (Phase I), completed in December 2010, implemented the ERH in the southwest and east treatment areas of the C-400 Cleaning Building. In addition to removing TCE and other VOCs from these areas, another important objective of Phase I was to evaluate the heating performance of the base design (DOE 2008) through the RGA down to the McNairy Formation interface in the southwest treatment area.

Based on the evaluation of the lessons learned from Phase I operations and performance, it has been determined that, with minor adjustments to the base design, ERH will be utilized to remove contaminants in the Upper Continental Recharge System (UCRS) and upper Regional Gravel Aquifer (RGA). Lessons learned, however, indicate that without extensive changes to the base design, ERH would not be effective in the lower RGA. Based on these conclusions, Phase II has been divided into two separate actions: (1) a UCRS/upper RGA action (Phase IIa) and (2) a lower RGA action (Phase IIb). This RDR revision addresses changes in the Phase I base design necessary to implement the ERH technology for Phase IIa in the C-400 southeast treatment area. This RDR revision does not address implementation of Phase IIb.

1.1 REGIONAL GEOLOGY AND HYDROGEOLOGY

The PGDP, including the C-400 area, is underlain by a sequence of clay, silt, sand, and gravel layers deposited on limestone bedrock. The sediments above the limestone bedrock are grouped into three major stratigraphic units (loess, Continental Deposits, and McNairy Formation) and three major hydrogeologic units (UCRS, RGA, and McNairy Flow System) as shown in Figure 2.

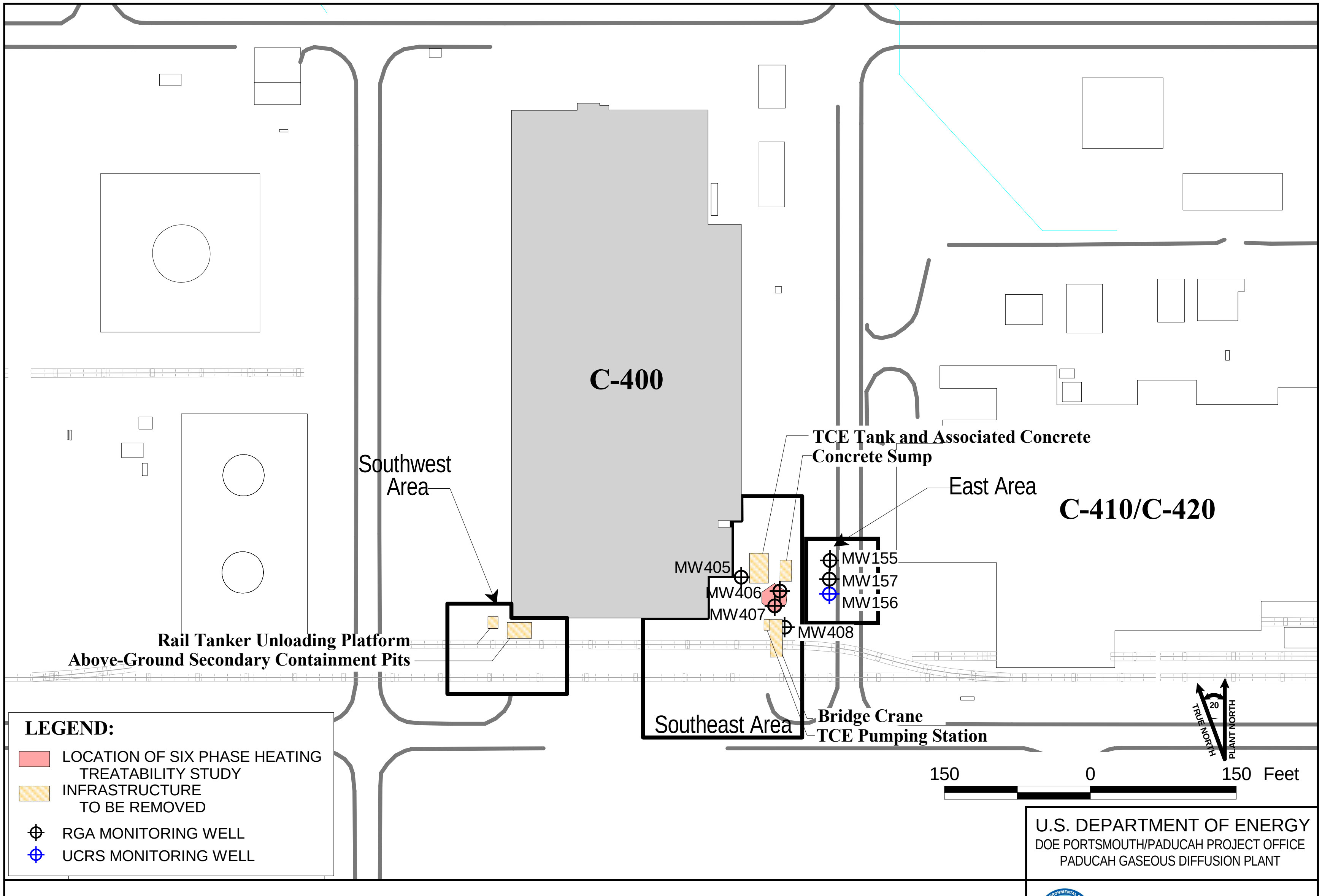

Figure 1. C-400 Area Layout

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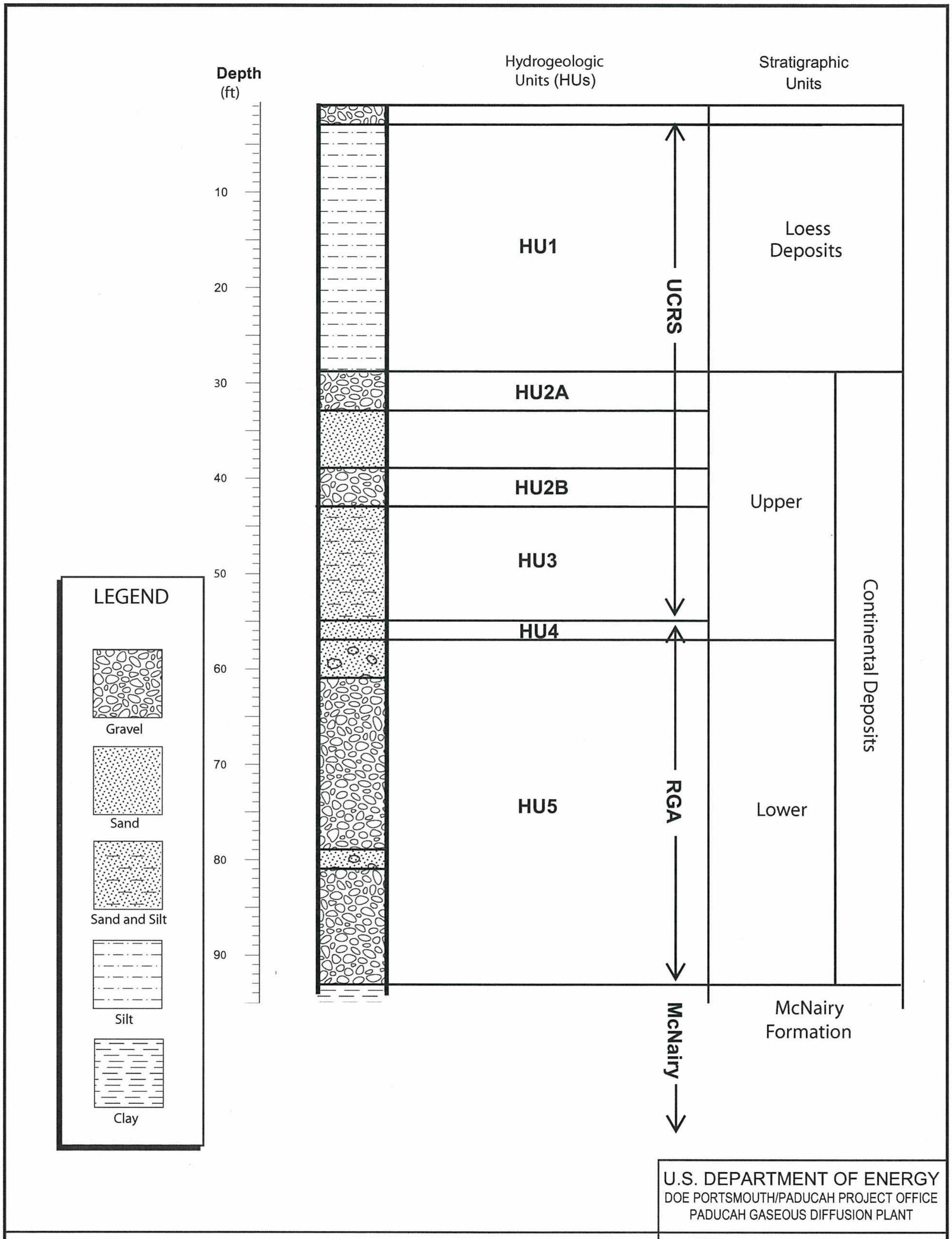

Figure 2. Stratigraphic and Hydrogeologic Units in Soil Boring H-007 of South C-400 Area

Across the PGDP site, the upper-most stratigraphic unit consists primarily of wind-deposited, clayey silt, known as loess, extending from the surface to a depth of approximately 6.1 m (20 ft) below ground surface (bgs). Fill material, when present, is included in this unit. Beneath the loess, the Upper Continental Deposits, a subunit of the Continental Deposits consisting of discontinuous sand and gravel layers within a sequence of silts and clays, extends to an average depth of 19.8 m (65 ft) bgs. The Lower Continental Deposits, also a subunit of the Continental Deposits, is a highly permeable layer of gravelly sand or chert gravel, typically extending from approximately 19.8 to 28.0 m (65 to 92 ft) bgs. Below the Continental Deposits is the McNairy Formation, a sequence of silts, clays, and fine sands that extends from approximately 28.0 to 106.7 m (92 to 350 ft) bgs. These depths represent general conditions; depths vary at specific locations.

Groundwater flow through the loess and the Upper Continental Deposits is predominately downward into the Lower Continental Deposits. The groundwater flow system in the loess and the Upper Continental Deposits is called the UCRS.

Groundwater flow in the Lower Continental Deposits is generally northward toward the Ohio River, although there is variability in groundwater flow as evidenced by the existence of multiple groundwater plumes, as discussed in Section 1.2. The groundwater flow system in the Lower Continental Deposits is called the RGA and constitutes the uppermost aquifer beneath PGDP and the adjacent area to the north.

The UCRS is subdivided into layers consisting of the loess and the underlying Upper Continental Deposits. Sand and gravel lenses are separated from the underlying RGA by a 3.7- to 5.5-m (12- to 18-ft)-thick silty or sandy clay aquitard. This aquitard reduces the vertical flow of groundwater from the sand and gravel units of the UCRS to the gravels of the RGA. The RGA consists of a basal sand member of the Upper Continental Deposits and the thick sand and gravel member of the Lower Continental Deposits. Below the RGA is the McNairy Flow System, which corresponds to the McNairy Formation. High contrast of hydraulic conductivity between the conductive Lower Continental Deposits and relatively nonconductive McNairy Formation limits flow between the Lower Continental Deposits and the McNairy. The middle portion of the McNairy Formation (the Levings Member, not shown in Figure 2) generally is considered an aquitard in the McNairy Flow System.

The depth of the shallow water table within the UCRS varies considerably across PGDP. In the C-400 area, ground covers (i.e., asphalt and concrete) and engineered drainage (i.e., storm sewers) limit rainfall infiltration. Many wells in the central and west areas of PGDP, including the C-400 area, define the site's water table trends. In MW157, which monitors the water table depth directly at the south end of C-400, the water table depth averages 9.4 m (31 ft).

The RGA potentiometric surface slopes to the north beneath PGDP. In the area of C-400, the depth of the RGA potentiometric surface is approximately 16.2 m (53 ft) bgs, as documented in the *Final Report Six-Phase Heating Treatability Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2004).

1.2 TREATMENT SITE LOCATION

Previous site investigations have identified three groundwater contaminant plumes resulting from past activities at PGDP. All three plumes are characterized by TCE contamination in the RGA. Two of these plumes, identified as the Northwest Plume and the Northeast Plume, receive considerable contaminant loading from TCE source areas southeast and southwest of the C-400 Building. Groundwater flow directions for these two plumes are shown on Figure 3. The other identified groundwater plume, the Southwest Plume, is located west of the C-400 Building and south of the Northwest Plume; TCE and other VOCs from the C-400 Cleaning Building also contribute to the Southwest Plume.[1]

The Waste Area Grouping (WAG) 6 Remedial Investigation (RI), as well as other investigations and studies, characterized the nature and extent of contamination around the C-400 Building (DOE 1999). Sample analyses from the WAG 6 RI indicate that the primary site-related VOCs in the subsurface soil and groundwater in the C-400 Building area are TCE and its degradation products (*trans*-1,2-dichloroethene, *cis*-1,2-dichloroethene, and vinyl chloride) and 1,1-dichlorethene (1,1-DCE). The WAG 6 RI concluded that there are zones of dense nonaqueous-phase liquid (DNAPL) TCE in the UCRS and RGA adjacent to and potentially beneath the C-400 Building. The *Feasibility Study for the Groundwater Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1799&D2, (DOE 2001) presents a summary of the characterization data for the C-400 area DNAPL zones and documents the DNAPL conceptual models for the area.

The data from the WAG 6 RI, as well as other investigations and studies, indicate that DNAPL zones in the southeast corner of the C-400 area account for the majority of the mass of DNAPL. High concentrations of TCE in several RGA groundwater wells and the collection of DNAPL from an RGA monitoring well (MW), MW408,[2] shown on Figure 1, demonstrate that DNAPL is located in the UCRS and extends into the RGA. As part of the WAG 6 RI, UCRS soil was characterized and shown to be a residual source of DNAPL. Figure 4 presents a contour map of maximum TCE concentrations detected in UCRS soil near the C-400 Building from the WAG 6 RI report.

Data from well clusters MW155 (lower RGA), MW156 (upper RGA), and MW157 (UCRS), located near the southeast corner of C-400 (Figure 1), have demonstrated local TCE trends since 1991. Beginning in 1991 and continuing through 1995, dissolved TCE levels in the UCRS (MW157) and upper RGA (MW156) commonly exceeded 400,000 ppb. Meanwhile, TCE levels in the lower RGA (MW155) typically were 2,000 ppb or less.

Recent TCE trends in the UCRS are undocumented. MW157 (UCRS) was last sampled in 1997. The TCE levels in the upper RGA declined steadily after 1995 to less than 10,000 ppb in 2006. In September 2009, before the start of the Phase I ERH, TCE levels had rebounded slightly and were 34,000 to 39,000 ppb. The TCE levels dropped to 2,400 to 3,700 ppb in 2011, following the application of ERH. Lower RGA TCE levels began rising in 2002 to greater than 10,000 ppb in 2006, and TCE levels ranged between 13,000 and 14,000 in September 2009. More recent TCE analyses from 2011 range between 65,000 and 83,000 ppb.

The TCE analyses of MW155 and MW156, in conjunction with TCE analyses from monitoring in other on-site PGDP monitoring wells, establish the directions of the TCE plumes that map the dominant groundwater flow pathways. The primary groundwater flow direction passing through the southeast corner of C-400 is to the northwest (with the Northwest Plume).

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[1] The evidence for a C-400 source to the Southwest Plume is the presence of dissolved TCE and technetium-99 (Tc-99) groundwater contamination in the RGA, upgradient of the C-747 Contaminated Burial Yard. No other potential source is known. The hydraulic gradient at C-400 toward the Southwest Plume is slight. The predominant groundwater flow direction in the area south of C-400 is to the northwest.

[2] MW408 is a multiport well, capable of supporting low-flow sampling, but inadequate to provide any appreciable groundwater or DNAPL recovery. TCE trends in MW408 indicate that pooled DNAPL accumulated within the basal sample interval of MW408 (completed within the McNairy Formation) for a period of four months during the Six-Phase Heating Treatability Study. Subsequent sampling of the basal sampling port in MW408 has recovered TCE levels indicative of residual DNAPL occurrence.

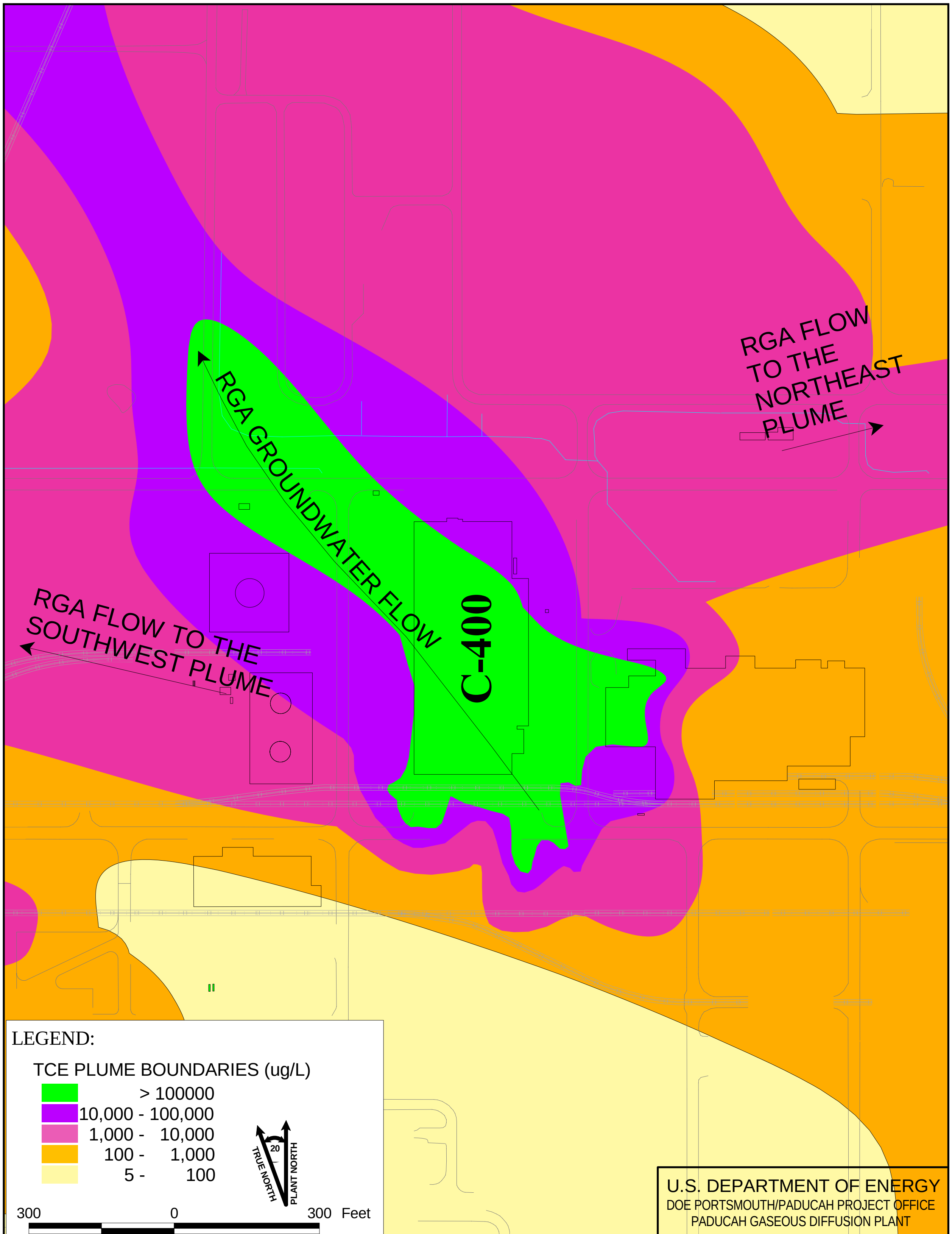

Figure 3. Groundwater Flow Direction Based on Maximum Interpreted TCE Concentrations in Groundwater at PGDP

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DATE 12-19-07

SOURCE: DOE 1999. Remedial Investigation Report for Waste Area Grouping 6 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-1727/V1&D2, United States Department of Energy, Paducah, KY, May.

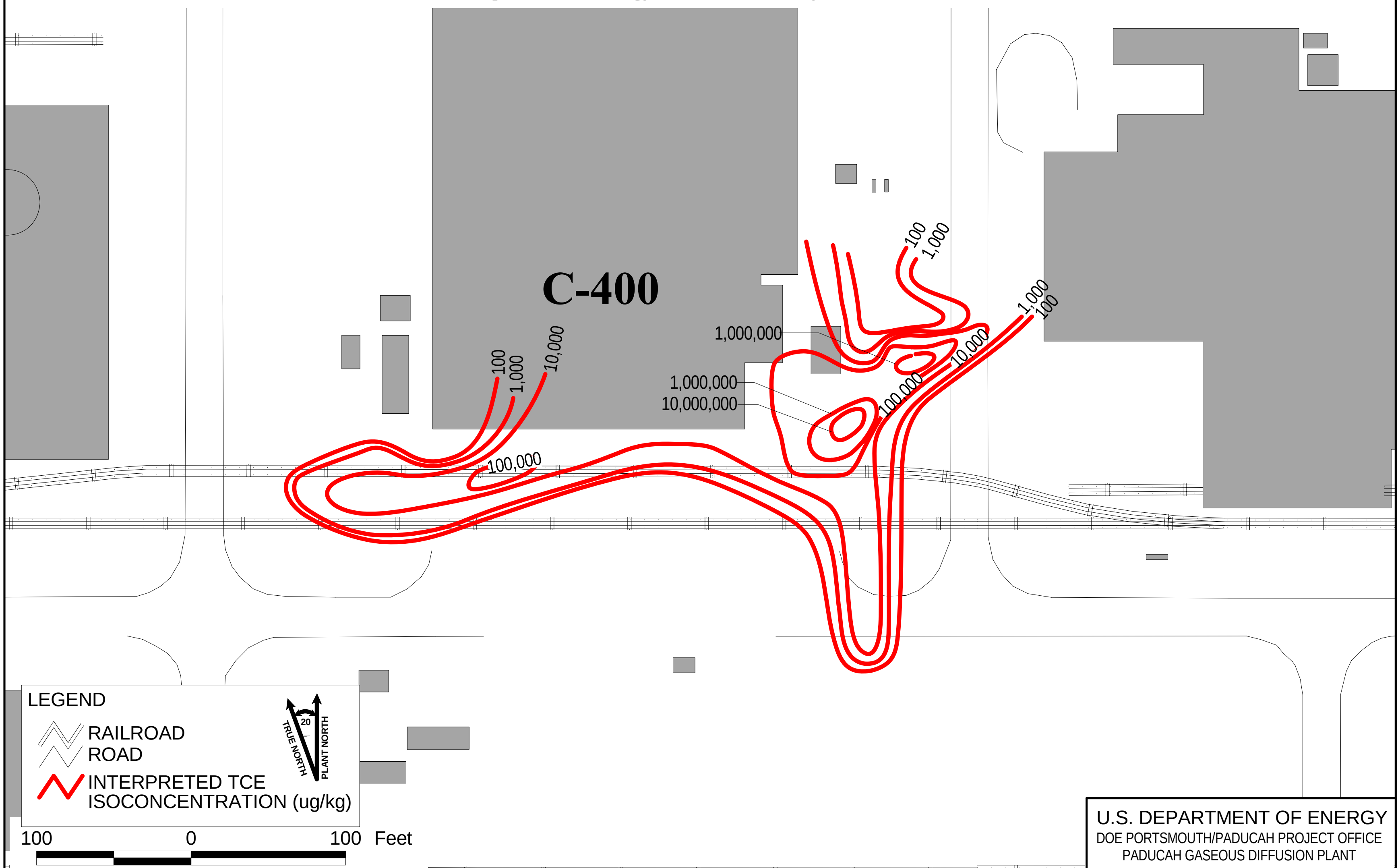

Figure 4. Contour Map of Maximum TCE Concentration Detected in UCRS Soil

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Figure No. c5ac90005sk012R5.apr
DATE 03-06-07

The March and April 2011 investigation of the Phase IIb treatment area (see March 2011 RAWP) sampled soils and groundwater in the UCRS, RGA, and uppermost McNairy Formation. TCE soil levels were highest in the vicinity of the former pump that transferred TCE from rail cars to an on-site holding tank, ranging up to 1,700,000 μg/kg in the upper RGA soil (indicative of DNAPL presence). All groundwater samples from the Phase IIb area exceeded 10,000 μg/L (a criterion for identifying the presence of DNAPL), ranging from 16,000 to 1,200,000 μg/L.

1.3 REMEDIAL DESIGN SUPPORT INVESTIGATION

The purpose of the RDSI was to improve the ERH design by determining the subsurface soil conditions and the presence and relative concentration of VOCs in the UCRS, the RGA, and the RGA/Upper McNairy interface. Remedial Design Support Investigation (RDSI) results were utilized in the delineation of the Phase I and Phase II treatment zones, both laterally and vertically. ERH implementation in Phase IIa will target the 20 to 60 ft bgs contours identified in the southeast treatment zone. Appendix A contains additional detail regarding results from the RDSI.

This investigation used membrane interface probe (MIP) technology. MIP technology readily collects soil conductivity profiles and VOC data from the UCRS, the RGA, and the McNairy with minimal generation of investigation-derived waste. Figure 5 shows locations of the MIP borings around the C-400 facility. Soil conductivity logs of each boring provided a means to discriminate lithologic intervals and a primary criterion for determining the completion depth of MIP borings that extended through the RGA. In one instance where conventional drilling techniques were utilized, as opposed to direct push technology, gamma ray logging was performed to determine lithologic intervals.

Geoprobe direct push soil sample rigs were used to deploy the MIP probes. For the RDSI, the Geoprobe rods were equipped with a shock damper to lessen stress on the MIP probe. Initial attempts with the MIP probe/Geoprobe system met refusal at depths ranging from 20 ft to 40 ft.

In attempting innovative methods to accomplish the RDSI, the investigation drillers found that standard Geoprobe rods with a slightly smaller diameter than that of the MIP probe and without the shock damper could be used to "pre" probe the sample locations to the planned depth. Thereafter, the investigation team was able to drive the MIP probe to the planned depths in "pre" probed soil borings at all locations. The MIP characterization data from the "pre" probed borings showed excellent response on all three organic chemical detectors (all three detectors demonstrated significant response to increasing VOC levels within the range of delineation of each detector) and definitive soil conductivity measurements. Intervals of high chemical detector response frequently presented significant detail with variations correlated to changes in lithology as defined by the soil conductivity log (as anticipated in undisturbed soils). The detailed responses, correlated to lithologic intervals, provided assurance that the "pre" probe process was not smearing DNAPL downward within the boreholes.

Damage to MIP tooling (i.e., MIP probe and carrier gas tubing) sometimes occurred during characterization of the RGA due to the extended stress on MIP tooling that was required to penetrate the geology encountered in the RGA. When equipment failures were encountered, advancement of the boring was terminated immediately. The failure then was evaluated to determine if tooling withdrawal was required to correct the problem. Often times, the problem could be corrected without withdrawing the MIP tooling from the boring. This sometimes was accomplished by reversing the airflow through the carrier gas tubing to remove obstructions that may have entered the system. When this approach was unsuccessful or other problems (i.e., heater failure, torn membrane, etc.) existed that couldn't be repaired from ground surface, the tooling had to be withdrawn and repaired. Once repaired, the tooling was advanced back to the depth interval where the problem began. Characterization of the subsurface then was

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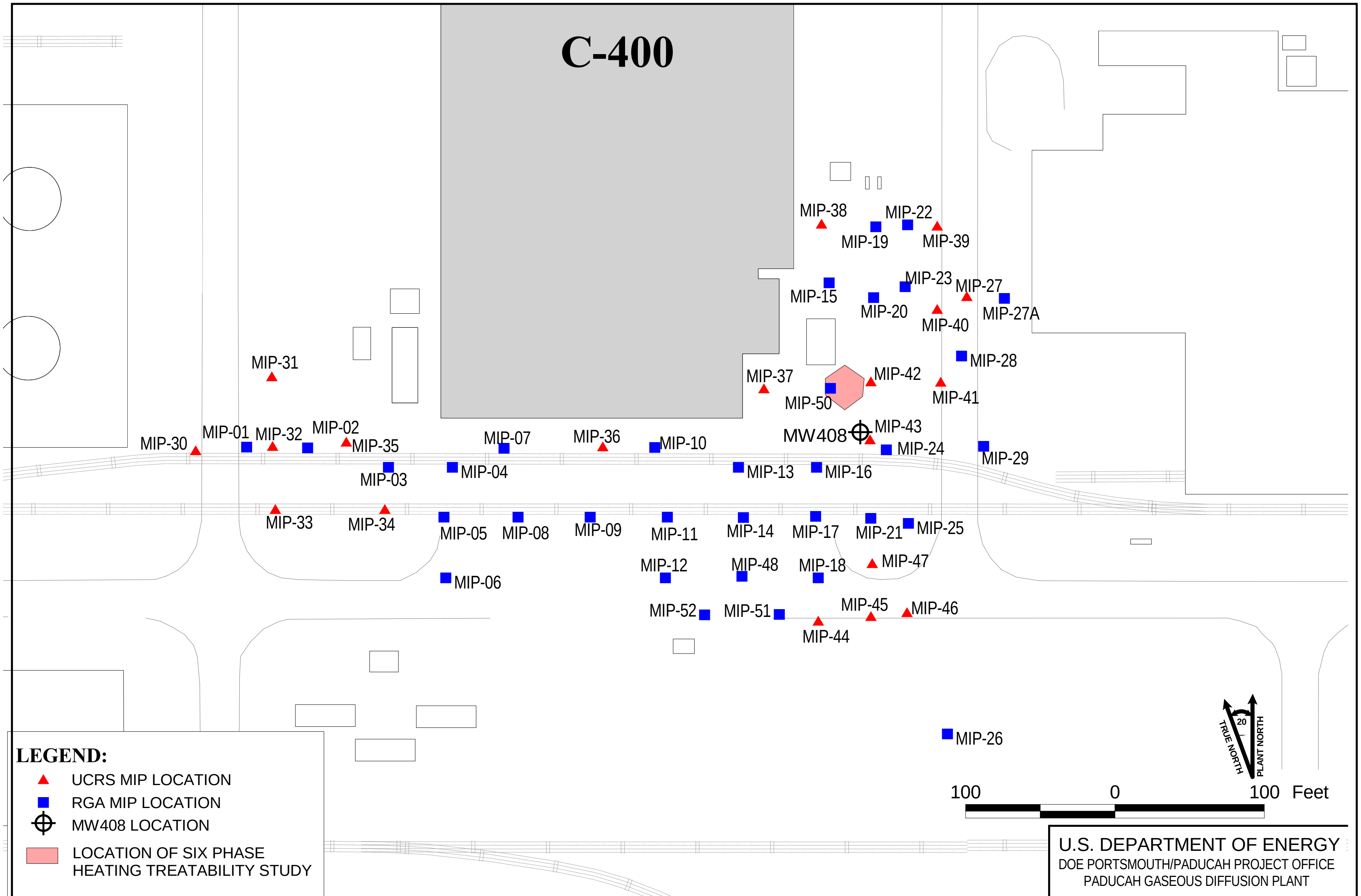

Figure 5. C-400 MIP Locations

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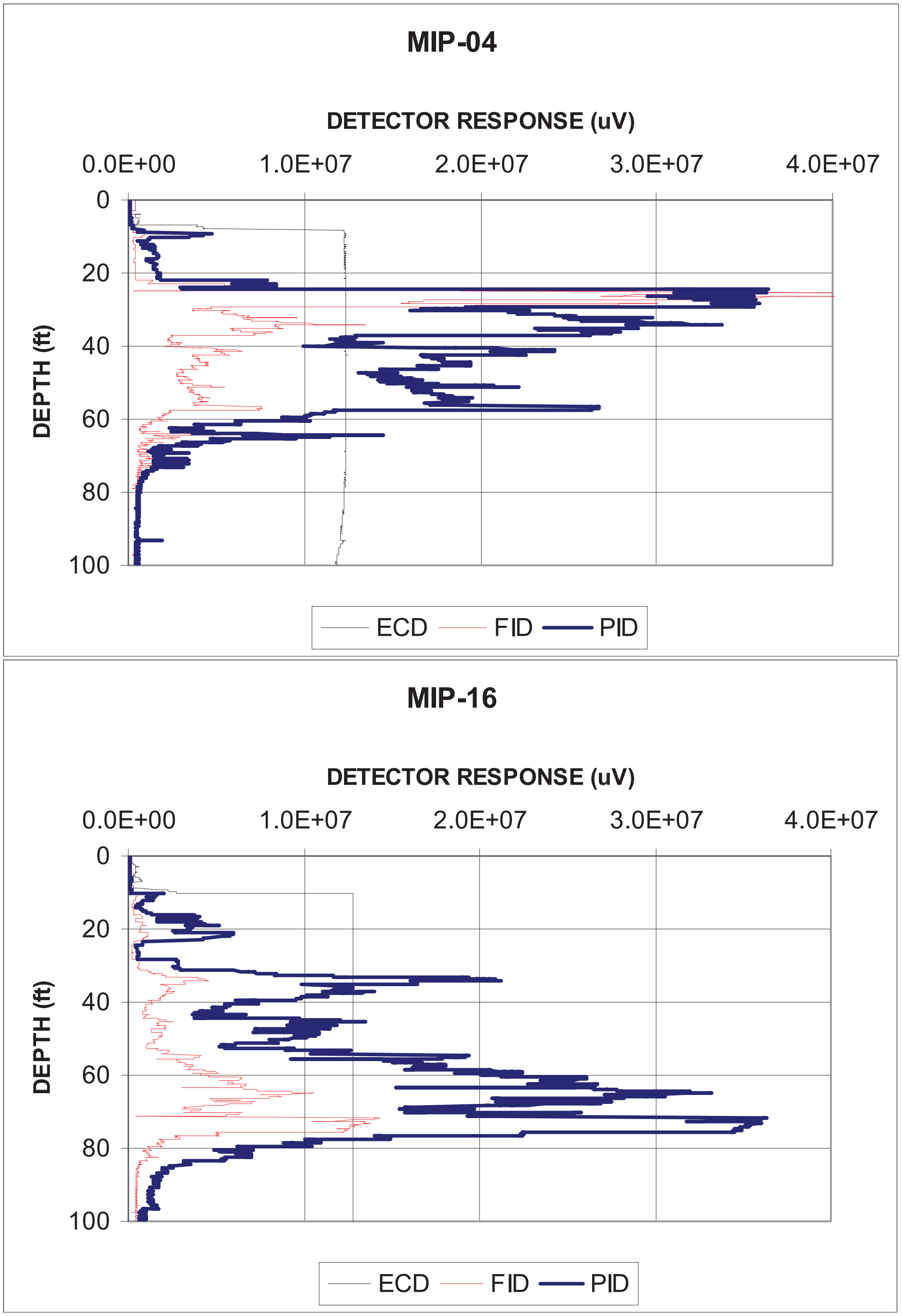

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Figure 6. Example MIP Detector Responses

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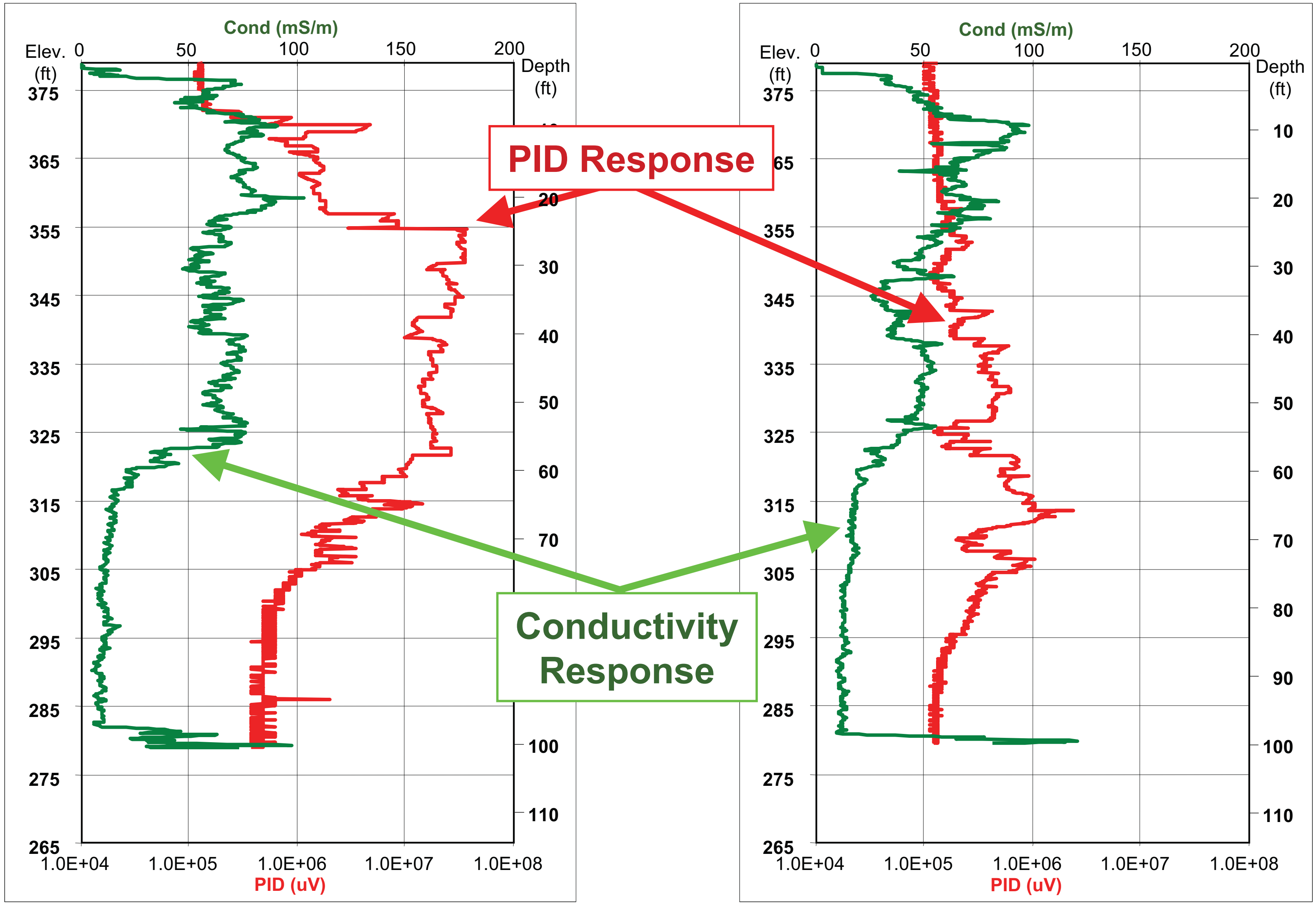
reinitiated at that depth interval. No negative impact to the quality of the MIP data occurred as a result of the withdrawal/repair process. MIP tooling advanced into the subsurface was irretrievable in five separate locations and had to be abandoned in place. None of the unrecoverable tooling is located within the Phase IIa treatment area footprint.

A MIP probe consists of a heating element and permeable membrane. VOCs diffusing through the MIP probe membrane are routed through tubing containing a carrier gas to a service truck at land surface containing organic chemical detectors. Detectors utilized in the RDSI included an electron capture detector (ECD), a flame ionization detector (FID), and a photoionization detector (PID). Each detector's response is reported in microvolts (µV). All three detectors responded to soil contamination by chlorinated solvents (such as TCE) to varying degrees (Figure 6). The ECD is the most sensitive of the detectors to chlorinated solvents, but also was the first detector to become saturated, which made it unable to detect higher levels of contamination. As used in the RDSI, the ECD's effective response ranged up to 1.3×10^7 µV (equivalent to approximately 2.7×10^5 µV on the PID detector in the saturated zone). An FID typically is suited to soil contaminants like methane and butane and generally proved to be the least responsive to soil contamination by chlorinated solvents. The FID response in the saturated zone commonly was approximately one half that of the PID. The PID is commonly used for investigation of soil contamination resulting from gasoline-related spills, but also is sensitive to chlorinated solvents and yielded good characterization of the primary TCE DNAPL zones. Example logs showing conductivity response [milliSiemens/meter (mS/m)] and PID response (µV) are shown in Figure 7 for MIP locations MIP-04 and MIP-07. Figure 8 shows how conductivity readings from the MIP logs were used to discriminate lithologic intervals. Note that contact with the RGA/Upper McNairy interface is clearly distinguishable by the sudden increase in conductivity response at approximately 100 ft.

During the RDSI, 18 MIP borings were completed through the UCRS to a depth of approximately 55 ft (16.7 m) bgs and 33 MIP borings were completed to the base of the RGA at an approximate depth of 100 ft (30.5 m) bgs in accordance with *Remedial Design Support Investigation Characterization Plan for the Interim Remedial Action for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2211&D2 (DOE 2005b). This plan optimized the location and depth of the MIP borings to complement the characterization data from the WAG 6 RI. Four of the 33 MIP borings completed to the base of the RGA were contingency borings that were required to assess uncertainties within the RGA. These contingency borings are shown on Figure 5 as MIP-48, MIP-50, MIP-51, and MIP-52. Contingency boring MIP-50 assessed residual VOC levels in the RGA in the area of the Six-Phase Treatability Study. The other three contingency borings delineated the southern extent of a basal RGA DNAPL pool in the southeast area of the C-400 facility. In total, the MIP borings characterized 4,200 ft of soil column.

Figure 9 shows the locations for MIP borings in a three-dimensional aspect that displays the vertical extent of the MIP borings. Also shown on Figure 9 is the color coded PID response at each of the MIP borings.

To evaluate MIP data, the maximum PID response values over five ft depths were contoured in intervals of 1×10^6 µV. Review of the PID contour maps for the vadose zone (20 to 25 ft and 25 to 30 ft depth intervals) and comparison of results to the conceptual site model developed using WAG 6 RI data indicates that the contours of 2×10^6 uV (PID) delineate DNAPL occurrence. Similarly, a review of the PID contour maps for the saturated zone (five ft intervals between 30 ft and 100 ft bgs) and comparison of results to the conceptual site model developed using WAG 6 RI data indicates that the contours of 9×10^6 µV (PID) define areas of DNAPL in the saturated zone.



MIP-04

MIP-07

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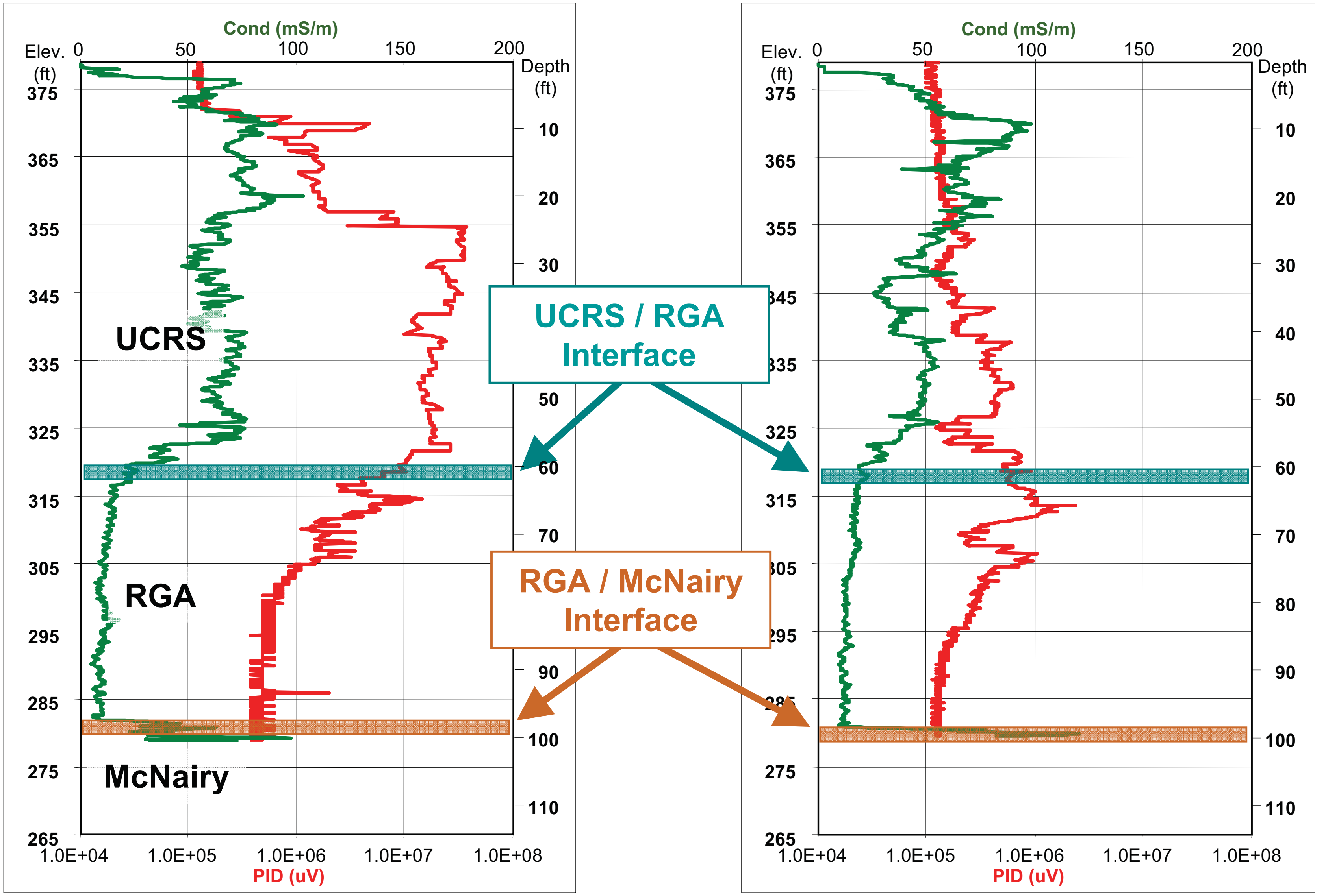
Figure 7. Example MIP Log Showing PID and Conductivity Responses



MIP-04 **MIP-07**

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Figure 8. Example MIP Log Showing Formation Interfaces

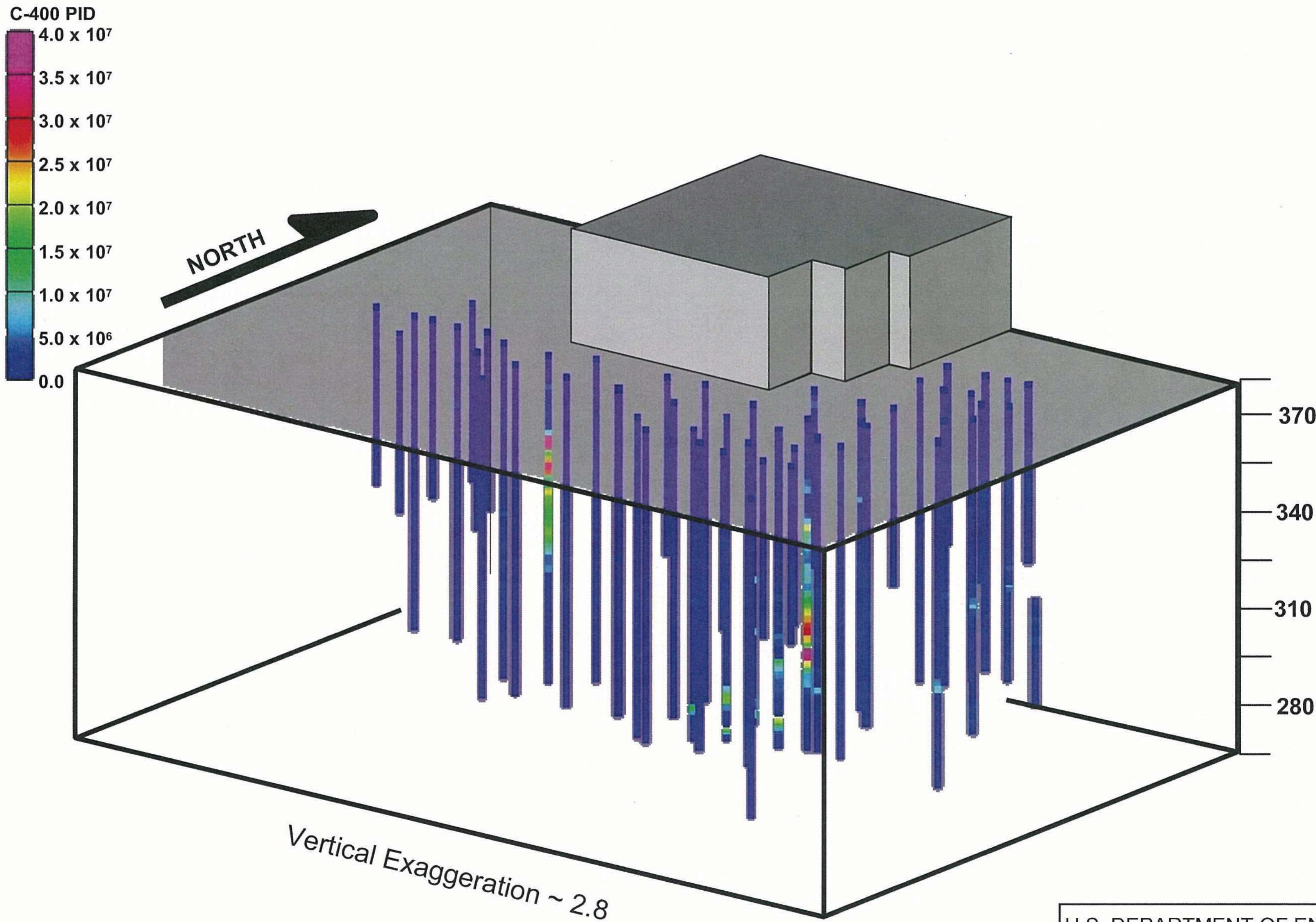

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Figure 9. C-400 MIP PID Response

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This criterion closely matched the experience of representatives of the MIP subcontractors who reported that areas with TCE contamination characterized as 1 x 10^7 µV by the PID commonly were DNAPL zones. Figure 10 shows examples of the interpreted DNAPL source zones on MIP logs from the vadose and saturated areas for location MIP-04 compared to readings for MIP-07 in which no DNAPL source zones were identified based on the before-mentioned criteria for DNAPL source zone delineations. Based on the MIP results and interpreted DNAPL source zones, a three-dimensional presentation of DNAPL source zones was defined as shown in Figure 11. Figure 12 shows the three-dimensional DNAPL source zone in relation to the C-400 Cleaning Building. This definitive DNAPL source zone delineation interpreted using data collected during the RDSI, coupled with data from previous investigations, has been assessed to delineate the areas of high TCE concentration more accurately, thereby allowing the design team to optimize placement of ERH electrodes, vapor recovery wells, and other subsurface components. Further detail concerning the MIP data interpretation is provided in Appendix A.

MIP results from the RDSI were used to delineate the extent of TCE soil contamination. The results are critical to interpreting the distribution of TCE DNAPL and the topography of the base of the Continental Deposits south of the C-400 Building. These data characterize the three-dimensional aspects of the TCE DNAPL source zones and demonstrate that the residual TCE distribution is consistent with the conceptual model from the WAG 6 RI. Moreover, the data show that the vertical extent of the DNAPL does not extend downward appreciably (0–1 ft) into the McNairy Formation below the primary RGA DNAPL pool at the base of the RGA. The MIP profile for boring MIP-14 (Figure 13) demonstrates these relationships in the lower RGA and upper 3 ft of the McNairy Formation.

The actual TCE mass removed during Phase I was much less than that estimated subsequent to the RDSI. Comparison of pretreatment and posttreatment collocated samples from Phase 1 demonstrated that ERH was very effective in the removal of VOCs from the UCRS soils. The mass of TCE recovered compared favorably to the RDR estimate for the east treatment area, where the estimate was based largely on preexisting soil analyses. In the southwest treatment area, where the estimate was based primarily on the conceptual model, the quantity of TCE recovered was significantly less than the RDR estimate; therefore, another confirmation sampling investigation was conducted to refine the estimate of mass in the Phase II treatment area.

The additional investigation was completed in April 2011 and described in the Remedial Action Work Plan (RAWP) (DOE 2011a). Soil and groundwater samples were collected from the Phase II southeast treatment area to provide data for a reevaluation of the TCE mass estimate. Table 1 summarizes the field characterization activities that were completed for the TCE mass estimate. The revised conceptual site model is summarized in Section 1.4 and the revised TCE volume and mass estimates are summarized in Section 1.5. Sample results from the additional investigation are summarized in the appendix of the *Revised Proposed Plan for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentuck*y (DOE 2011b).

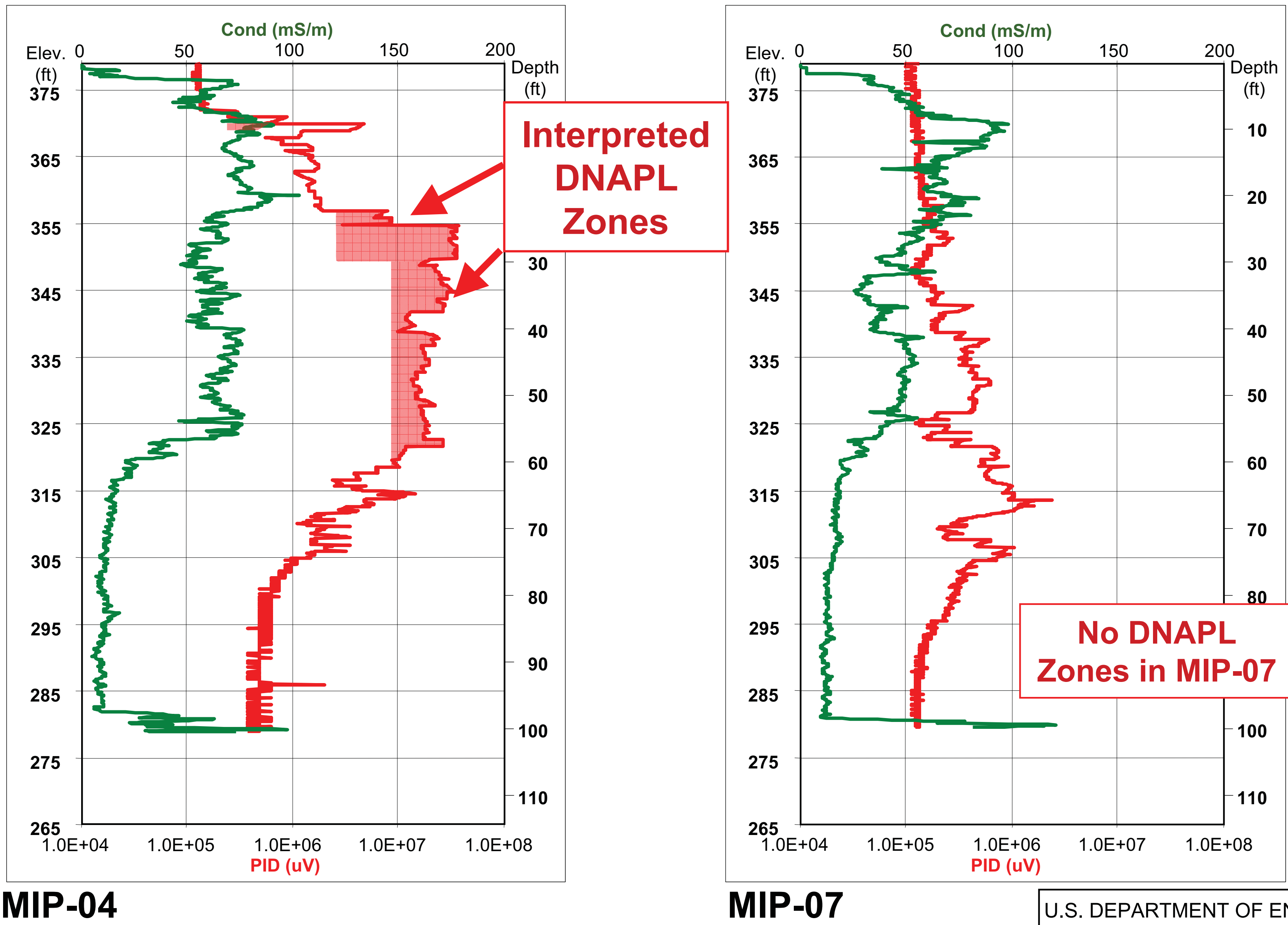

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Figure 10. Example MIP Log Showing Interpreted DNAPL Zones

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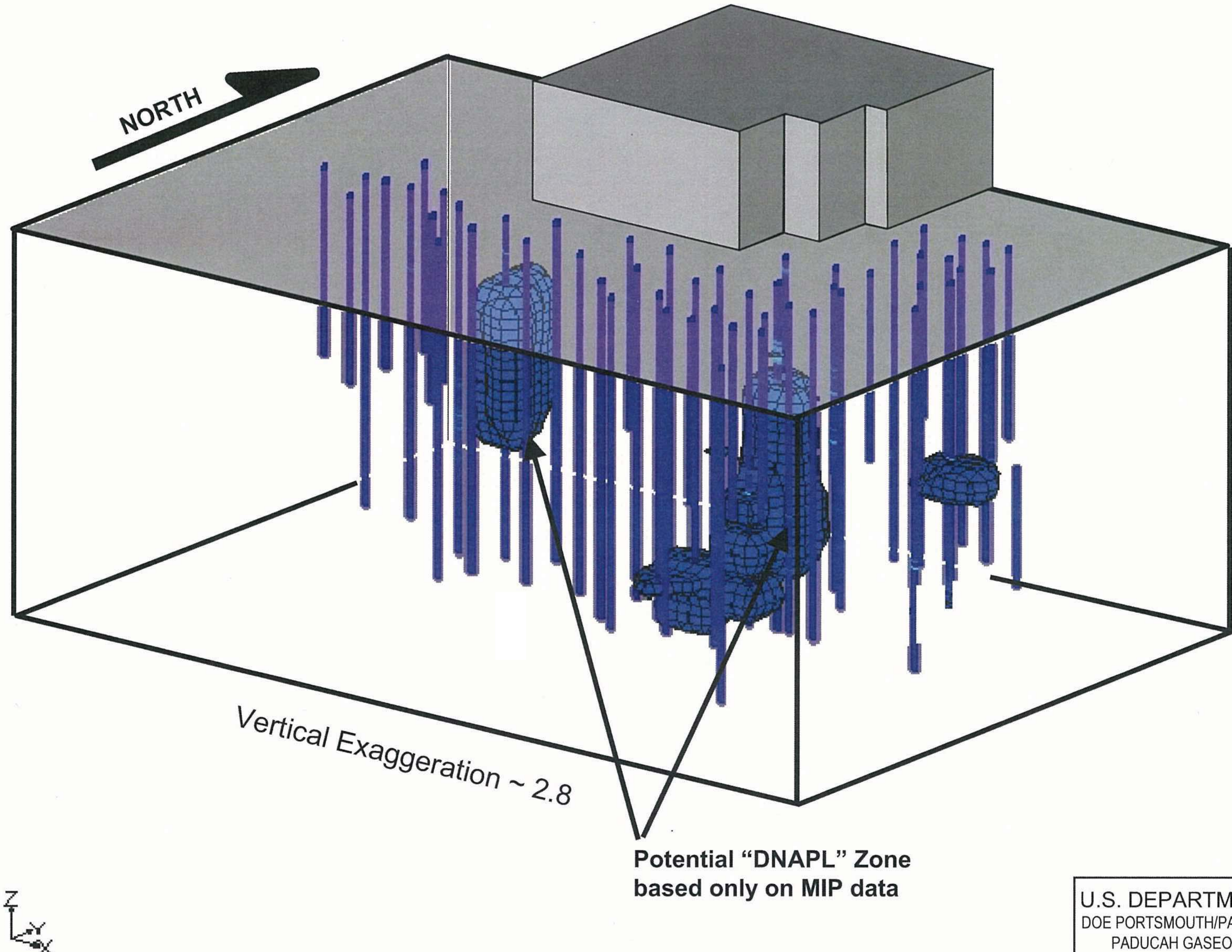

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Figure 11. Potential DNAPL Zone with MIP Borings

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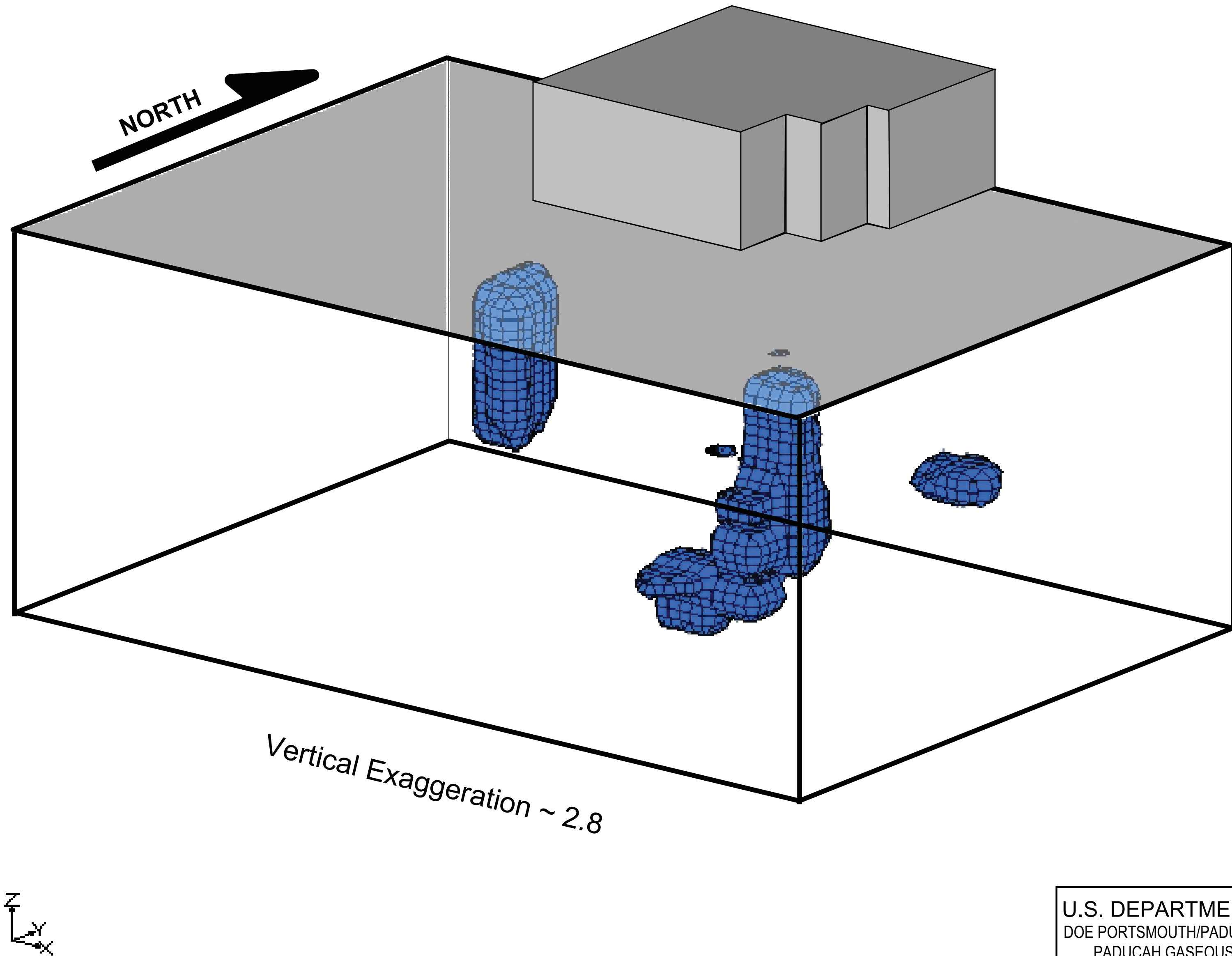

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Figure 12. Potential DNAPL Zone

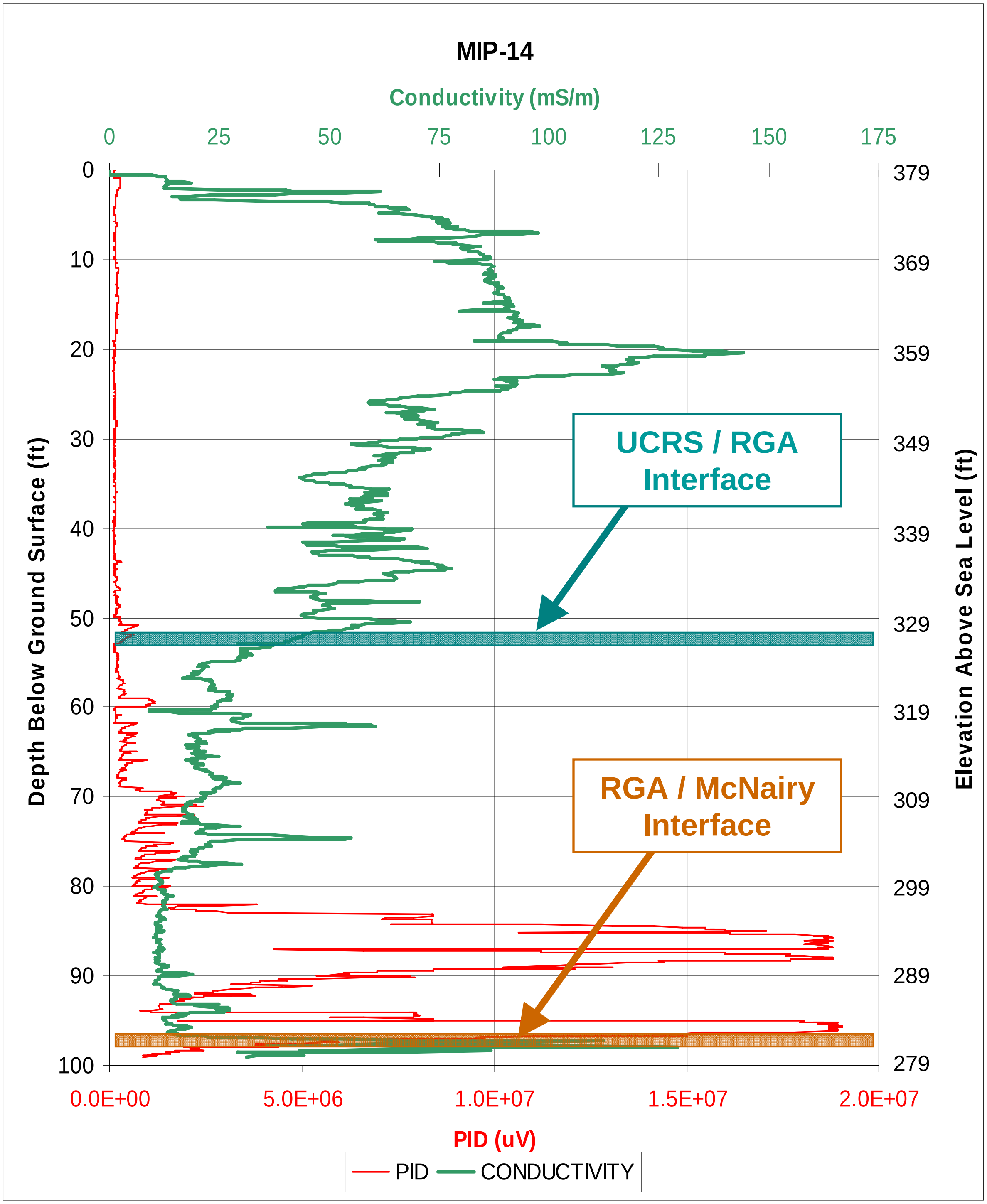

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Figure 13. PID and Conductivity Logs for Boring MIP-14 Illustrating Minimal DNAPL Penetration into the McNairy Formation

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Table 1. 2011 Sampling Activities in the Phase II Area to Support the TCE Mass Estimate

RDSI (2006) Boring ID	2011 MIP Boring ID	2011 Sample Boring ID	Samples for VOC Analysis						
			Soils				Groundwater		
			Horizons	Frequency	Depths (ft bgs)	# Samples	Horizons	Depths (ft bgs)	# Samples
MIP-13	MIP-53	SB53	UCRS/McN	1	20-65, 95	46	RGA	70, 75, 80, 85, 90, 94	6
MIP-14	MIP-55	SB54	UCRS/McN	2	20-55, 97	19	RGA	60, 65, 70, 75, 80, 85, 90, 95	8
MIP-16	MIP-54	SB55	UCRS/McN	1	5-62, 94	63	RGA	65, 70, 75, 80, 85, 90, 95	7
MIP-17	MIP-56	SB56	UCRS/McN	2	20-65, 96	24	RGA	70, 75, 80, 85, 90, 95	6
MIP-21	MIP-57	SB57	UCRS/McN	2	20-57, 95	20	RGA	60, 65, 70, 75, 80, 85, 90, 94	8
MIP-43	MIP-58	SB58	UCRS	2	20-61	21	N/A	N/A	N/A
MIP-44	N/A	SB60	UCRS	2	20-61	21	N/A	N/A	N/A
MIP-48	N/A	SB59	UCRS/McN	2	20-61, 94	22	RGA	65, 70, 75, 80, 85, 90, 93	7

bgs = below ground surface
McN = McNairy
MIP = membrane interface probe
N/A = not applicable
RDSI = remedial design support investigation
RGA = Regional Gravel Aquifer
SB = sample boring
UCRS = Upper Continental Recharge System

1.4 CONCEPTUAL SITE MODEL

It is prudent to continue to update the conceptual site model (CSM) from initial identification through the remedial action for any site as additional data become available. The initial CSM developed during the remedial investigation (RI) for Waste Area Group (WAG) 6 postulated a release from the TCE supply tank pipeline and additional loss at the loading area based on reported releases from C-400 sump pump discharges in 1970-1980. Figure 14 shows the C-400 Cleaning Building, former location of the TCE supply tank, pipeline, loading area, and an outline of six-phase heating treatability study area. The pipeline was replaced during the operating history of the TCE supply tank. The initial assessment with process knowledge, but with limited data, anticipated significant quantities of TCE released to the environment. The Six-Phase Heating Treatability Study (2003), in the vicinity of the pipeline leak, conducted ERH and removed an estimated 1,900 gal (≈ 23,000 lb at 12.2 lb per gal) of TCE. These data along with the MIP investigation resulted in an estimate of 75,000 gal (≈ 915,000 lb) of TCE in the subsurface in the vicinity of the southern part of C-400 (DOE 2008).

This conceptual understanding then was modified with the implementation of the Phase I ERH, which recovered approximately 580 gal (≈ 7,000 lb) of TCE from the southwest and east areas within the UCRS. An estimate, based on the CSM, anticipated approximately 23,000 gal (≈ 280,000 lb) of TCE in the Phase I areas. This discrepancy in mass led to the field characterization effort conducted in early 2011 and the reevaluation and update of the CSM.

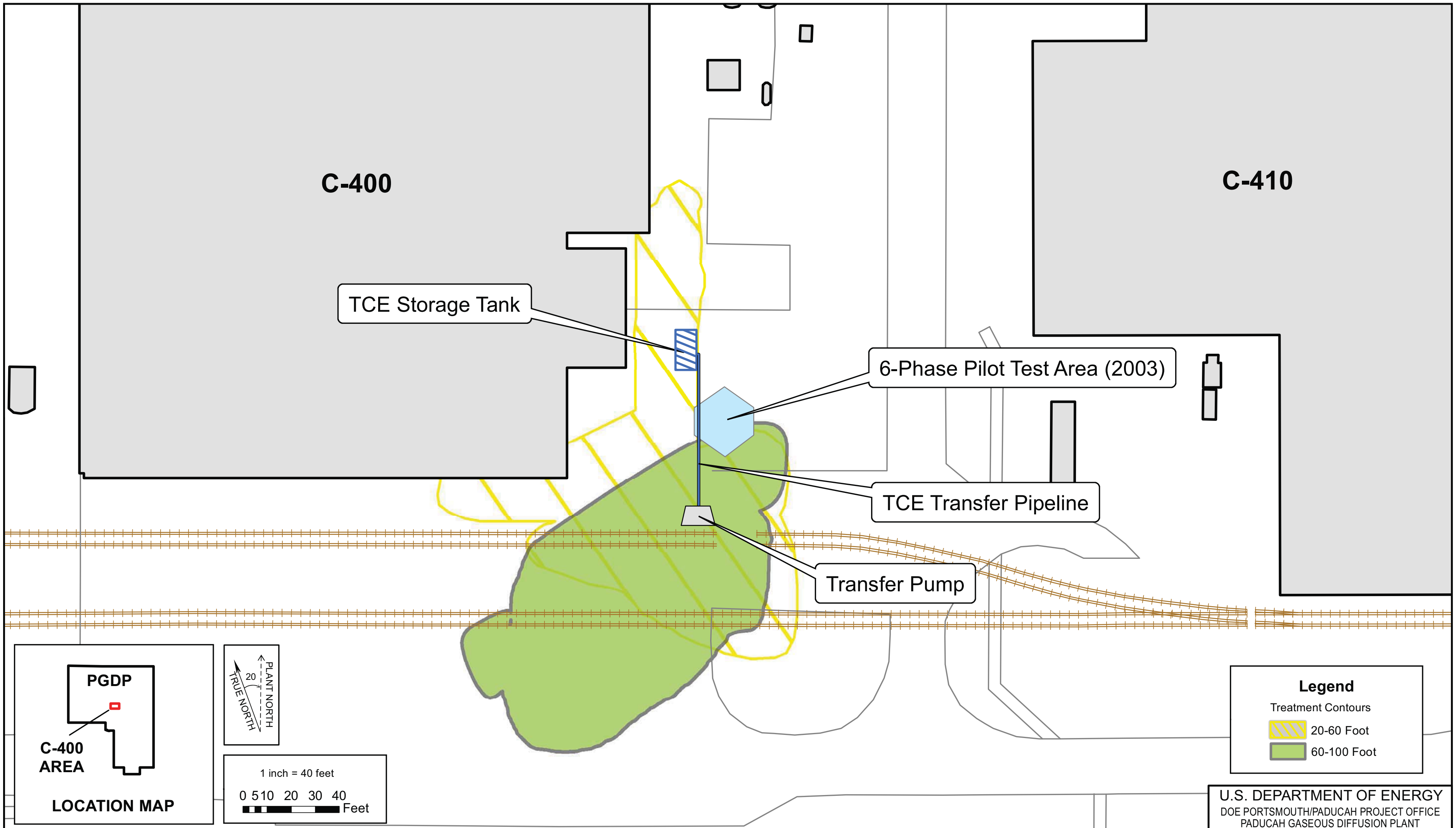

Figure 14. C-400 Phase II Interim Remedial Action Treatment Area and Vicinity

The 2011 investigation results confirmed the locations of the TCE leaks and spills and refined the geologic framework for the CSM, identifying undulations in the top of geologic members and the absence of the upper RGA sand layer directly below the pipeline loading point. The most significant revisions to the CSM involved the distribution and mass of the subsurface TCE sources. Previous MIP data from the RDSI were interpreted in the base design report (DOE 2008) to indicate of the presence of a discrete zone of vertical DNAPL migration with residual DNAPL saturation in excess of 5% and the occurrence of a thick DNAPL pool at the base of the RGA. Data from the 2011 investigation document much lower levels of TCE contamination below the TCE release site and the absence of a thick DNAPL pool at the base of the RGA in the Phase II area.

This section discusses a further evaluation of the CSM including geologic structure, refining the mass estimate, and attempting to further understand the anticipated DNAPL. The revised CSM then is used to help guide the decisions for remedial alternatives to address the contamination.

The following are the key characteristics of the updated C-400 CSM.

· The origin of the TCE in the subsurface is postulated to be from TCE pipeline leak(s) and spills at the loading point. The Six-Phase Heating Treatability Study was implemented in close proximity to the area of the former pipeline leak and recovered an estimated 1,900 gal (≈ 23,000 lb) of TCE from the UCRS and upper RGA.

· The TCE release traveled vertically through the UCRS as DNAPL due to its density and the porous permeable character of the surface and near surface sediments and construction backfill in this area. When encountering a less permeable lense (e.g., clay), the DNAPL would travel laterally until encountering a discontinuity in that lense and then resume its downward migration.

· Over time, the DNAPL in the UCRS continues to dissolve into the water phase with subsequent infiltration events (precipitation or plant line losses) resulting in dissolved-phase transport of TCE into the RGA.

· As the DNAPL disperses laterally in the finer grained sediments of the upper RGA, fine-grained zones may retain residual DNAPL.

· In the gravelly (more permeable) RGA, the DNAPL may be dispersed in the groundwater, may be transported vertically as DNAPL, or may be present as residual DNAPL in the form of connected blobs and ganglia trapped by the capillary forces in the pore spaces.

· If the DNAPL had sufficient mass for continuous interconnection, it would continue traveling vertically through the permeable RGA until it reaches a tighter matrix (i.e., McNairy) where it may pool. In the absence of significant depression in the top of the McNairy, pooling would be limited to a thickness of 3 cm.[3]

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[3] Numeric modeling of DNAPL in *Final Report, Feasibility of Using Enhanced Recovery Techniques at the C-400 Site for DNAPL Removal* (C. McConnell and D. Numbere 1995), calculates likely pool heights at the base of the RGA (3 cm), based on the Brooks-Corey pore index parameter. These calculations are consistent with calculated pool heights for a chlorinated solvent in coarse sand (1.6 cm) documented in, *An Illustrated Handbook of DNAPL Transport and Fate in the Subsurface*, (R&D Publication 133 of the Environment Agency) by B. Kueper and others 2003.

The current observed concentrations of TCE in the RGA could be from a continuing release from the UCRS, from DNAPL pooled in segments of the RGA, from discrete DNAPL ganglia, or from residual sorbed mass on the soil matrix. Figure 15 provides a conceptualization of the CSM.

1.5 DNAPL MASS ESTIMATE

DOE reevaluated the mass volume of the Phase II area based on the analyses of soil samples obtained during the field characterization effort conducted in early 2011 to refine the CSM. Three approaches were used to assess TCE mass volume for the treatment area and determined that a reasonable estimate of the range of TCE mass remaining in the Phase II treatment area is between 600 and 7,000 gal. The TCE mass volume estimate calculations are documented further in Appendix B. Summary findings are provided here. The lower end of the range of the estimate, 600 gal (≈ 7,300 lb), is based on soil and groundwater samples collected to date (including the WAG 6 RI, the Six-Phase Heating Treatability Study, and additional data collected in 2011). The higher end of the range of the estimate includes observation of TCE in groundwater and assumptions of potential DNAPL occurrence that, although not encountered in the samples collected to date, are considered to be representative of conditions based on the CSM. These observations and assumptions include the following:

- Persistent TCE mass flux associated with the Northwest Plume (approximately 4,000 lbs/330 gal per year for as long as 50 years);
- Past recovery of DNAPL from MW408, which is located in the SE treatment area; and
- The knowledge that DNAPL distribution in subsurface environments is typically heterogeneous and difficult to characterize using conventional sampling techniques.

A breakdown of DNAPL mass volume in the UCRS and RGA is as follows:

- For the interval 0 to 60 ft bgs, which is primarily the UCRS, the estimate is 290 to 30,500 lbs (24 to 2,500 gal); and
- For the interval 60 to 100 ft bgs, which is the RGA, the estimate is 7,000 to 55,000 lbs (576 to 4,500 gal).

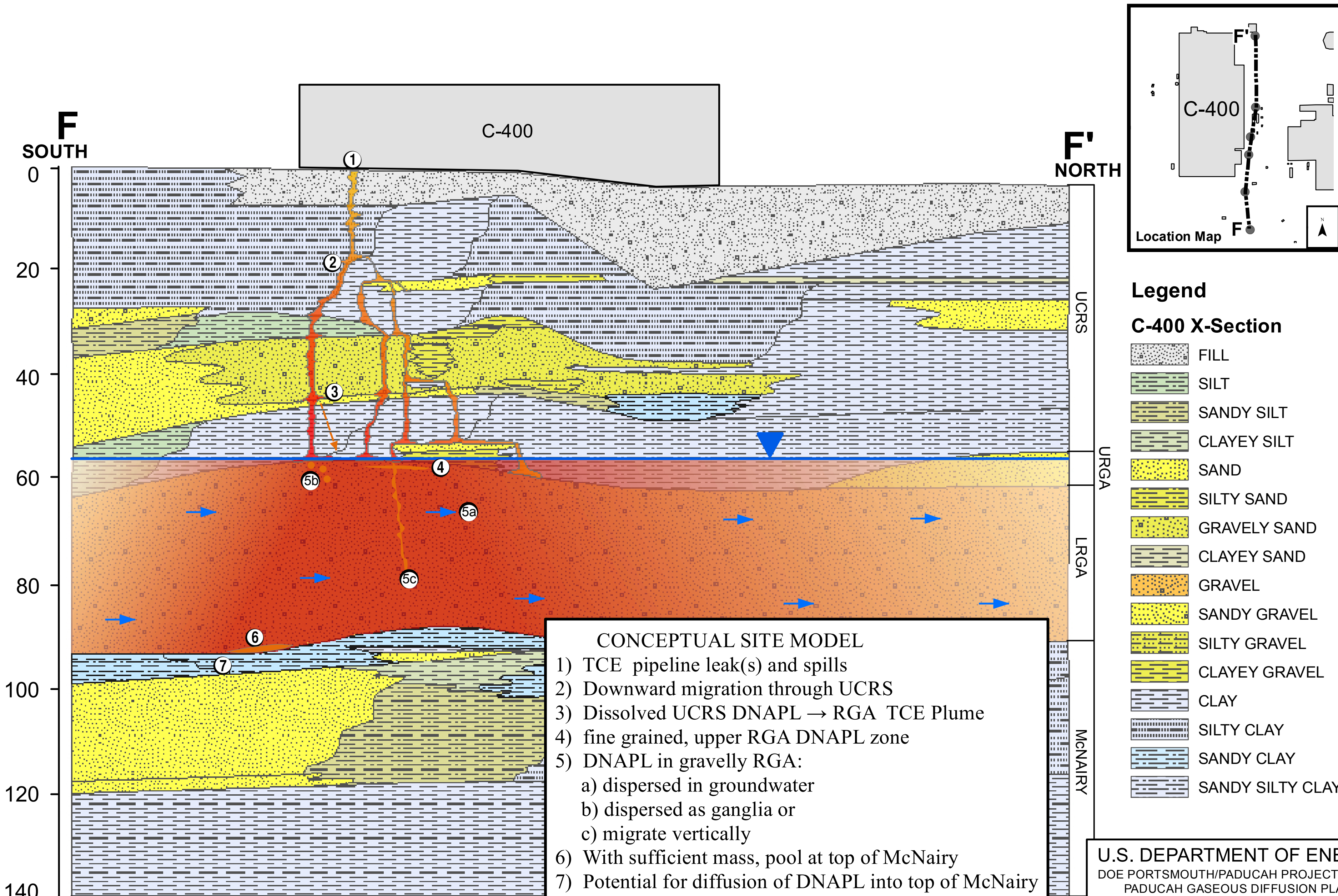

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Figure 15. C-400 Conceptual Site Model Cross-Section Area

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2. TREATMENT TECHNOLOGY

2.1 ELECTRICAL RESISTANCE HEATING DESCRIPTION

The C-400 IRA includes the installation and operation of a three-phase ERH system to heat the subsurface, volatilize VOCs, and remove them by way of a vapor recovery system. The three-phase ERH system consists primarily of a network of inground electrodes, vapor extraction wells, and vacuum monitoring piezometers (also referred to as vacuum monitoring wells) distributed throughout the zone of contamination (Figure 14). Electrical power for the electrodes will be supplied to the ERH system by an existing electrical feeder, 23B5B from the PGDP C-531-1 electrical switchyard. In the process of VOC volatilization, steam also will be generated, which will facilitate the stripping of VOCs (primarily TCE and its breakdown products) from the treatment area.

The original Phase I and Phase II subsurface treatment area was broken down into three specific treatment areas: the east, southeast and southwest treatment areas. Within these three treatment areas, there were treatment zones at various depths bgs. The colored contour lines shown within the three treatment areas, depicted in Figure 16, define the treatment zone depth intervals.

Based on Phase I results, the Phase II southeast treatment area has been split into two separate actions: (1) a UCRS/upper RGA action (Phase IIa) and (2) a lower RGA action (Phase IIb). This RDR revision addresses changes in the Phase I base design necessary to implement the ERH technology for Phase IIa in the C-400 southeast treatment area. This RDR revision does not address the implementation of Phase IIb. The detailed plan view layout of Phase IIa components and treatment zone depth intervals is provided in Appendix C.

The Phase IIa treatment system installation and operation will include the following activities:

- Installation of electrodes, vapor/liquid extraction wells, vacuum monitoring piezometers, thermocouple arrays, and pressure sensors in the TCE source zones at the C-400 Cleaning Building area;
- Heating of subsurface soil, contaminants, and groundwater via application of electrical current to the UCRS and upper RGA soils;
- Withdrawal of volatilized VOCs (primarily TCE and its breakdown products) by high vacuum vapor extraction;
- Extraction of a nominal quantity of groundwater to assist in controlling local gradients and groundwater migration;
- Treatment of contaminated groundwater/vapor through the use of an aboveground treatment system;
- Recovery of free-phase DNAPL in the event it is extracted from the subsurface;
- Reinjection of treated groundwater at subsurface electrodes to maintain electrical conductivity and facilitate heat transfer;
- Monitoring of contaminants in recovered groundwater and vapor;

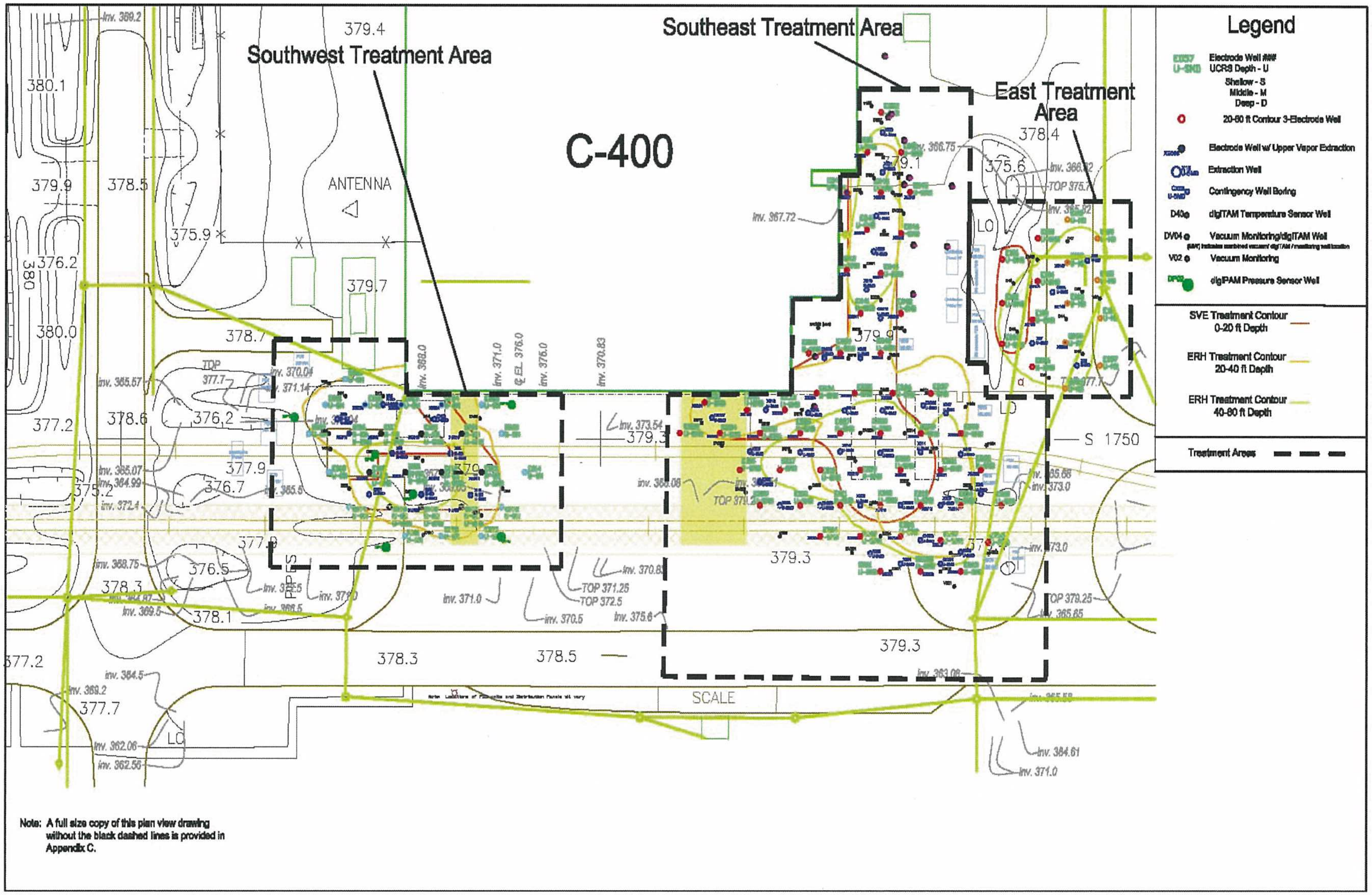

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Figure 16. Treatment Areas

- Discharge of treated groundwater/condensate through Kentucky Pollutant Discharge Elimination System (KPDES) Outfall 001;

- Discharge of treated vapors to the atmosphere and real-time monitoring of treated vapors; and

- Waste classification for on-site and off-site disposal.

Section 4 of this report provides additional detail relative to the ERH and vapor/liquid treatment systems.

2.2 APPLICABILITY TO THE PGDP SITE

A treatability study of six-phase ERH was conducted in 2003 at the C-400 Cleaning Building to demonstrate the implementability of ERH technology in the unsaturated and saturated soils of the UCRS and in the underlying RGA. According to the results documented in the *Final Report Six-Phase Heating Treatability Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2004), the ERH implementation exceeded the criteria for success outlined in *Six-Phase Heating Technology Assessment* (GEO 2003). The criteria for success were defined as greater than 75% reduction of TCE soil concentrations in the UCRS and a reduction of TCE groundwater concentrations to less than 1% (11,000 ppb) solubility in the RGA. The ERH in the treatability study reported a 98% reduction in TCE soil concentration in the UCRS, on average, and reduced TCE groundwater concentration to less than 1% of solubility in the RGA. The C-400 ROD documented ERH as the selected remedy for the C-400 IRA.

Postoperational soil sample results from Phase I indicated average percent reductions in TCE concentrations of 95% and 99% in the Phase I east and southwest treatment areas. Groundwater analytical results from postoperational samples indicated average reductions of 76% and 99% in the east and southwest areas, respectively.

ERH can be implemented in either a six-phase or three-phase heating approach. In both cases, the subsurface is heated as a result of the resistance of the soil to the flow of an applied electrical current. Three-phase heating is the preferred electrical phasing method for large and noncircular remediation areas (TRS 2007). Based on Phase I results, three-phase heating was retained for the C-400 IRA Phase IIa treatment area.

2.3 PHASED DEPLOYMENT

A phased deployment of ERH is being implemented. The first phase (Phase I) implemented the base design in the southwest and east treatment areas. In addition to removing VOCs from these areas, another important objective of Phase I was to evaluate the heating performance of the base design through the RGA down to the McNairy interface in the southwest treatment area. Treatment in the east treatment area involved only the UCRS. Operation of Phase I also provided the opportunity to evaluate the radius of influence of the vapor recovery system, assess hydraulic containment, and optimize the aboveground vapor/liquid treatment system. Lessons learned from Phase I were evaluated and appropriate design improvements (e.g., T-100 surge tank, closer spacing of extraction wells, and higher vacuum at the wellhead) were identified for implementation prior to installation and startup of Phase II near the southeast corner of the C-400 Cleaning Building.

Based on the evaluation of the lessons learned from the Phase I operations and performance, it has been determined that, with minor adjustments to the base design, ERH will be utilized to remove contaminants in the UCRS and upper RGA. Specific Phase I lessons learned and the design changes that will be made in Phase IIa to address them are summarized in Appendix C. Lessons learned, however, indicate that without extensive changes to the base design, ERH would not be effective in the lower RGA. Based on this conclusion, Phase II has been divided into two separate actions: (1) a UCRS/upper RGA action (Phase IIa) and (2) a lower RGA action (Phase IIb). This RDR revision addresses only the Phase IIa design.

3. TREATMENT SYSTEM OBJECTIVES

3.1 INTERIM REMEDIAL ACTION OBJECTIVES

The IRA objectives for the C-400 Cleaning Building, as defined by Section 2.8 of the ROD, are as follows:

- Prevent exposure to contaminated groundwater by on-site industrial workers through institutional controls (e.g., excavation/penetration permit program);
- Reduce VOC contamination (primarily TCE and its breakdown products) in UCRS soil at the C-400 Cleaning Building area to minimize the migration of these contaminants to RGA groundwater and to off-site points of exposure (POEs); and
- Reduce the extent and mass of the VOC source (primarily TCE and its breakdown products) in the RGA in the C-400 Cleaning Building area to reduce the migration of the VOC contamination to off-site POEs.

Bullet 1 above is addressed in the Land Use Control Implementation Plan for the C-400 IRA, which is included as Appendix D to this design report. The design of the treatment systems to be installed, which will address bullets 2 and 3 above, is discussed in Section 4. With regard to Phase IIa, the third bullet applies only to the upper RGA. Phase IIb will address the lower RGA.

3.2 DESIGN FACTORS INFLUENCING IRA SUCCESS

3.2.1 Extent of Treatment Area Adequately Defined

Existing characterization data for the south C-400 area, notably data from the WAG 6 RI and the RDSI, delineate zones of soil and groundwater in the UCRS and RGA that are contaminated by high concentrations of TCE that are indicative of the presence of DNAPL. Other VOCs are known to be present. Optimal placement of a remediation system required further refinement of the known magnitude and extent of the zone of highest contaminated soil and groundwater. The RDSI was performed to address this problem. RDSI results and subsequent definition of the treatment area are summarized in Section 1.3. Refer to Appendix A for additional discussion of the treatment area definition.

3.2.2 Subsurface Heating Technology Evaluated and Selected

Based on the evaluation of the lessons learned from the Phase I operations and performance, it has been determined that, with minor adjustments to the base design (increase vacuum at the wellhead and reduced spacing of the extraction wells etc.), the ERH technology installed during Phase I will be effective in removing contaminants in the UCRS and upper RGA of the Phase II treatment area. Specific Phase I lessons learned and design changes for Phase IIa are summarized in Appendix C.

3.2.3 Recoverable VOC Mass Adequately Estimated

The recoverable TCE mass in the Phase IIa treatment area has been updated based on characterization data from the 2011 confirmation sampling investigation and the subsequent data evaluation (DOE 2011a). Details regarding the updated estimate are provided in Section 1.5 and Appendix B. The estimates of DNAPL mass volume range from 290 to 30,500 lbs (24 to 2,500 gal) for the interval 0 to 60 ft bgs and 7,000 to 55,000 lbs (576 to 4,500 gal) for the interval 60 to 100 ft bgs. The lower end of the range is based on interpolation of existing characterization data and is provided only for informational purposes. The upper end of the range is anticipated to be within an order of magnitude of the DNAPL mass that is present in the Phase IIb area. Although the order of magnitude range (290 to 2,900 lbs/3,500 to 35,000 gal) is broad, it adequately defines the DNAPL mass/volume to support remedial design.

3.2.4 Soil Features and Properties Identified and Analyzed

In order to execute the ERH design, soil parameters must be compiled and/or determined through laboratory analysis. Soil properties that are critical inputs to the subsurface design include soil conductivity (electrical resistance), hydraulic conductivity, and permeability. These data are required for each distinct lithology within the treatment area. Soil samples collected as part of the RDSI were supplied to Mc^2 (McMillan-McGee Corp.) for laboratory analysis to determine these properties. Results of the analyses were used as input to the numerical simulations discussed in Section 3.2.5 and Appendix E. Additionally, site hydrogeology is important to the subsurface design; the flow of groundwater into and out of the treatment area impacts the energy balance of the system. The site-specific information also was used as input in the simulations. Previously available site data provided a basis for assessing the site hydrogeology.

3.2.5 Subsurface Numerical Modeling Executed

Mc^2 uses numerical simulation programs and numerical models to design the optimum implementation of ET-DSP™ for site-specific requirements. These programs and models were used to predict the following critical design elements for the base design as implemented in Phase I: optimum configuration of electrodes and extraction wells, temperature monitoring, and vacuum monitoring locations.

Results of the numerical simulation are presented in Section 4.2.1 and Appendix E.

Additional numerical simulation was not required for ERH design in the Phase IIa treatment area. Phase I numerical simulation results were scaled for use in the Phase IIa design in accordance with calculations in Appendix C.

3.2.6 Operational Strategy Adequately Described

The Phase IIa operational strategy is based on results of Phase I operations and the numerical simulation for Phase I. This strategy is defined as follows:

- Due to the extensive underground utilities present down to approximately 10 ft bgs, the uppermost electrodes will be placed to limit the heating influence to areas below this depth and minimize interference with existing electrical systems. Vapor extraction will be used to treat identified areas from 0 to 15 ft bgs to minimize interference with the previously-mentioned underground utilities. Vapor extraction from these shallow extraction wells will not begin until after target temperatures have been achieved in the UCRS, which is after approximately 50-60 days of ET-DSP™ operations according to the numerical simulation. If routine monitoring at the surface and in the vicinity of site workers indicates that VOC vapors are migrating to the surface and are becoming a safety concern, before target temperatures have been achieved in the lower UCRS, the shallow vapor extractors will be put into service. If monitoring at the shallow vapor extraction points prior to their operation indicates that vapors migrating from the heated zone may have bypassed the vapor extraction wells for the heated volume, the shallow vapor extractors will be put into service.

- To achieve uniform vacuum levels across the treatment area, the vapor extraction wells radius of capture (ROC) will be 15 ft (Phase IIa). This will require using the contingency wells for normal operation. A vapor cap also will be installed to prevent short-circuiting of vacuum to atmosphere at the XE well locations and will consist of 30 mil plastic sheeting covered with 4 inches of #57 stone. See Figure 17 for a depiction of the vapor cap locations.

- The simulation results assume 180 days of ET-DSP™ operations. The primary factors that will be adjusted that affect the stability or changes to the treatment system are the injection rate of water to the electrodes and the extraction rate of water from the wells. Other factors such as changes to energy input have a less immediate effect on the treatment system. Energy input will be adjusted as necessary to achieve and maintain target temperatures. Hydraulic control will be maintained by adjusting the injection and extraction rates of water (i.e., injection rates of water to the electrodes will be reduced if they are exceeding the extraction rates of water from the wells).

- Because the groundwater is relatively stagnant in the UCRS and treatment depth for Phase IIa only extends approximately 5 ft below the top of the RGA (and 9 ft below the RGA potentiometric surface, which is anticipated to be the approximate water table when ERH heating is established), it is not necessary to consider groundwater flow conditions as was done in the original simulation report. Although the electrode spacing for the simulation report was set at 20 ft due to higher resistivity and groundwater flow in the RGA, this spacing proved effective for operation of the UCRS electrodes in the southwest and east areas during Phase I. Maintaining 20-ft electrode spacing for Phase IIa allows flexibility both for operating the electrodes in varying electrical and hydraulic soil properties across the SE area and for placement of electrodes with respect to subsurface utilities and no-drill zones.

- The original Phase I design for the southeast treatment area included electrodes placed within the RGA for remediation of the contaminant plume below 60 ft bgs. Because the Phase IIa design will remediate the UCRS and upper RGA (20–60 ft bgs) portion of the SE area only, the number of electrodes has been reduced from 227 to 156. Thus the operating parameters have been recalculated as presented in Appendix C.

3.2.7 Electrode Field and Well Field Layout Established

The electrode and extraction well field was sited using the results of the ET-DSP™ numerical simulation. Phase I numerical simulation results were scaled for use in the Phase IIa design in accordance with calculations in Appendix C. The layout takes into consideration known subsurface obstructions, overhead obstructions, other space limitations, and plant operations. The arrangement of electrodes and extraction wells was followed by placement of power delivery systems (PDSs), water circulation systems (WCS), temperature monitoring equipment, and pressure monitoring equipment. Actual location of individual electrodes can be adjusted from the proposed location up to 3 ft during construction activities, as needed, without affecting the expected temperature results shown in the numerical simulation. Final location of the aboveground components, temperature indicating devices, pressure indicating devices, and groundwater extraction locations is subject to change as construction and site limitations mandate.

Due to the prevalence of utility lines to approximately 10 ft bgs to 15 ft bgs, the targeted heated volume was limited to below this depth. The ERH system along with the vapor and groundwater recovery system installed in the heated volume is not intended to completely volatilize and remove source from the

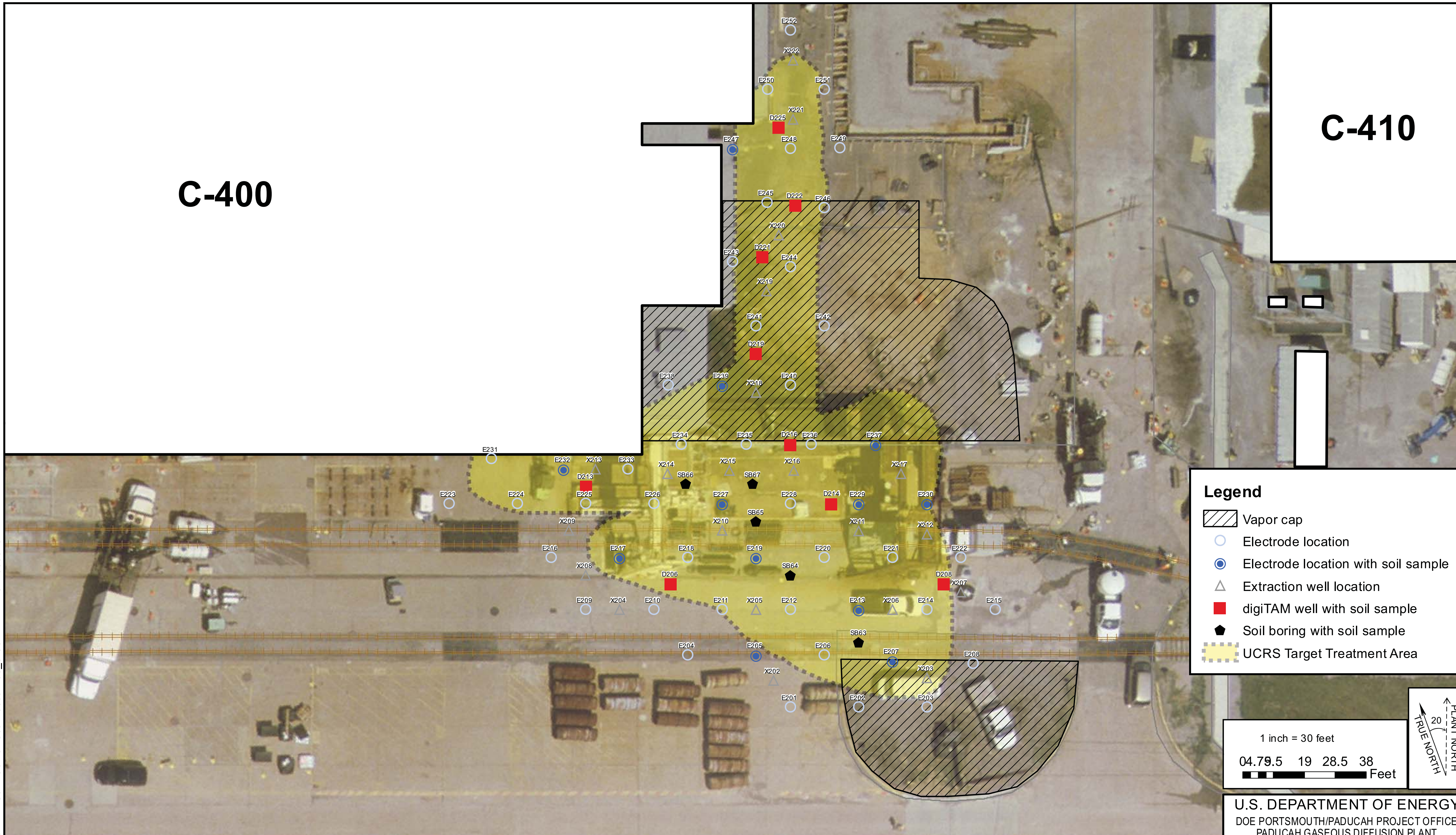

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Figure 17. C-400 Vapor Cap Layout for Southeast Well Field

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shallow zone (0 to 15 ft bgs). Shallow vapor recovery screens (screened from approximately 6 ft bgs to 13 ft bgs) are included to provide additional vapor recovery should VOC vapors bypass the heated volume vapor recovery system and, as an added benefit, to remove, to the extent practicable, source material already present in the shallow zone. Also, after approximately 60 days, it is anticipated that a portion of this zone will be heated by conductive heat transfer. The shallow vapor extraction wells are designed to capture any contamination volatilized from this heating.

3.2.8 Aboveground Treatment System Design Parameters Established

Influent design parameters and effluent discharge criteria for the Phase IIa vapor treatment system are listed in Table 2. Influent design parameters and effluent discharge criteria for the Phase IIa liquid treatment system are shown in Table 3. When compared to Phase I, the Phase IIa design reduces the soil vapor flow while increasing the required vacuum at the wellhead. The vapor flow rate was reduced due to a decrease in the number of extraction wells. In response to Phase I lessons learned, the increase of vacuum at the well head is required to optimize the vapor extraction system.

3.2.9 Key Operational Parameters Identified

The design will allow for operational parameters to be evaluated during the treatment period. Operational parameters to be measured include the following:

- Vapor recovery and treatment rates;
- Subsurface temperatures throughout the treatment zone;
- Pressure at vapor extraction well heads;
- Vacuum monitoring piezometer readings;
- Water injection rate through electrodes and groundwater extraction rate;
- Contaminant concentrations at vapor recovery wells and vapor headers; and
- Effluent contaminant concentration to demonstrate compliance with permit requirements.

Details regarding the monitoring of operational parameters will be presented in the C-400 Phase IIa RAWP that currently is under development.

Table 2. Vapor Treatment System Design Parameters and Discharge Criteria

Analyte/Design Parameter	Influent	Design Discharge Limit[1]
Soil vapor flow (dry air basis)	1,000 scfm	N/A
TCE concentration	20,000 ppmv	20 ppmv
Vinyl chloride concentration	30 ppmv	20 ppmv
trans-1,2-DCE concentration	50 ppmv	20 ppmv
cis-1,2-DCE concentration	50 ppmv	20 ppmv
1,1-DCE concentration	Non-detectable[2]	20 ppmv
Soil vapor temperature	203˚F (95˚C)	N/A
Pressure at wellhead	15 in Hg vacuum	N/A
Air from air stripper (dry air basis)	300 scfm	N/A

[1] Using the design discharge limit as an input, the maximum off-site concentration for each pollutant was estimated utilizing the air dispersion modeling software BREEZE AERMOD GIS Pro v5.1.7 (the modeling is presented in the C-400 Phase IIa RAWP that currently is under development). The simulation software modeled a stack that was 20 ft tall, 8 inch diameter, discharging at the anticipated range of flow rates at 70̊F. A risk factor of 10^{-6} was used to establish the off-site limit. Based on results of the model, the discharge design concentrations would yield off-site concentrations that would be lower than the limit. Air dispersion modeling results will be provided in the C-400 Phase IIa RAWP that currently is under development.

[2] Although the Six-Phase Treatability Study vapor sampling results for 1,1-DCE were nondetectable, there were detectable levels of 1,1-DCE in groundwater samples; therefore, 1,1-DCE will be monitored for in the vapor discharge.

Table 3. Liquid Treatment System Design Parameters and Discharge Criteria Relative to Outfall 001

Analyte/Design Parameter	Influent	Discharge Limit
Groundwater flow	20–80 gpm	N/A
Condensate flow	10 gpm max	N/A
TCE concentration	5–1,100 ppm	30 ppb[1]
1,1-DCE concentration	154 ppb	3.2 ppb[1]
Technetium-99 activity	14-342 pCi/L (observed in groundwater sampled during the Six-Phase Treatability Study and Phase I)	900 pCi/L[2]
Temperature	203˚F (95˚C) maximum 185˚F (85˚C) average	89˚F (31˚C) daily max[3]
pH	5.5–6.5	6–9[3]
Total suspended solids	10–50 ppm	30 mg/L monthly average[3] 60 mg/L daily max[3]
Total residual chlorine	Plant potable water levels	0.011 mg/L monthly average[3] 0.019 daily max[3]

[1] Discharge limits are based on *Kentucky Administrative Regulations* (*KAR*) 401 *KAR* 5:031.
[2] DOE target limit
[3] KPDES permit limit for Outfall 001 effluent discharge

3.3 CRITERIA FOR CEASING IRA SYSTEM OPERATIONS

The remediation goal for this interim action, as stated in Section 2.9.3 of the ROD (DOE 2005a), is to operate the ERH system until monitoring indicates that heating has stabilized in the subsurface and that recovery of TCE, as measured in the recovered vapor, diminishes to a point at which further recovery is at a constant rate (i.e., recovery is asymptotic). At asymptosis, continued heating would not be expected to result in further significant reduction of toxicity, mobility, or volume of the zone of contamination.

The first part of the remediation goal is to operate the ERH system until monitoring indicates that heating has stabilized. (Note that it is anticipated that continued application of ERH will temporarily dry the soils above the RGA potentiometric surface so that the RGA potentiometric surface will become the water table during ERH operation.) The stable heating goals for Phase IIa are defined as follows:

- Temperatures in the soil above the potentiometric surface of the RGA (approximately 53 ft bgs at the C-400 Building) are at or above 90ºC (194ºF). The boiling point of free-phase TCE is 87ºC (189ºF) at sea level pressure conditions.

- Temperatures below the potentiometric surface of the RGA are at or above the boiling point of the free-phase TCE at the depth of treatment [e.g., approximately 87ºC (189ºF) at the potentiometric surface and approximately 93ºC (199ºF) at 60 ft bgs].

- The target temperatures at each depth interval will be verified by 90% of the digital temperature monitoring sensors installed at 3-ft intervals throughout the heated volume.

- The target temperatures presented in bullets one and two are maintained for the period of time necessary to achieve asymptosis, as defined below.

The free-phase boiling point of TCE (adjusted for depth) is a conservative goal since it is known that a phase change for a TCE/water mixture is achieved at the azeotropic boiling point of the solvent/water mixture (a lower temperature than that of either TCE or water). In the case of a TCE/water mixture at one atmosphere, a phase change will begin when the mixture is heated to ≈ 73ºC (87ºC for free-phase TCE and 100ºC for water). At a depth of 7 ft below the water surface and assuming a hydrostatic pressure distribution, the TCE/water boiling point is ≈ 77ºC (105ºC for water) and the free-phase TCE boiling point is ≈ 93ºC. Figure 18 shows graphs of the anticipated boiling temperature versus depth in the treatment zone for a TCE/water mixture, for free-phase TCE, and for groundwater. The graphs display boiling temperatures to approximately 70 ft bgs, Phase IIa heating will target soils in the UCRS and upper RGA at depths of 20–60 ft bgs.

If the temperature goals are not achieved or maintained as necessary until asymptotic recovery in the vapor phase has been accomplished, contingency measures will be implemented in an effort to accomplish the required heating. These contingency measures include directing additional power to operating electrodes in the problem area or attempting either to restore power to a failed electrode or to increase the power to electrodes in the vicinity of a failed electrode if an electrode does fail.

The second part of the remediation goal is asymptotic recovery of TCE in vapor. Asymptotic conditions will be identified based on visual inspection of data plots showing TCE mass removal rate and TCE vapor concentration versus time for individual vapor recovery wells. When the slope of the curves presented in these data plots approaches zero at a slow rate of change, the curves are at asymptosis. At asymptosis, the rate of TCE recovery is constant.

Vapor recovery and groundwater extraction wells will be monitored routinely throughout heating operations to monitor progress and to develop data plots for use ultimately in identifying when asymptosis has been achieved. These activities will be included in a detailed monitoring plan in the operations and maintenance (O&M) Plan. TCE concentrations in recovered vapor initially will increase as the subsurface is heated to and above the boiling point of TCE in the vadose zone and to the boiling point of free-phase TCE, adjusted for pressure, below the water table. Over time, the TCE vapor concentration and mass recovery rate will decrease to an initial asymptotic level, which will be determined by the project engineer to ensure required operational flexibility. At this point, the system will undergo a "pulsed operation," whereby vapor recovery will be reduced or stopped for a period of time to allow the subsurface to equilibrate. Pneumatic control will be maintained during pulsing operations by limiting the number of wells that have reduced vacuum or by limiting the reduction in vacuum at each well. The frequency of monitoring the vacuum levels will be increased during pulsing events. The O&M Plan will include additional detail with regard to these activities.

When the vapor recovery flow rate is increased to previous levels, the TCE vapor concentration may rebound to a level above where it settled at asymptosis. System operations will continue until recovery again decreases to an asymptotic condition. This process may be repeated several times depending on the significance of the rebound increment as compared to the asymptotic level for vapor concentration and mass recovery rate before pulsed operation.

In Phase I, groundwater TCE concentrations and mass recovery in groundwater were considered as indicators of when the point of diminishing returns in TCE mass recovery was being approached. Phase IIa ERH design and operations will be targeting only UCRS and upper RGA soils. No near-term impact on groundwater concentrations below 60 ft bgs is expected (source removal from the RGA will be addressed in Phase IIb of the C-400 IRA). Although groundwater TCE concentrations and mass recovery in groundwater will be monitored, they are not expected to play a role in determining when to cease Phase IIa operations.

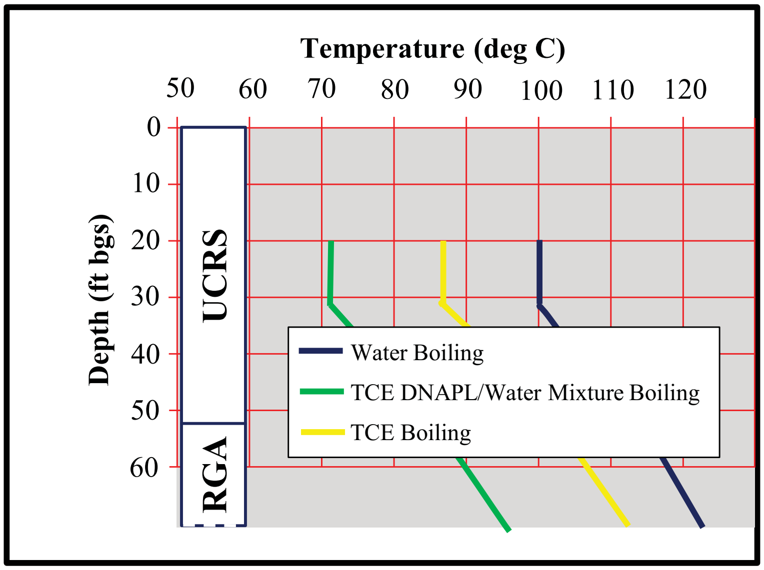

Figure 18a. Boiling Temperature Versus Depth (start of heating)

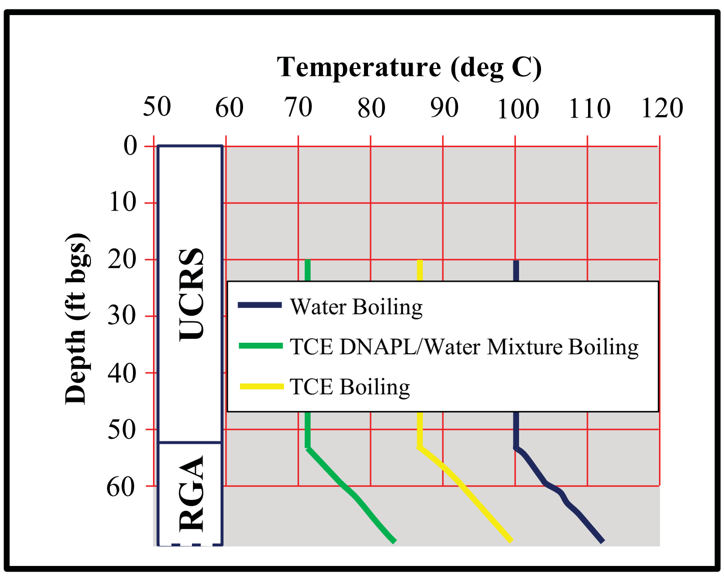

Figure 18b. Boiling Temperature Versus Depth (once UCRS becomes dry)

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 18. Boiling Temperature Versus Depth

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A regular project status meeting will be held each month to coincide with the monthly Federal Facility Agreement Managers' meeting. These status meetings will be used to review the operational data, discuss data trends, and evaluate the overall progress of the project in terms of meeting the remediation goals. The frequency of these meetings may be increased to a biweekly schedule as the project gets closer to completing operations. When the body of evidence, consisting of TCE vapor concentration versus time and statistical analyses results indicate that the remediation goal, as stated in the ROD, has been achieved, the DOE project team will seek concurrence from U.S. Environmental Protection Agency and Kentucky Department for Environmental Protection that the remediation goal has been met. The parties agree to target a 30-day time frame for review and concurrence that the remediation goal has been met. Operational data and analytical results will be obtained and provided in a timely manner (expedited laboratory turnaround times) to facilitate the project review. The three parties will consult with one another to reach consensus as to whether the system should remain in operation after the remediation goal has been met and, if so, under what conditions.

The criteria for ceasing IRA system operations are summarized in Table 4.

Table 4. Criteria for Ceasing IRA System Operations

Performance Assessment Model Parameters (P)	**Performance Metrics (PM)**	**Potential Deviation from Performance Assessment Model**	**Contingencies**
P 1: Heating has stabilized in the subsurface.	**PM 1**: Monitor/record temperature readings from temperature sensors installed in the treatment zones to the required depth of heating. Phase IIa stable heating goal: · Temperatures in the soil above the potentiometric surface of the RGA (approximately 53 ft bgs) reach 90ºC (194ºF). The boiling point of free-phase TCE is 87ºC (189ºF) at sea level pressure conditions. · Temperatures below the potentiometric surface reach the boiling point of the free-phase TCE at the depth of treatment [e.g., approximately 87ºC (189ºF) at the potentiometric surface and approximately 115ºC (239ºF) at 98 ft bgs]. Refer to Figure 18). · The target temperatures presented in bullets one and two are maintained for the period of time necessary to attain Performance Metric 2 below. · At least 90% of the temperature sensors installed at each depth interval verify that target temperatures have been achieved.	The temperature does not reach required levels in a treatment zone within 60 days after the estimated 90 days necessary to heat the zone.[a] The target temperature is attained and then declines before asymptosis in TCE recovery is achieved. In treatment volumes above the potentiometric surface, unintentional and extended (seven days or more) temperature excursions below the boiling point of TCE would be considered problematic. In the treatment volumes below the potentiometric surface, unintentional and extended (seven days or more) temperature excursions excess of 10% below the target temperature would be considered problematic.	If temperatures specified in **PM1** are not achieved in a treatment zone within the estimated time required to heat the zone,[a] operations personnel will attempt to determine the reason for the deviation. If there is a problem with temperature sensing equipment, it will be replaced. If the electrodes are operating normally, then additional energy will be applied to the electrodes in zones that have not achieved or fail to maintain the required temperature in an attempt to increase temperatures. If electrode failure is the cause, attempts will be made to restore functionality to the electrode. If functionality cannot be restored, additional energy will be applied to electrodes in the vicinity of the failed electrode in an effort to compensate for the failed electrode. For Phase IIa operations, if contingency measures herein are unsuccessful and the temperature targets are still not achieved, then DOE will evaluate, in consultation with regulators, the cost/benefit of continuing ERH operations in the treatment zone.

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Table 4. Criteria for Ceasing IRA System Operations (Continued)

Performance Assessment Model Parameters (P)	Performance Metrics (PM)	Potential Deviation from Performance Assessment Model	Contingencies
P 2: Recovery of TCE, as measured in the recovered vapor, diminishes to a point at which further recovery is at a constant rate (i.e., recovery is asymptotic). Asymptotic recovery is anticipated to occur within 180 days[a] unless VOC levels in recovered vapors exceed the capacity of the vapor treatment system requiring changes to the rate of heating and/or vapor extraction, in which case up to 240 days may be required.	**PM 2:** Assuming that stable target temperatures have been achieved (see PM 1 above), asymptotic conditions will be identified based on visual inspection of data plots showing TCE mass removal rate and TCE vapor concentration versus time for individual vapor recovery wells. Once the slope of the curves presented in these data plots approaches zero at a slow rate of change, the curves will be understood to be asymptotic. At asymptosis, the rate of TCE recovery is constant. The body of evidence, consisting of data plots of TCE mass removal rate and TCE vapor concentration versus time, and statistical analyses results will be used by DOE to identify when asymptosis has been reached.	TCE vapor concentrations and mass removal rate, plotted across time do not exhibit asymptosis within the estimated 180 days[a] required to treat the zone.	The treatment period may be extended beyond 180 days if VOC levels exceed the capacity of the vapor treatment system requiring changes to the rate of heating and/or vapor extraction. If asymptosis has not been achieved after 240 days of ERH operations, then DOE will evaluate, in consultation with regulators, the cost/benefit of continuing ERH operations in the treatment zone.

[a] Time estimates for achieving required temperature levels and for treating treatment zones are based on the results of numerical simulations conducted by Mc^2. Refer to Section 3.2.6 and Section 4.2.1 for additional detail.

4. PHASE IIa TECHNICAL DESIGN

4.1 SYSTEM DESIGN

Appendix C provides a detailed design of the Phase IIa ERH system with specific locations determined for subsurface components such as electrodes, extraction wells, vacuum monitoring piezometers, and temperature monitoring equipment.

Specific Phase IIa plant coordinates have been identified for subsurface components and are listed in Appendix C. Underground utilities will be marked prior to commencing drilling activities. During installation, there will be some flexibility to adjust the locations to accommodate unexpected underground hazards. Electrodes can be moved from their proposed location by up to 3 ft without impacting expected subsurface heating performance. There is more flexibility with regard to adjusting the locations of other subsurface components. Mc^2 subject matter experts will be on-site to provide consultation and guidance prior to relocating any of the components. Subsurface components will be installed as designed in borings completed using traditional drilling techniques.

There is the potential for significant interference during installation of subsurface components caused by existing underground and overhead utilities, active PGDP operations at the C-400 Cleaning Building, and train and cylinder hauler traffic in the treatment area. As a result, final engineering activities and mechanical/electrical connections to the ERH treatment components will be field engineered.

Vaults used in below grade completions will be designed to allow unobstructed access to the C-400 Cleaning Building roll-up doors and will be designed to withstand appropriate traffic loads for work performed in the affected areas. Pipe racks will be designed and used to elevate abovegrade ERH components to allow unobstructed rail traffic through the treatment area.

4.2 ET-DSP™ SYSTEM DESIGN

ERH via ET-DSP™ involves heating soil in the saturated and unsaturated zones by passing current between electrodes buried in the soil, with simultaneous injection of water through the electrodes in order to maintain conductivity and to transfer heat by convection. The coupling of electrical resistance heating with heat transfer by convection greatly enhances the efficiency and uniformity of heating by ERH technology. Volatilization of contaminants will be achieved as the temperature in the UCRS approaches the boiling point of TCE [87˚C (189˚F)] or the boiling point of the TCE/water mixture at depth below the potentiometric surface of the RGA (see Figure 18). Simultaneous vapor extraction from vapor recovery wells in the heated volume will remove the contaminants from the subsurface.

Water injection through the ET-DSP™ electrode - a patented feature of the technology - helps to maintain a conductive pathway through the soil. Consequently, resistive or “cold” zones within the treatment area will be minimized. The injected makeup water supplied to electrodes also will be vaporized creating a guided steam front that strips contaminants away and carries them to extraction wells.

In a typical application of ET-DSP™, electrodes are placed strategically in and around the contaminated zone. The pattern of electrodes is designed so conventional three-phase power can be used to heat the soil. The distance between electrodes and their location is determined from the heat transfer mechanisms associated with vapor extraction, electrical heating, and fluid movement in the contaminated zone. Soil vapor extraction wells and vacuum monitoring piezometers are located within the contaminated soil. If there is inadequate vacuum at the piezometers, they will be converted to vapor extraction wells. The position of the extraction wells and piezometers relative to the electrodes is determined so that heat transfer by convection within the porous soil is maximized, thus minimizing heat loss and increasing the uniformity of the temperature distribution. Consideration of the heat transfer mechanisms results in the most effective heating process, hence, a more successful remediation project.

A Phase I numerical simulation, performed by Mc² considered site specific soil properties and groundwater flow conditions in order to model the subsurface heating response. Phase I numerical simulation results were scaled for use in the Phase IIa design in accordance with calculations in Appendix C. Results obtained from this simulation were critical in the design of the electrode and extraction well layout.

4.2.1 Numerical Simulation Results

Mc² uses numerical simulation programs and numerical models to design the optimum implementation of ET-DSP™ for site-specific requirements. The simulation was performed using a commercial numerical simulation program mathematically customized for electro-thermal processes. Average water saturation, hydraulic conductivity, contaminant concentration, porosity data, and electrical resistivity as a function of temperature represent a portion of the data that were used for the input data set.

The numerical simulation for the C-400 area consisted of a two part model of the southeast treatment area of the C-400 facility to predict heating in the RGA and UCRS. The groundwater is largely stagnant in the UCRS,[4] so the Phase IIa treatment zone was modeled with no groundwater flow.

Soil properties that are important to the subsurface design include soil conductivity (electrical resistance), coefficient of thermal expansion, hydraulic conductivity, permeability, average water saturation, contaminant concentration, and site hydrogeology. Section 3.2.4 and Appendix E contain additional related discussion. Design parameters for the southwest and east treatment areas were extrapolated from the UCRS model on the southeast treatment area. Input data for the simulation are based on previously determined site characteristics for the area surrounding the C-400 facility; therefore, the numerical simulation provides results based on this process knowledge of subsurface lithology. Site specific soil samples were tested for resistivity. Results of these soil resistivity tests are included in Appendix E. The spacing of the electrodes is based on the most resistive area. Installation and operational parameters for individual subsurface components determined for the southeast treatment area of the UCRS from the model were adapted to the source area delineations for the other two treatment areas.

The results of the scaled numerical simulation, plan view layout of ET-DSP™ system components, and coordinates for placement of ERH subsurface components are presented in Appendix C.

4.2.2 Stacked Electrodes

A stacked electrode system, proven on similar remediation projects, has been engineered to safely and effectively heat the vertical and horizontal extent of the C-400 treatment area. Electrode boreholes are drilled 12 inch in diameter to house the 10 inch diameter electrodes. The ET-DSP™ electrodes will be stacked to allow for electrical current to be directed between the electrodes and through the vertical extent

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[4] The depth-averaged hydraulic conductivity of the UCRS is approximately 1E-06. Assuming a vertical hydraulic gradient of 1 (common in the UCRS at PGDP) and a porosity of 40%, the average groundwater flow velocity (vertical) is approximately 3 ft/year.

of the contaminated soil. The benefits of this approach are a uniform temperature distribution throughout the entire vertical profile of the soil, the ability to create preferential flow paths for steam, and the ability to reduce the number of boreholes required for installation. Ultimately the ET-DSP™ stacked electrode will allow heating to be controlled in discrete (vertical and horizontal) intervals of the subsurface. Stacking of electrodes in a single borehole is covered by the ET-DSP™ patent.

Specific Phase IIa design information is provided in Appendix C.

4.2.3 Power Delivery System

The PDSs developed and manufactured by Mc^2 are computer-controlled to deliver the proper amount of energy to individual electrodes, both laterally and vertically, to compensate for differences in the electrical resistance of the geological units. The ET-DSP™ PDSs utilize a system of time distributed control (TDC) and inter phase synchronization (IPS) to control the power to the electrodes. This process effectively controls the amount and timing of power sent to individual electrodes. For example, should it become apparent that certain electrodes are in electrically resistive zones that may result in cold spots, the power to the electrodes in these areas will be increased to facilitate uniform heating. This method controls the electrical sine wave of three-phase power to the millisecond such that each phase can be individually manipulated. Additionally, the PDSs are equipped with multiple voltage taps to further control the power. In areas that prove to be more resistive than anticipated, the voltage applied to an electrode is increased to overcome the higher resistivity. Injection of an electrolytic solution (i.e., salt water) also is a measure that can be taken to overcome areas with higher than anticipated resistivity. The salt water is injected into electrodes that have low power due to higher than anticipated resistivity. Salt water injection is not planned for Phase IIa, although this still could be used if necessary.

In addition, when using TDC in combination with IPS, the phases of power applied to individual electrodes may be alternated to reorient the flow of current among the electrodes as required (ET-DSP™ patent) to uniformly heat up the entire target area. This system is fully programmable and can be accessed via the internet for remote monitoring and control.

Appendix C provides specific PDS design information for Phase IIa. Appendix C offers two PDS options, depending on unit availability: (A) 7 24-electrode PDS units or (B) 2 60-electrode and 2 24-electrode PDS units. This revision is based on the use of Option B.

4.2.4 Temperature Monitoring

Subsurface temperature is one of the most important operational parameters monitored during an ERH remediation project. Temperature data need to be current and comprehensive. In order to meet this data need, a distribution of digital Temperature Acquisition Module (digiTAM) sensors will be deployed in the subsurface at the C-400 Building area. DigiTAMs are digital temperature sensing devices composed of long strings with imbedded sensors placed at approximately 3-ft intervals. The sensors are individually addressed and are accurate to 0.5°C. Each temperature sensor transmits to the ET-DSP™ site computer every thirty minutes with a current temperature reading. ERH system operators utilize this temperature feedback to optimize system settings. Temperature sensors will be installed downgradient of the treatment areas in some locations.

Subsurface temperature levels will be summarized daily for each sensor, each string, each 3 ft layer, and cross-section. The digiTAMs will be distributed throughout the treatment area. Strategic placement of digiTAMs provides an accurate representation of actual temperatures in the subsurface; visualization of temperature field is accomplished using IsoTemp maps. The IsoTemp maps will be generated as frequently as required to monitor progress.

Additional discussion of temperature monitoring for Phase IIa is provided in Appendix C.

4.3 LIQUID AND SOIL VAPOR EXTRACTION SYSTEMS

4.3.1 Soil Vapor Extraction System

Soil vapor extraction (SVE) is an established technology that is commonly used to extract volatile compounds from unsaturated soil. During SVE, a vacuum is applied to an extraction well to lower the vapor pressure in the vicinity of the well. Lowering the pressure at the extraction well induces an advective flow of soil vapors and flow of groundwater containing VOCs (primarily TCE and its breakdown products) from regions of higher pressure to the extraction point. This process enhances the volatilization of contaminants from within grains of soil and promotes the diffusion of sorbed contaminants into soil pores where they can be swept and extracted along with soil vapors. In addition to using SVE in the heated zones to recover volatilized VOCs and steam, it also will be used to remediate VOCs from shallow unsaturated soil in the UCRS (15 ft bgs and shallower). Although SVE and ERH systems normally will be operated concurrently, the SVE system will have the flexibility to be operated with ERH turned off.

A positive displacement blower will exert a vacuum on the SVE wellheads and air in the subsurface will flow toward the SVE well screens. As ERH progresses, volatilized VOC and steam vapors will be generated. These vapors will rise into the vadose zone and will be swept toward the SVE wells by vacuum flow to the SVE well screens. Because of the permeability difference between the RGA and lower UCRS, a portion of the vapors may preferentially travel laterally at the RGA/UCRS interface. The extraction of groundwater from the bottom of the vapor extraction wells will promote transport of these vapors held up at the RGA/UCRS interface to vapor extraction wells. The design of groundwater extraction wells connects the well casing to the vapor recovery system. By positioning the intake of the groundwater pump at the bottom of the well and connecting the well bore to the vapor recovery system, both DNAPL and entrained bubbles will be effectively captured. As subsurface heating progresses, however, it is expected that the permeability of the UCRS will increase and the permeability difference between the UCRS and RGA will become less pronounced.

As ERH progresses and vapor production increases, the vapors will continue to move into the SVE well screens because of the low pressure created by the SVE vacuum blower. As the remediation approaches maximum vapor generation, the vapor flow rate will increase, but not enough to significantly increase the wells' capture zones.

The design extraction rate of 1,000 scfm of air from the subsurface is based on the number and types of extraction wells needed for Phase IIa. The Phase IIa design requires 22 multiphase extraction (X) wells at 20 scfm, 11 vapor extraction (VX) wells at 20 scfm, and 39 upper vapor extraction wells (XE) at 8 scfm. In the relatively tight vadose zone soil beneath the treatment area, relatively high vacuum (15 in Hg at the wellhead) will be required to maintain capture radii of 15 ft (4.57 m) at each SVE well. Each vapor extraction wellhead will have a temperature and pressure gauge to indicate the temperature of the extracted vapor and the vacuum at each well. A pitot tube also will be installed near the wellhead to allow vapor flow to be measured and a vapor sample to be obtained. Note that obtaining a vapor sample will require use of a vacuum pump to overcome the vacuum in the vapor line.

For ERH remediation, vapor recovery piping will be sized for the combined flow of soil vapors and steam; thus, the piping will be relatively larger than in standard SVE systems that do not have steam traveling in them. All piping, fittings, and valves used will be made of materials that are appropriate for the chemicals and temperatures that will be experienced. Header piping also will be heat resistant and constructed of carbon steel or other compatible material.

SVE will be performed using a positive displacement blower. Positive displacement blowers are best suited for applications of high vacuum and relatively high flow. A vapor treatment system, described further in Section 4.5, will be manifolded to the soil vapor extraction system. Sampling ports and gauges will be supplied to measure vacuum, flow, and temperature at the blower inlet and pressure and temperature at the blower outlet. Vacuum and temperature will be measured by gauge, while flow is measured by a compilation of manometers, capsuhelic gauges, inline flow tubes, and venturi flow meters at various locations throughout the ERH and aboveground treatment system.

Specific design and operating information for Phase IIa SVE is provided in Section 4.5 and Appendix C.

4.3.2 Liquid Extraction System

Groundwater will be extracted via submersible pneumatic pumps during system operations to maintain hydraulic control in the treatment area and to aid in the transport of VOCs to the extraction wells. These pumps will be manufactured to withstand the expected subsurface operating temperatures. It is estimated that 3 to 5 gpm of groundwater will be extracted from each well. A typical groundwater extraction well design is shown in drawing C7DC40000C007 in Appendix C. At each groundwater extraction wellhead, a sample port will allow groundwater samples to be obtained. Specifications for the submersible pumps are included in Appendix C.

4.4 LIQUID TREATMENT SYSTEM

Liquids will be extracted from the subsurface in two ways. First, groundwater will be entrained as droplets in the vapor stream and removed in the liquid/vapor separators. Second, groundwater will be removed by submersible pumps installed in extraction wells strategically placed in the treatment zones.

The groundwater treatment system is designed to remove VOCs from entrained droplets in the vapor stream, from extracted groundwater, and from condensed steam from the vapor conditioning system. The liquid treatment system is designed to treat up to 80 gpm of water at concentrations up to 1,100 mg/L of TCE. The system is designed to accommodate water at temperatures up to 203°F (95°C), but also can effectively remove VOCs from groundwater at ambient temperatures [approximately 55°F (13°C)] extracted before the soil is heated. Treatment unit materials of construction/fabrication will be compatible with the conditions expected in the liquids treatment system. The liquid treatment system also is designed to maintain technetium-99 (Tc-99) levels below discharge criteria as described in Section 3.2.8. A portion of the treated water will be pumped back to the electrode field for injection through the electrodes. The balance will be discharged to the existing KPDES Outfall 001.

The liquid treatment system consists of a separator to remove TCE DNAPL from the liquid stream, an air stripper to remove the dissolved TCE from the liquid stream, ion exchange beds to remove Tc-99, a liquid-phase carbon adsorber that will remove residual TCE from the liquid stream, and ancillary equipment (pumps, tanks, etc.). The individual components of the liquid treatment system are described in the following sections and are shown on process flow diagrams P7DC40000A001, P7DC40000A14, P7DC40000A15, and P7DC40000A016 in Appendix F. Data sheets are provided for process equipment in Appendix G.

4.4.1 Feed Surge Tank

All groundwater extracted from the treatment area enters the Feed Surge Tank (T-100) prior to entering the liquid treatment system. This allows groundwater to be continually collected during maintenance and unplanned downtime. T-100 also allows for continued operations of the liquid treatment system in the event of interruptions of groundwater extraction due to unforeseen circumstances. As a precaution, overflow from T-100 will be routed to sump P-908 in the event that the high level switch in T-100 fails. The sump water level will be monitored by a level switch and interlock to shut down water flow to the treatment system in the event that water in the sump reaches a high-high level.

Additional bag filters (F-107A/B & F-108A/B) are installed downstream of the Feed Surge Tank pump (P-100) to reduce the introduction of solids in the liquid treatment system equipment.

4.4.2 DNAPL Separator

Extracted groundwater from the well field and water containing TCE from the vapor treatment system will be processed through the DNAPL separator. The water from the vapor treatment system includes condensate and any entrained droplets of water from the vapor extraction system. The DNAPL separator (T-105) is a plate-type separator designed to remove small droplets of pure TCE from the groundwater. Although the settling velocity for DNAPL is greater at higher temperatures, the separator is designed to treat 80 gpm of water at typical groundwater temperatures. Higher settling velocities improve the performance of gravity separators. Since the separator will work better with hot groundwater, the DNAPL separator will be designed with enough separation area for normal groundwater temperatures of 10°C to 16°C (50°F to 60°F). During normal operation at elevated temperatures, the separator will give better removal of small droplets of DNAPL. The materials of construction will be designed to resist hot groundwater and TCE DNAPL.

The DNAPL will collect in the bottom of the separator and be pumped to a dedicated 7,000-gal storage tank (T-107). DNAPL will be pumped from the storage tank (T-107) to an appropriate container for disposition. Conductivity switches will be used to monitor the level of DNAPL in the bottom of the separator and control the DNAPL transfer pump (P-108). The DNAPL pump will be designed to accommodate the high vapor pressure of hot DNAPL. The water flows through the separator plate pack and overflows into a small compartment from which it will be directed into the air stripper feed tank.

4.4.3 Air Stripping System

Dissolved-phase TCE contaminated groundwater exiting the DNAPL separator combined with water from the vapor treatment system will enter the 1,500-gal air stripper feed tank (T-106). From the air stripper feed tank, contaminated groundwater will be pumped into the air stripper (A-102). A level controller will adjust the feed to the air stripper to maintain the air stripper feed tank level within an operational bandwidth. The controller will be tuned to react slowly to changes in the feed tank level to avoid drastic changes in feed rates to the air stripper. A high-high level alarm and switch will provide protection against overflow of the air stripper feed tank by shutting down the pneumatic extraction well pumps.

The air stripper equipment will consist of two packed towers. Air for stripping will be provided by a designated air stripper blower. Stripping air flow rate will be set at approximately 300 scfm by a flow control valve. The air stripper is designed to reduce the concentration of TCE in the groundwater from 1,100 mg/L to less than 5 mg/L at 16°C (60°F) at a flow rate of 80 gpm. Once ERH raises the temperature of the groundwater to the operational range, liquid effluent TCE concentrations from the air stripper are expected to be less that 0.5 mg/L. Treated groundwater will be collected in the internal sump of the air stripper prior to overflowing into a collection tank (T-103). TCE-laden off-gas from the air stripper system will be processed through the vapor treatment system prior to discharge to the atmosphere.

4.4.4 Groundwater Filtration and Destination

Prior to groundwater entering the air stripper system, it will pass through a set of bag filters (F-102A/B) for removal of solids that may be present in the extracted groundwater to minimize fouling or plugging of the air stripper. The bag filters will be configured so that one set can be taken offline for bag change-outs, while the other set remains online. The treated groundwater from tank T-103 then will pass through another set of filters (F-101A/B) to further remove solids that may have precipitated at the air stripper to minimize fouling or plugging of the liquid-phase carbon.

Following air stripping and the second set of bag filters, a portion of the liquid flow (treated groundwater and condensate) will be returned to the electrode field for reinjection through the electrodes. The air stripper effluent to be injected at the electrodes initially may contain as much a 5 ppm TCE, based on anticipated initial TCE concentrations and temperature of the influent to the air stripper. As the soil and groundwater are heated, the air stripping process is expected to become more efficient, and the effluent used for injection into the electrodes is expected to have a much lower TCE concentration than 5 ppm. In addition, as the cleanup progresses, TCE concentration in groundwater extracted from the upper RGA is expected to drop, resulting in lower TCE concentration in the air stripper influent, which will result in lower effluent TCE concentration. In addition to the air stripping, this water will be treated in two ion exchange adsorbers (C-102 A/B) to remove Tc-99. A portion of this effluent will be directed to a hot groundwater tank (T-104) for reinjection at the electrodes. A level controller will control the flow of treated water to T-104 to maintain an appropriate level in the tank. The flow rate of water to the electrodes will be controlled by the water circulation systems in the field. The remaining liquid flow continues downstream where it will pass through the air stripper effluent cooler (E-104). This heat exchanger will lower the temperature of the treated water to a temperature acceptable for introduction into the liquid-phase carbon adsorbers.

4.4.5 Ion Exchange System

Based on previous investigations, Tc-99 levels in the groundwater treated through the liquid treatment system are expected to be below the 900 pCi/L target limit established by DOE for KPDES Outfall 001 discharges. As a precaution, liquid processed through the treatment system will be treated for Tc-99 prior to discharge. An ion exchange system (C-102A/B) will be placed upstream of the air stripper effluent cooler (E-104). The ion exchange system will include two ion exchange beds containing Purolite A-520-E anion exchange resin. This resin was selected for Tc-99 removal in groundwater based on proven effectiveness at the site. The ion exchange beds for removal of Tc-99 are included in the design to protect against discharge exceedances and to minimize potential Tc-99 contamination of the carbon beds downstream so that spent carbon will not have to be managed as a mixed waste. During operation of the groundwater treatment system, the effluent of the lead ion exchange vessel will be monitored for Tc-99. When the lead vessel is determined to be spent, the valves on the ion exchange beds will be changed to put the lag bed online as the lead bed and the exhausted resin will be replaced with fresh resin. A detailed monitoring plan specifying the criteria for determining when an ion exchange vessel is exhausted will be included as part of the O&M Plan.

4.4.6 Liquid-Phase Carbon Polishing System

The water entering the liquid treatment system may contain high levels of dissolved-phase TCE. As a result, the effluent from the air stripper may not always meet the KPDES Outfall 001 discharge criteria for VOCs. The residual VOCs will be removed from the air stripper effluent in a liquid-phase carbon adsorber system (C-103A/B). The system will contain two adsorber beds each containing liquid-phase activated carbon. The adsorbers will act as a polishing system prior to discharge of the liquid to the KPDES Outfall 001.

4.5 VAPOR TREATMENT SYSTEM

The soil vapor produced from ERH operations will be a mixture of air, water vapor, and high levels of VOCs (primarily TCE). The vapor produced by ERH operations will be as hot as 203°F, and the composition of the gas may be quite variable. Materials used in the vapor treatment system will be rated for the expected temperature encountered. The total vapor stream will consist of a maximum of 1,300 scfm with up to 2,500 lb/hr of steam generated by ERH soil heating operations. The soil vapor also may contain up to 20,000 ppmv of TCE and other VOCs. The average concentration is expected to be much less, but the heterogeneous distribution of DNAPL in the soil may result in very high peak concentrations of VOCs.

The vapor treatment system is designed to process the maximum peak loading of the steam and VOCs produced by ERH operations. This system will include an SVE and vapor condensation train designed to remove the vapor from the vapor extraction wells, a steam regenerated carbon adsorption system to remove TCE and other VOCs, and a vapor polishing system that uses vapor-phase carbon and permanganate impregnated zeolite to remove VOCs remaining in the soil vapor. VOCs will be recovered as an organic solvent stream from the decanter of the steam regenerated carbon adsorption system. The individual components of the vapor treatment system are described in the following sections and shown on the process flow diagrams P7DC40000A001, P7DC40000A14, P7DC40000A15, and P7DC40000A016 in Appendix F. Data sheets are provided for each piece of equipment in Appendix G.

4.5.1 SVE and Vapor Conditioning Train

The SVE and vapor conditioning train will consist of vapor/liquid separators (T-101 and T-102), heat exchangers (E-101 and E-102), and positive displacement vacuum blowers (B-101A and B-101B). These components will be designed to pull the soil vapor from the extraction wells, separate gas from liquid, and then cool and condense the vapor in order to separate the steam/water. This series of operations will produce a dehumidified vapor that is an acceptable feed to the steam regenerated carbon adsorption system.

The two positive displacement blowers (B-101A and B-101B) will be fitted with variable frequency drives that will control extraction pressure and flow for the well field. The blowers will operate in parallel and will be able to provide 100% of the desired flow rate (1,000 scfm) and 15 inches of mercury vacuum at the wellheads. A 300 scfm flow rate will be supplied from the air stripper's dedicated blower and it will be introduced into the system after the blowers and prior to entering the glycol chiller (E-102). B-101A also can be manually started and powered from the emergency power generator in the event of a loss of main power. Although B-101A will operate at a reduced flow rate and vacuum, it still will provide enough capacity to avoid fugitive emissions in the well field.

Under normal operation, the soil vapor will be drawn through two liquid/vapor separators and a heat exchanger by the blowers B-101A and B-101B. The soil vapor from the SVE system may contain entrained groundwater. The first vapor/liquid separator (T-101) will remove entrained water droplets from the soil vapor (primarily water that has condensed on the walls of the piping in the vapor collection manifold). The separator is a vertical knockout pot fitted with a mesh demister pad for liquid separation. Any condensate or water that collects in the separators will drain into the condensate sump tank (T-108);

from there it will be pumped to the liquid treatment system. A high level switch will alarm if the water level increases to the point where it might reenter the gas stream.

After T-101, the vapor then will pass through a finned-tube heat exchanger (E-101) using cooling water to lower the temperature so that most of the steam from the vapor condenses. The cooling water will be cooled through the cooling tower (Y-901). This heat exchanger will be oversized for the average steam flow rate in the vapor so that it can handle surges in steam flow and still produce an acceptable outlet vapor temperature.

The heat exchanger (E-101) will produce condensate. Under high condensate loading, some of the condensate can be reentrained into soil vapor. A second vapor/liquid separator (T-102) will remove liquid in the vapor that condenses in the heat exchanger. The T-102 separator will be similar in construction to the T-101 separator. A high-high level switch will alarm if the water level increases to the point where it might become reentrained in the gas stream. If the fault condition persists, the high-high switch also will shut down the operating blowers (B-101A or B-101B), thereby shutting down the vapor treatment system and alerting operations personnel. Condensate from both vapor/liquid separators and E-101 will drain into the condensate sump tank (T-108) and then will be pumped to the liquid treatment system. Downtime associated with the vapor treatment system will be kept to a minimum; however, if the vapor treatment system will be off-line for an extended period (i.e., more than an hour), power to the electrodes also may be shut off to prevent the potential release of fugitive emissions. The ERH operator will determine shutdown requirements based on the existing electrode field conditions such as the amount of energy in the formation, subsurface temperatures/pressures, and projected downtime of the vapor treatment system.

After the T-102 Separator, the vapor goes to the positive displacement vacuum blowers. The blowers boost the pressure of the vapors from roughly 18 inches of mercury vacuum at the separator outlet to just above atmospheric pressure. The vapor then will flow through a second, finned-tube heat exchanger (E-102) to lower the temperature. This heat exchanger also will be a finned-tube unit that uses chilled glycol from a refrigerated chiller system (Y-902) to remove heat from the gas. The vapor then will enter the steam regenerated carbon adsorption system. Vapor flow set point will be adjusted and optimized in the field.

4.5.2 Steam Regenerated Carbon Adsorption System

The steam regenerated carbon adsorption system will be a multiple bed system with two carbon beds operating in series at any given time, while the additional bed(s) is being regenerated or in standby mode. The system will include a minimum of three carbon adsorber vessels, a condenser, a decanting tank, aqueous and nonaqueous-phase pumping tanks with pumps constructed of 316L stainless steel or equivalent compatible material. The liquid in the aqueous phase pumping tank will be pumped back to the liquid treatment system, and the nonaqueous-phase TCE will be pumped to the liquid TCE storage tank (T-107). The unit will be equipped with automatic valves, instrumentation, and controls for fully automated operation.

Static, deep bed, steam-regenerated activated carbon beds will be used for TCE recovery. Regeneration is accomplished by injecting steam through the carbon bed for desorbing the adsorbed TCE. The steam and TCE vapors are condensed and cooled in a water-cooled heat exchanger and collected in a decanting tank where the steam condensate and TCE form separate phases, which are automatically separated and gravity-drained into respective pumping tanks. A steam boiler unit will provide the steam necessary for carbon regeneration cycles.

During the design process, other technologies for removing/destroying VOCs in the extracted vapor were evaluated. Steam regenerated carbon adsorption was selected for Phase IIa because it offers adequate operating flexibility and capacity and is a fully automated system. In addition, it has moderate capital and operating costs and is not a proprietary system, thus allowing maintenance without vendor involvement. Economic analysis led to the decision to use on-site rather than off-site regeneration. Based on Phase I results, cryogenic adsorption was not selected because of its operating complexity, capital and operating costs, and its proprietary nature that results in higher maintenance costs.

4.5.3 Vapor-Phase Polishing System

The vapor-phase polishing system will consist of two sets of adsorbers (C-106A/B and C-107A/B) that will remove low levels of VOCs from the effluent air of the steam regenerated carbon adsorber system. Each polishing unit adsorber system will be fabricated with piping and valves needed to allow either set to operate as the lead or lag unit. The first set will contain two activated carbon adsorbers to remove residual VOCs (primarily TCE and degradation products) from the air.

The second set will be similar to the first system except that it will contain two adsorbers (C-107A/B) filled with a zeolite media that is impregnated with potassium permanganate. These adsorbers are designed to remove vinyl chloride that may be present in the effluent from the steam-regenerated carbon adsorber system. Vinyl chloride does not adsorb well onto carbon. The permanganate in the zeolite medium will oxidize the vinyl chloride and will keep the effluent levels below the discharge criteria of 20 ppmv. Each adsorber will contain zeolite and will be mounted with piping and valves needed to allow either adsorber to operate as the lead or lag unit. If the vinyl chloride levels in the steam-regenerated carbon adsorber unit discharge meet discharge criteria, the zeolite beds will not be needed. The zeolite beds will be provided with a vapor bypass line and will be used only to the extent they are needed. If the zeolite in the lead adsorber becomes exhausted and vinyl chloride breaks through the bed, the polishing adsorber will be switched to the lead position and the media in the exhausted bed will be replaced.

Off-gas from the vapor-phase polishing system will be discharged to the atmosphere through a 20-ft tall by 8-inch diameter stack. Off-gas emissions will be monitored by a photoacoustic analyzer. The analyzer will communicate with a control system to shut down the vapor extraction and treatment system, including the vacuum blowers, and notify operations personnel in the event of an exceedance of discharge criteria. The set point at the stack that will cause the vapor extraction and treatment system to shut down is 20 ppmv of any VOC of concern. This is based on the air dispersion modeling results presented in the C-400 Phase IIa RAWP that currently is under development. The air dispersion modeling results indicate that a stack concentration of 20 ppmv results in property boundary concentrations that are significantly lower than the off-site limits; thus, the system will be shut down before emissions reach the quantities that will exceed acceptable risk levels.

Interlocks associated with off gas monitoring will not be disabled while the system is in operation unless appropriate alternate monitoring is in place. A weekly calibration check is required for the photoacoustic analyzer, which requires the unit to be placed off-line and the associated interlock disabled. When this occurs, the process display will clearly indicate that the interlock is disabled and/or the system is operating in manual mode.

Alternate monitoring will include the use of a portable photoacoustic analyzer, which has the same detection limit and accuracy as the stationary unit. The portable photoacoustic analyzer will have the capability to clearly communicate via visual and/or audible alarms if discharge criteria have been exceeded. This equipment will be monitored on-site at all times by trained personnel during any operational period when the off gas monitoring interlock is disabled. The operator will have the capability to manually shut down the aboveground treatment systems via a single stand-by shutdown switch. The manual shut down process will terminate these operations within a time frame comparable to an automatic system interlock shutdown of these systems. If a shutdown is required, power to the electrodes also may be shut off if the aboveground treatment system will be off-line for an extended period. The ERH operator will determine shutdown requirements based on the electrode field conditions such as the amount of energy in the formation, subsurface temperatures, and projected downtime of the aboveground treatment system.

4.6 SYSTEM CONTROLS

The ERH system and the vapor/liquid treatment system will have separate computer-based control systems. While both systems will have numerous automatic shutdowns designed to protect personnel and equipment and to prevent release of contaminants to the environment, there are no direct interlocks between the two systems. The system operators will make necessary changes to the ERH system or the vapor/liquid treatment system should problems occur in the other unit.

On-site and remote operators can turn the ERH PDSs on or off, reset some PDS alarms, and record temperatures throughout the ERH system. Voltage changes can be made by ramping up or down over set time intervals. Alarms are provided for transformer over-temperature, for current trips and faults, and for excessive voltage and current levels. The ERH system can be shutdown by anyone on-site by depressing one of the emergency shutdown devices; however, only authorized operations personnel can energize the electrode well field.

Remote operators can determine if system faults or undesirable operating conditions exist in the ERH system. Most faults and undesirable operating conditions can be corrected remotely by altering operating parameters or can be tolerated until the next scheduled site visit. More severe ERH system faults may require system shutdown and operator call out.

The controls for the vapor/liquid treatment system provide remote operators with indications of system faults/upsets at one of 4 distinct levels (auto dialer channels). Auto dialer Channel 1 indicates a total vapor/liquid system shutdown. Channel 2 indicates shutdown of the well field extraction. Channel 3 indicates high priority alarms for conditions which, if not corrected, could lead to a shutdown of the well field extraction or total vapor/liquid treatment system. Channel 4 indicates low priority alarms for undesirable conditions, which should be corrected as soon as practical. The remote operator will evaluate the auto dialer call out and respond as necessary. If stack emissions exceed discharge limits as measured by the photoacoustic analyzer, automatic system shutdown will be initiated regardless of any upset level reported to the remote operator by the auto dialer.

The operation of the aboveground treatment system does not have to be adjusted due to minor problems/adjustments with the ERH system; however, the ERH system operator and the aboveground treatment system operator will communicate all operational equipment changes/requirements to each other via the Front Line Manager or designee.

Alarms associated with the ERH and the vapor/liquid treatment systems (along with actions required in response to the alarm) are identified in Table 5. Additional alarms will be identified and implemented in the hazard and operability study, the O&M Plan, and standard operating procedures. Refer to process and instrumentation drawings P7DC40000A005, P7DC40000A008-1, P7DC40000A008-2, P7DC40000A009, P7DC40000A010, P7DC40000A011-1, P7DC40000A011-2, P7DC40000A012, P7DC40000A013, P7DC40000A023, in Appendix F, for additional information regarding alarms and interlocks.

In the event of a sitewide power failure, all ERH and vapor/liquid treatment system equipment will shut down, and the auto dialer will contact operations staff using an emergency battery backup for power. Stack emissions monitoring will continue uninterrupted operation using a separate battery backup (uninterruptible power supply) until the emergency generator is operational, which typically occurs within a matter of minutes.

Table 5. System Alarms and Actions

Condition	Alarm	Action/System Response
Sitewide Power Failure		
Sitewide power failure	1. ERH PDS alarms 2. Autodialer calls out	1. All equipment stops running. 2. Operations staff is notified. 3. Vapor recovery at reduced rates with backup power started manually. 4. ERH can be restarted remotely after brief (20 minute) power failures; site visit required following extended power failures.
ERH PDS –Major Fault		
• Power failure • PDS transformer overheating • Tap switch out of position • Loss of power to controls	ERH PDS alarms	1. ERH PDS shuts down. 2. Vapor and groundwater treatment and recovery systems remain operational. 3. Alarm cleared remotely or by site visit.
ERH PDS – Minor Fault		
• Loss of an electrical phase • Unbalanced electrical phases	No alarms	1. All systems remain operational. 2. Remote or on-site adjustments made.
Electrode Field		
• Electrode malfunction or failure • Electrode overheating • Loss of temperature in subsurface	No alarms	1. All systems remain operational. 2. Perform on-site inspection.
Vapor Recovery Heat Exchanger and Chiller System		
• Cooling tower fault (fan failure, low water flow) • Low temp chiller fault (compressor fault, low coolant flow) • High-high liquid level in Vapor/Liquid separators	1. Vapor/treatment alarms 2. Autodialer calls out	1. Vapor recovery blowers are shut down. 2. Recovery/treatment operations staff is notified. 3. ERH control is alerted and operator shuts down power to electrodes. 4. Groundwater recovery/treatment shut down. 5. Site visit required to restart systems, if fault does not autocorrect.
Vapor Recovery Blowers		
• Blower failure	1. Vapor recovery blower alarms 2. Autodialer calls out	1. Vapor treatment and ERH systems remain operational with only 1 blower in operation, which operates at reduced flow rate and vacuum. 2. Operations staff is notified. 3. Site visit required to restart blower if fault does not autocorrect.

Table 5. System Alarms and Actions (Continued)

Vapor Recovery System (Both Blowers Fail)		
• Power failure • Blower failure	1. Vapor Recovery blower alarms 2. Autodialer calls out	1. Treatment/recovery system (groundwater and vapor) shuts down. Operations staff is notified. 2. ERH control is alerted and operator shuts down power to electrodes. 3. Site visit required to restart systems if blower fault does not autocorrect.
Vapor Treatment System		
High VOC in outlet of steam regenerated carbon vapor treatment skids	Autodialer calls out	1. All systems remain operational. Treatment/recovery operations staff is notified. 2. Treatment/recovery operators trouble shoot system to identify problem.
High VOC outlet of lead or primary carbon/zeolite beds	Problem seen in routine system monitoring	1. All systems remain operational; operator switches secondary adsorber to primary adsorption duty. 2. GAC/zeolite vessel change-out may be required.
High VOC outlet at stack of vapor treatment system	1. Systems alarm 2. Autodialer calls out	1. Vapor/groundwater extraction and treatment systems are shutdown. 2. Treatment/recovery operators trouble shoot system to identify problem.
Groundwater Treatment System		
High-high level in DNAPL separator	1. Systems alarm 2. Autodialer calls out	1. Groundwater recovery pumps shut down. Vapor recovery/treatment and ERH systems remain operational. 2. Site visit required to troubleshoot and correct.
High-high level in TCE storage tank	1. Systems alarm 2. Autodialer calls out	1. All inlet pumps to TCE storage tanks are shut down. Vapor recovery/treatment and ERH systems remain operational. 2. Site visit required to troubleshoot and correct.
High-high level in air stripper feed tank	1. Systems alarm 2. Autodialer calls out	1. Groundwater recovery pumps shut down. Vapor recovery/treatment and ERH systems remain operational. 2. Site visit required to troubleshoot and correct.

Table 5. System Alarms and Actions (Continued)

Groundwater Treatment System (Continued)		
• High conductivity in TCE transfer line • High/low level in hot groundwater tank • Low reinjection water flow • High/low level in air stripper effluent tank • Low level in air stripper feed tank • High temperature in water discharge • High low air flow from air stripper	1. Systems alarm 2. Autodialer calls out	1. Treatment system operator notified. Vapor recovery/treatment and ERH systems remain operational 2. Site visit required to troubleshoot and correct.

ERH = electrical resistance heating
GAC = granular activated carbon
PDS = power delivery system

The vapor/liquid treatment system has a backup diesel generator to supply electrical power to allow operation of the vapor treatment system at a reduced flow rate. The generator has the capacity to run the vapor treatment system using vacuum blower B-101A. The groundwater recovery/treatment system, water injection, and ERH will remain off-line. Vacuum blower B-101A and the vapor treatment system can be started once the diesel generator is operating and the automatic transfer switch has shifted to the emergency power supply. This will allow for 400-500 scfm of vapor recovery from the soil, which should minimize the potential for diffusion of VOCs from the heated soil. When normal power is restored, the vapor/liquid treatment system and ERH will be reset to normal configuration and restarted. Following brief power outages, the ERH system can be restarted remotely. Following an extended power failure, a site visit will be required to reset and restart the control computer and resume ERH operation.

4.7 COMMON UTILITIES

Several utilities will be common to the ERH system, the vapor treatment system, and the liquid treatment system. The utilities include compressed air, potable water, electricity, telecommunications, and back-up power. The individual components for Phase IIa are described in the following sections and are shown on process flow diagrams P7DC40000A001, P7DC40000A014, P7DC40000A015, and P7DC40000A016 in Appendix F. Data sheets are provided for each piece of equipment in Appendix G.

4.7.1 Process Utilities

Process utilities include compressed air, cooling water, and chilled glycol/water. Compressed air will be generated by a compressor (Z-901). The compressed air will be used to operate instruments, control valves, groundwater extraction pumps, and other equipment, as needed. Cooling water will be supplied from a packaged cooling tower. This packaged system will include the cooling tower/fan and the recirculation pumps as well as all controls. Makeup water for the cooling tower will come from the plant potable water line, and cooling tower blowdown is routed to T-100 and the liquid treatment system. Chilled glycol/water will be supplied by a packaged chiller system, Y-902. The packaged system will include the compressor/chiller, condenser, and glycol tank and all controls.

4.7.2 Potable Water

Potable water will be supplied through an existing plant potable water supply line in the vicinity of the C-400 facility. The potable water will be used as make-up water in the cooling tower system that supplies cool water to heat exchangers, blowers, and a condenser in the steam-regenerated carbon adsorption system located in the liquid and vapor treatment systems. Potable water also will be required by the steam generator for carbon regeneration cycles. Appendix C provides supplemental information with regard to Phase IIa. A backflow preventer will be installed on the potable water supply line to protect the potable water supply from contamination.

4.7.3 Electricity

Electricity will be required by the ERH system, vapor treatment system, and liquid treatment system. Adequate electrical supply will be provided from the existing PGDP electrical grid. Appendix C provides supplemental information with regard to Phase IIa.

4.7.4 Telecommunications

Telecommunications will be provided to the site to allow for system monitoring. Various phases of each treatment system will have the capability to be monitored remotely. The treatment systems also will notify operations personnel via an automatic telephone dialing system if predetermined alarm conditions occur. Appendix C provides supplemental information with regard to Phase IIa.

4.7.5 Back-up Electrical Power

Back-up electrical power will be provided to the site via an emergency power generator. The generator will be diesel powered and capable of generating 800 kW/1,000 kVA of 480 v three-phase power and will have a sound-attenuation enclosure. In the event of an electrical outage to the treatment systems, the emergency power generator would supply electricity for critical operational equipment such as the auxiliary vacuum blower, cooling tower, glycol chiller, steam regenerated carbon adsorption system, backup air compressor, various system pumps, and the photoacoustic analyzer. The generator has an integral double contained fuel tank. The generator will be maintained to support 24-hour operation.

5. EQUIPMENT AND SITE PREPARATIONS

Site preparation may include, but is not limited to, the installation of asphalt or concrete pads on which some of the aboveground ERH components and some of the aboveground treatment systems can be placed. Site preparation also will include the staging of an operations trailer and removal of infrastructure to allow flexibility in the placement of remedial system components. Site preparations will be performed in accordance with the specifications listed in Appendix G.

Equipment for the ERH system, vapor treatment system, and liquid treatment system will be staged at various locations around the C-400 facility. A plan view of the Phase IIa ERH system layout is included in Appendix C. A plan view for equipment related to the aboveground treatment systems is shown in drawing M7DC40000A002 in Appendix F.

6. SAMPLING AND MONITORING

6.1 BASELINE AND POST-OPERATIONAL SAMPLING

Baseline and post-operational soil and groundwater sampling will be conducted to support analysis of the efficiency of removal of TCE by the ERH remedial action. The difference in baseline and post-operational TCE (and TCE degradation products) levels is intended to be a direct measure of the percent reduction of TCE. The primary means to assess the removal efficiency of TCE in the UCRS and upper RGA will be a comparison of soil sampling results.[5] Soil samples will be collected during installation of planned electrode, digiTAM, and/or extraction well borings as well as from locations between electrodes and extraction wells in order to characterize soil TCE levels prior to the operation of the ERH electrodes. Colocated samples, collected from adjacent soil borings, will characterize residual TCE levels subsequent to the operation of the ERH electrodes.

Groundwater extraction wells will be used to characterize TCE levels in groundwater before and after operation of the ERH system in an effort to observe the effect of Phase IIa operations on groundwater TCE concentrations in the upper RGA. Baseline and post-operational sampling and analysis requirements are addressed in more detail in the C-400 Phase IIa RAWP that currently is under development.

6.2 OPERATIONAL SAMPLING AND MONITORING

During operations, trained personnel will monitor the treatment system to assess the performance and progress of the remedial action activities. Systems have been designed to accommodate operational sampling and monitoring for parameters such as the following:

- Vapor recovery and treatment rates;
- Subsurface temperatures throughout the treatment zone;
- Pressure at vapor extraction well heads;
- Water injection rate through electrodes and groundwater extraction rate;
- Vapor phase concentrations from vapor extraction wells; and
- Effluent contaminant concentration to demonstrate compliance with permit requirements.

These parameters will assist in controlling system operations and in determining when the criteria for ceasing IRA system operations have been met. A sampling and analysis plan for use during system operations will be included in the O&M Plan (see Section 7).

Operational sampling and monitoring are discussed in greater detail in the C-400 Phase IIa RAWP that currently is under development.

6.2.1 Sampling for VOC Recovery

The recovery of contaminants from the subsurface will be evaluated by monitoring the extracted vapor, condensed liquid, and groundwater extraction streams for flow rates and VOC (primarily TCE and its

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[5] Collection and analysis of colocated soil samples allows direct comparison of baseline and postoperational TCE levels in a discrete volume. Groundwater samples are more indicative of average conditions in the vicinity of the sample pump. Numerous soil samples will be collected and analyzed to evaluate both location-specific and area-wide trends in TCE removal efficiency.

breakdown products) concentrations. The extracted vapor stream represents the influent to the vapor phase treatment unit, while the liquid condensate and groundwater extraction streams represent the influent to the liquids treatment system. Monitoring of these influent streams will help to determine when the performance criteria for ceasing operations have been achieved. Vapor sampling ports will be installed at each vapor extraction wellhead.

6.2.2 Monitoring of Vapor Treatment Discharge

Measurements of total VOC (primarily TCE and it breakdown products) concentrations at the discharge stack of the vapor treatment system will be performed using photoacoustic analyzers (specification provided in Appendix G). The analyzer will communicate with a control system to shut down the vapor treatment system and notify operations personnel in the event of a discharge criteria exceedance. Discharge criteria were discussed previously in Section 3 of this report.

6.2.3 Subsurface Temperature and Pressure Monitoring

The ERH heating process is monitored by process controllers connected to thermocouple arrays known as digiTAMs. DigiTAM arrays will be installed vertically in the subsurface in the ERH treatment area and are discussed further in Section 4. Vacuum monitoring will be performed throughout the treatment area to ensure radius of capture.

6.3 ANALYTICAL REQUIREMENTS

During the ERH project, a fixed-base laboratory will perform analyses for water and soil samples and for confirmation samples, as necessary. Some parameters, such as vapor-phase VOCs, groundwater pH, oxidation-reduction potential, dissolved oxygen, temperature, and specific conductivity, will be measured in the field using appropriate field instruments. Additional details concerning the analytical requirements will be presented in the O&M Plan and C-400 Phase IIa RAWP that currently is under development.

7. OPERATIONS AND MAINTENANCE

An O&M Plan will be revised and submitted for review and comment as a secondary document. Per Section XV of the Federal Facility Agreement for the Paducah Gaseous Diffusion Plant, the schedule for submitting the O&M Plan is addressed in the C-400 Phase IIa RAWP that currently is under development.

8. QUALITY ASSURANCE/QUALITY CONTROL AND DATA MANAGEMENT

Project-specific quality assurance/quality control and data management requirements are addressed in the C-400 Phase IIa RAWP that currently is under development.

9. HEALTH AND SAFETY

A project-specific health and safety plan is addressed in the C-400 Phase IIa RAWP that currently is under development.

10. WASTE MANAGEMENT

A project-specific waste management plan is addressed in the C-400 Phase IIa RAWP that currently is under development.

11. ENVIRONMENTAL COMPLIANCE

Project-specific environmental compliance requirements are addressed in the C-400 Phase IIa RAWP that currently is under development.

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APPENDIX A

EVALUATION OF THE REMEDIAL DESIGN SUPPORT INVESTIGATION RESULTS AND DERIVATION OF THE DNAPL VOLUME ESTIMATE FOR THE AREA SOUTH OF THE C-400 CLEANING BUILDING

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EVALUATION OF RDSI RESULTS FOR THE AREA SOUTH OF THE C-400 CLEANING BUILDING

INTRODUCTION

The C-400 Remedial Design Support Investigation (RDSI) provides qualitative volatile organic compound (VOC) analysis for 51 membrane interface probe (MIP) boring locations (28 shallow borings and 33 deep borings[1]) in the area south of the C-400 Building (Figure A.1). These data and trichloroethene (TCE) analyses of area soil and groundwater samples from the Waste Area Grouping 6 Remedial Investigation (WAG 6 RI) are a basis for revising the estimate of VOCs, primarily TCE, as dense nonaqueous-phase liquid (DNAPL) in the subsurface. The following calculation package documents the assumptions and calculations.

MEMBRANE INTERFACE PROBE DATA

The RDSI MIP data include qualitative measure (as microvolts *or* μV) of VOC levels for three common gas chromatograph detectors as follows:

- Electron capture detector (ECD),
- Flame ionization detector (FID), and
- Photoionization detector (PID).

Quantitative measures of soil conductivity (as milliSiemens/meter *or* mS/M) are also collected in the MIP data. Unlike laboratory gas chromatographs, the MIP system does not include a chromatographic column. Instead, the tubing which circulates the carrier gas from the MIP probe to the gas chromatograph detectors serves as a diffusion column. The rigid structure and stable temperature and pressure environment of the chromatographic column of laboratory gas chromatographs are critical aspects influencing the instrument's analytical resolution. Variation in temperature and pressure exposure for the MIP probe and its carrier gas system prevent a laboratory-type calibration of the detector responses to VOCs; however, the magnitude of response of the detectors to VOCs remains consistent, and the MIP data provide a measure of VOC level with depth. The MIP system makes measurements 20 times per ft. with the operator advancing the MIP probe, as governed by procedure; the MIP dataset includes measurements for all three gas chromatograph detectors and for soil conductivity on 0.05 ft intervals.

Each detector has a unique response. The ECD is the most sensitive of the three detectors to VOCs, particularly chlorinated compounds. In many of the MIP boring locations, VOC/TCE concentrations exceeded the linear range of calibration and saturated the ECD. The FID is relatively insensitive to VOCs in the low-to-intermediate concentration ranges. Review of the data revealed that the PID response (which was optimized by the selection of a detector with ionization energy similar to TCE) provided the best measurement of VOCs/TCE across the concentration range encountered in the borings and, thus, constitutes the best data set for evaluating TCE levels in the subsurface. Figure A.2 presents the log for all three gas chromatograph detectors for MIP-16, a MIP boring in an area with high TCE levels. Attachment A1 summarizes the PID logs for all MIP borings of the RDSI. The enclosed CD presents additional logs of the ECD and FID data of each MIP borehole.

[1] All 51 MIP borings characterized the uppermost 55 ft of soils. The 33 deep MIP borings characterized soils down into the top of the McNairy Formation, found at depths of 87 to 98 ft.

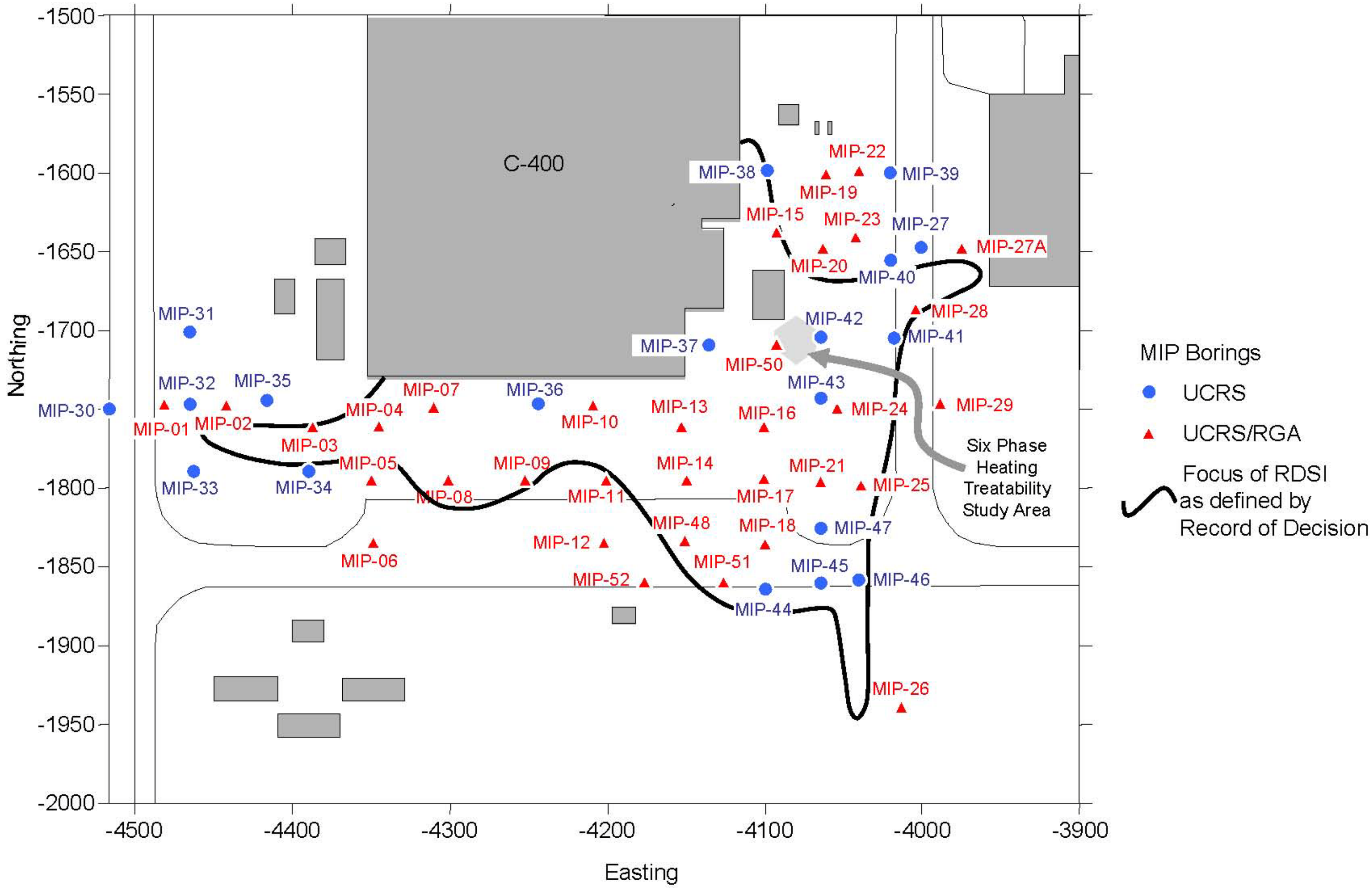

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Figure A.1. Remedial Design Support Investigation MIP Boring Locations

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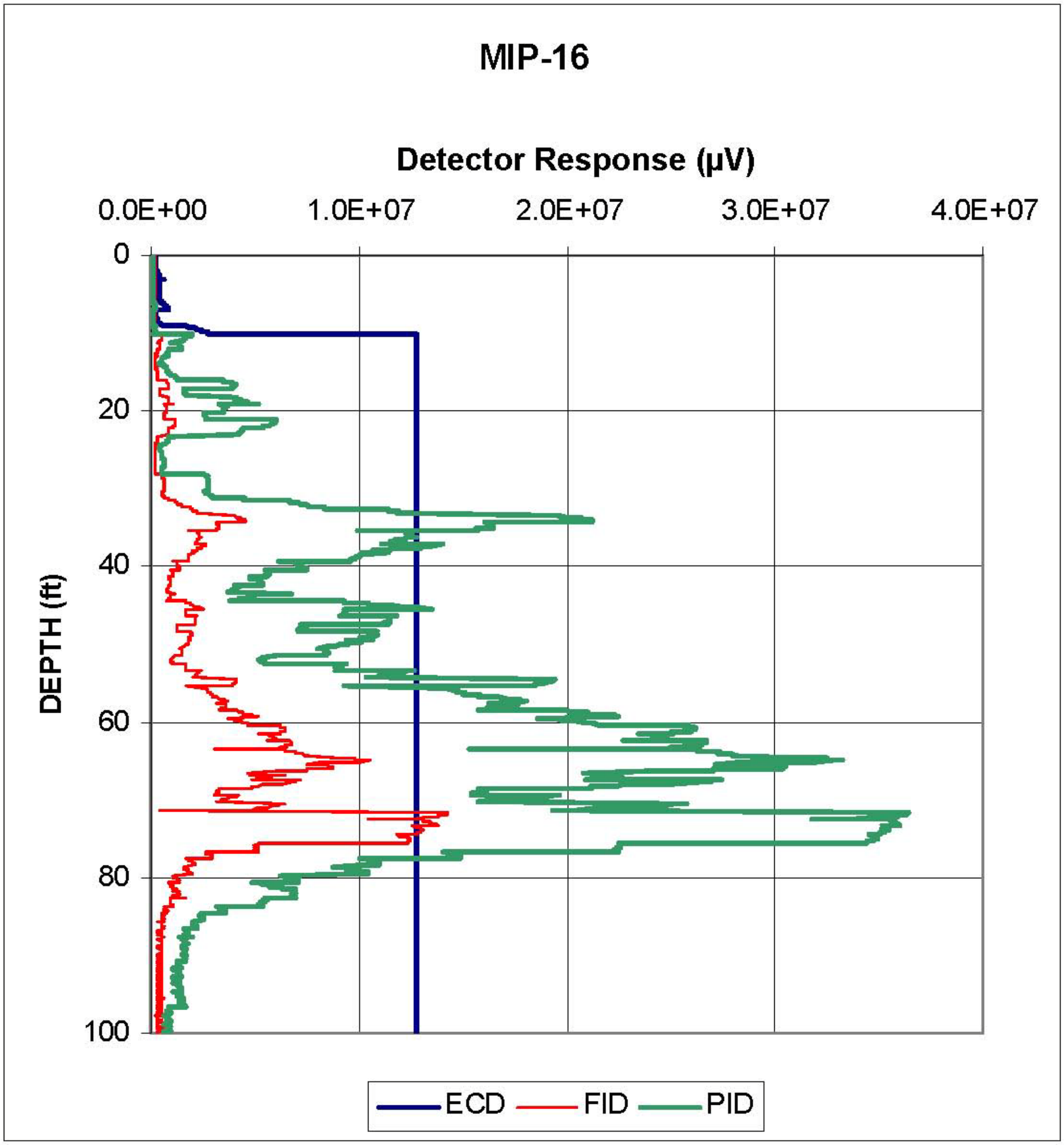

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Figure A.2. Comparison of Detector Response for Boring MIP-16

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TCE ANALYTICAL DATA

The WAG 6 RI is the primary source of TCE analyses of soil and groundwater in the area to the south of the C-400 Cleaning Building. In this area, the WAG 6 RI data are derived from the following:

- 43 borings for soil samples (providing analyses for 223 discrete soil samples of the Upper Continental Deposits, 4 samples of the Lower Continental Deposits, and 2 samples of the McNairy Formation),
- Water samples of the Lower Continental Deposits/Regional Gravel Aquifer (RGA) from three borings (analyses for 22 discrete samples), and
- Water samples of two RGA monitoring wells and one Upper Continental Deposits/Upper Continental Recharge System (UCRS) monitoring well.

Attachment A2 presents the WAG 6 RI TCE analyses for soil and groundwater from the area of the RDSI. The WAG 6 RI data form the basis for the pre-RDSI conceptual site model.

DNAPL ZONE DELINEATION

This assessment of DNAPL volume focuses on the depth interval of 20 to 100 ft below ground surface (bgs). The selected remedy, electrical resistance heating (ERH), requires a minimum 10 ft separation between the ERH electrodes and any buried, electrically-conductive utilities. Numerous utilities underlie the south C-400 area, commonly at depths of 10 ft bgs and shallower; thus, the top of the interval of interest is 20 to 25 ft bgs.

Electrical conductivity logs define the base of the Lower Continental Deposits for the MIP borings.[2] Finer-grained sediments of the McNairy Formation have a much higher electrical conductivity than the coarser sands and gravels of the Lower Continental Deposits. The range of depth of the base of the Lower Continental Deposits in the areas of the RDSI is 87 to 98 ft (with an average of 94 ft) for the 33 deep MIP borings and eight previous soil borings that have penetrated the underlying McNairy Formation in the south C-400 area. The PID trends for each of the MIP borings demonstrate that the DNAPL zones are limited to the Upper and Lower Continental Deposits (and the uppermost one ft of the underlying McNairy Formation in the area of a DNAPL pool at the base of the Lower Continental Deposits). No DNAPL zones extend to depths of 100 ft bgs.

The ERH electrodes that will be used for the C-400 remedial action consist of individual 10 ft-long electrode units. Each of the electrode units heats a soil column thickness of approximately 16 ft. The electrode units are spaced as required to address the thickness of the subsurface interval to be treated.

For convenience, the PID data were assessed over five ft depth intervals because the five ft resolution, approximately 1/3 of the minimum thickness that will be treated by the ERH electrodes, provides sufficient resolution to optimize the electrode design. Comparison of contours of maximum and average MIP values of the PID data over five ft depth intervals demonstrated that the two methods of summarizing the data yielded similar definition of areas with high PID values. The maximum PID values were selected to provide assurance that minor DNAPL intervals would not be ignored.

[2] The conductivity probe malfunctioned in boring MIP-06. A gamma ray log for boring MIP-06 defined the base of the Lower Continental Deposits.

Attachment A3 provides the contoured maps of maximum PID values over five ft depth intervals, generated by the contouring and gridding software SURFER™. Twelve extrapolation techniques were available for contouring as follows:

- Inverse distance to a power
- Kriging
- Local polynomial
- Minimum curvature
- Modified Shepards method
- Moving average
- Natural neighbor
- Nearest neighbor
- Polynomial regression
- Radial bias
- Triangle with liner
- Interpretation

The PID data for the 90 to 95 ft depth interval[3] served to compare contoured maps developed with SURFER™, a standard computer code for contouring and 3-D surface mapping, using the eleven extrapolation techniques (Attachment A4) versus a conceptual model of DNAPL distribution. PID trends identified a DNAPL pool that should be continuous within this depth interval between the adjacent borings MIP-14 and MIP-17 (see later text under DNAPL Pool for a discussion of this conceptual model). Several extrapolation techniques contoured a continuous area of high PID value that included the adjacent borings. Of these, the natural neighbor technique best correlated the adjacent borings without influence of values from unrelated distal borings and was selected as the extrapolation technique for contouring all of the data sets of maximum PID values over the five ft depth intervals.

Record of Decision (ROD) *for Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2050&D2/R2, issued August 2005, delineates the area of investigation for the RDSI based, in part, on the WAG 6 RI interpretation of the area of TCE soil contamination[4] exceeding 10^4 µg/kg. Additional analysis of the RDSI data determines the PID criteria used to define DNAPL zones. This approach assumes the PID responses to DNAPL are unique (i.e., characteristically high PID responses). It is anticipated that PID response to DNAPL in the vadose zone (where soil, water, and air are present and the air will dilute the volatilized DNAPL) will be significantly different than PID response to DNAPL in the saturated zone (where only soil and water are present and no air is present to dilute the volatilized DNAPL).

To evaluate the MIP data, the maximum PID values over five ft depths were contoured in intervals of 1×10^6 µV. Review of the PID contour maps for the vadose zone (20 ft to 25 ft and 25 ft to 30 ft depth intervals[5]) indicates that contours of 2×10^6 µV (PID) delineate discrete areas that are consistent with the conceptual model of DNAPL occurrence from the WAG 6 RI data; thus 2×10^6 µV (PID) was used to define areas of DNAPL in the vadose zone. Similarly, a review of the PID contour maps for the saturated zone (five ft depth intervals between 30 ft and 100 ft bgs) indicates the contour interval of 9×10^6 µV (PID) defines discrete areas that correlate to conceptual models of DNAPL occurrence; thus, 9×10^6 µV (PID) was used to define areas of DNAPL in the saturated zone. This criterion closely matched the experience of representatives of the MIP contractor for the RDSI (Columbia Technologies) who reported that areas with TCE contamination in the saturated zone characterized as 10^7 µV by the PID commonly were DNAPL zones.

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[3] The 90 ft to 95 ft depth interval represented the most likely interval to contain a significant DNAPL pool, being at the base of the RGA, and thus represented the best applicable conceptual model.

[4] The definition of the investigation area for the RDSI also was based on the area of TCE groundwater contamination exceeding 10^5 µg/L, as defined by *Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1857&D2 (Volume 4), issued August 2001.

[5] The water level record for monitoring well MW157 (completed in the UCRS) provides a representative record of the depth of the water table in the south C-400 area. For the 10 year period of 1991 through 2001, the average depth to water in MW157 is 31 ft bgs. The water level typically ranges between 29 and 32 ft bgs. MW157 is screened from 30 to 35 ft bgs. Thus, these measurements are a true measure of the depth to the water table (i.e., not influenced by the vertical hydraulic gradient of the UCRS).

The definition of the DNAPL areas thus defined proved consistent between adjacent five ft depth intervals. To simplify the design of the ERH electrode array, the DNAPL areas defined by contours of the maximum PID values over five ft intervals have been composited over the following 20 ft depth intervals:

- 20 to 40 ft bgs,
- 40 to 60 ft bgs,
- 60 to 80 ft bgs, and
- 80 to 100 ft bgs.

Figures A.3 through A.6 present the composite maps of DNAPL areas over these intervals. Note: the definition of DNAPL zones for the 20 ft to 40 ft bgs and 40 ft to 60 ft bgs depth intervals[6] incorporates the TCE analyses of soil samples from the WAG 6 RI data (few WAG 6 soil analyses are available for deeper intervals). The combined data define two prominent DNAPL zones (MIP-04 Area and MIP-16 Area) and five other areas of lesser TCE-contaminated soil (West Storm Sewer, SWMU 11 TCE Leak Site, TCE Tank Area, 400-016 Area, and 400-163 Area) that were included in the DNAPL volume calculation.

DNAPL CONCEPTUAL MODELS

The calculation of DNAPL volume is predicated upon conceptual models of DNAPL occurrence. Primary conceptual models used in these calculations include the following:

- Zones of vertical migration of DNAPL,
- Perched pools of DNAPL above barriers that limit further vertical migration, and
- Zones of residual contamination associated with previous DNAPL occurrence.

Numerous field studies outside PGDP (e.g., Canadian Forces Base Borden, Ontario; Cape Canaveral Launch Complex 34, Florida; and Hill Air Force Base Operational Units 1 and 2, Utah) have demonstrated that DNAPL distribution is complex and readily transitions spatially among the above settings. These conceptual models are intended to characterize the general nature of DNAPL zones, consistent with interpretations of general DNAPL occurrence at PGDP.

Zone of Vertical Migration: Where DNAPL is present in sufficient mass, DNAPL will overcome capillary forces and migrate vertically into the underlying soil. The capillary resistance to DNAPL flow is less within zones previously saturated by DNAPL, therefore DNAPL typically migrates downward through a limited number of "fingers." The vertical migration continues until the DNAPL mass is reduced by sorption such that capillary force prevents further vertical migration or a physical barrier to migration is encountered and DNAPL pools above the barrier.

[6] The C-400 ROD indirectly identified TCE levels in soil of 10 mg/kg and greater as indicative of a DNAPL area to be treated. As a conservative approach, this calculation package includes several areas with TCE levels in soil of 1 mg/kg and greater.

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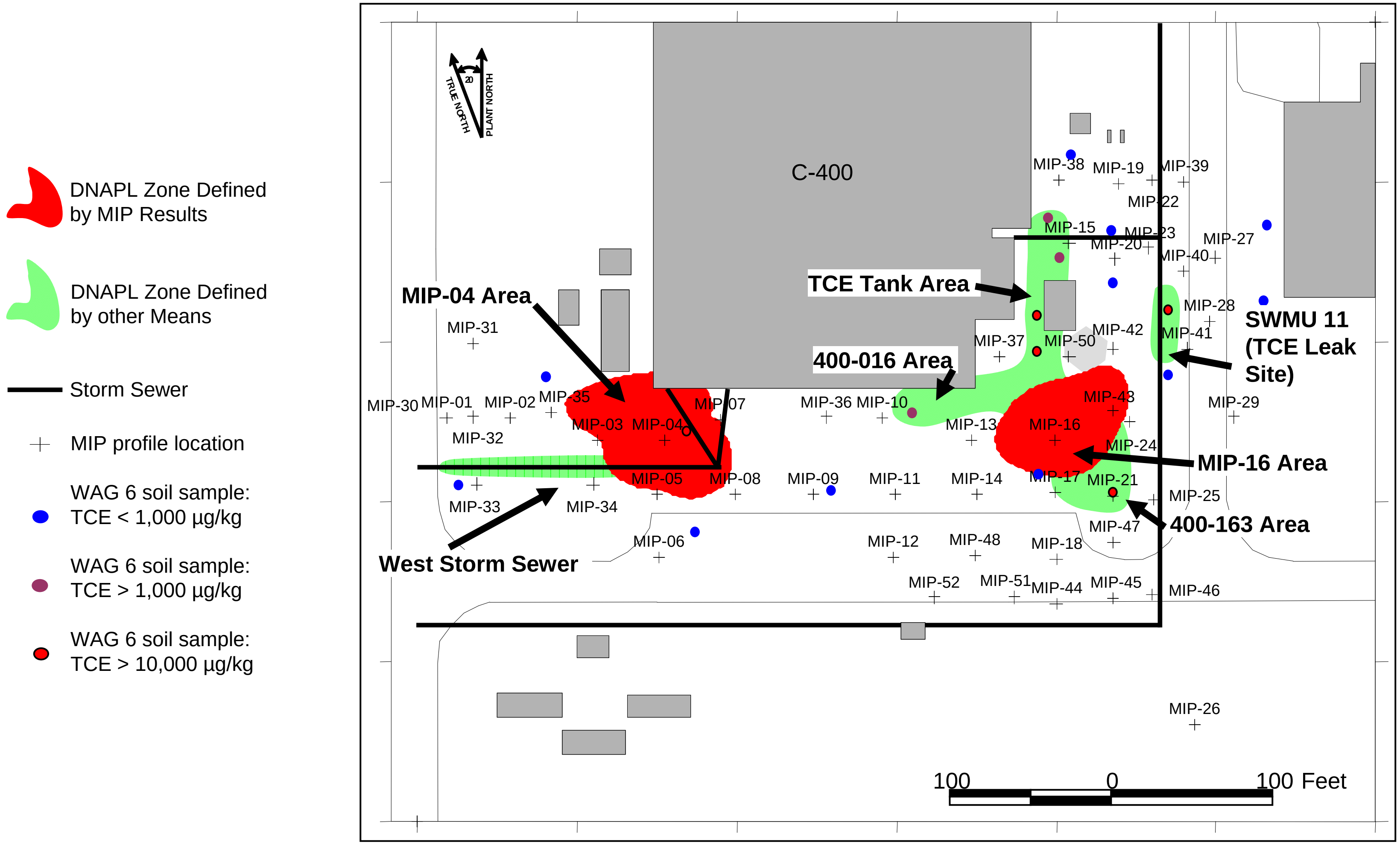

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Figure A.3. Composite Map of DNAPL Areas, 20-40 ft Depth Interval

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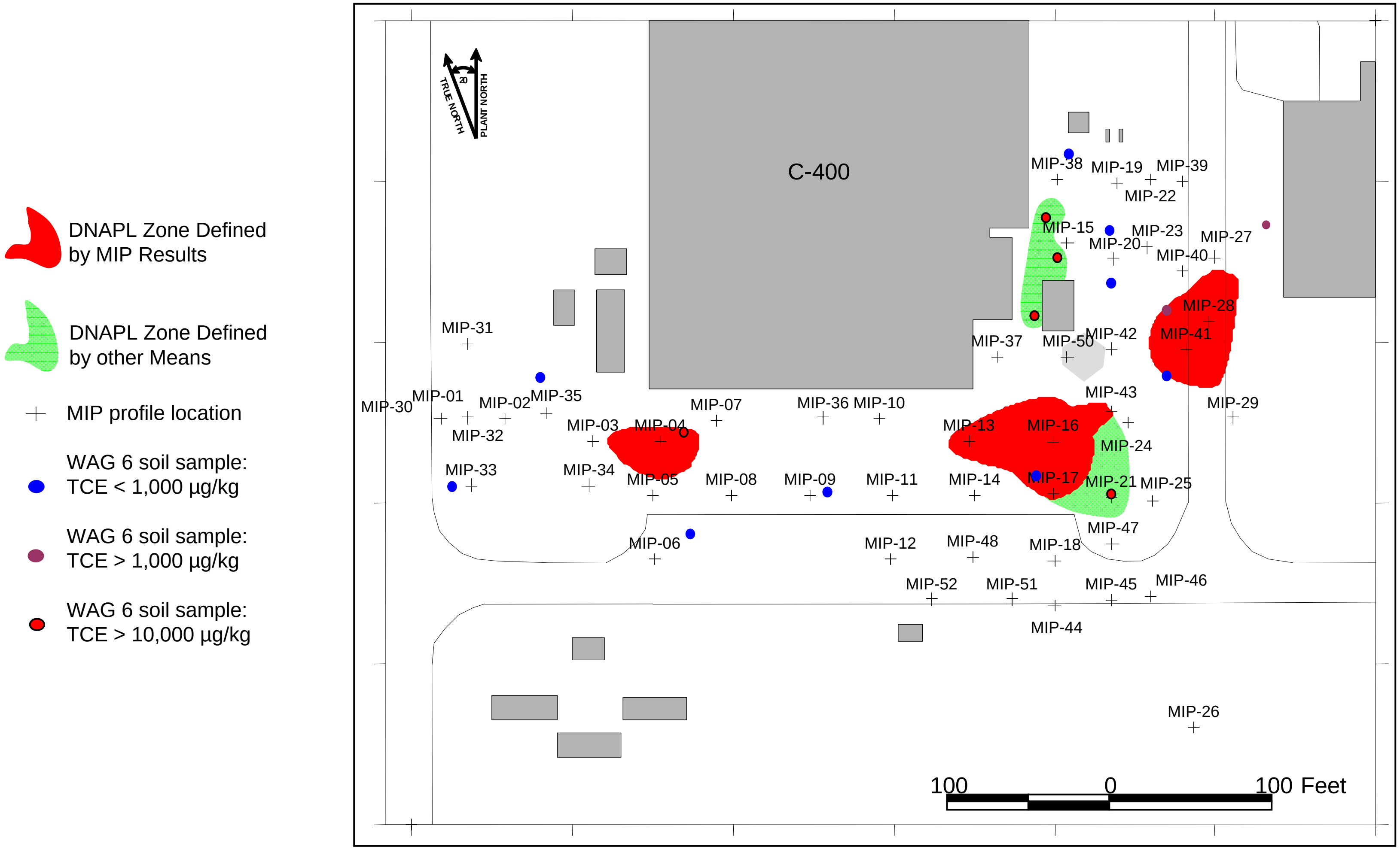

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Figure A.4. Composite Map of DNAPL Areas, 40-60 ft Depth Interval

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DNAPL Zone Defined by MIP Results

MIP profile location

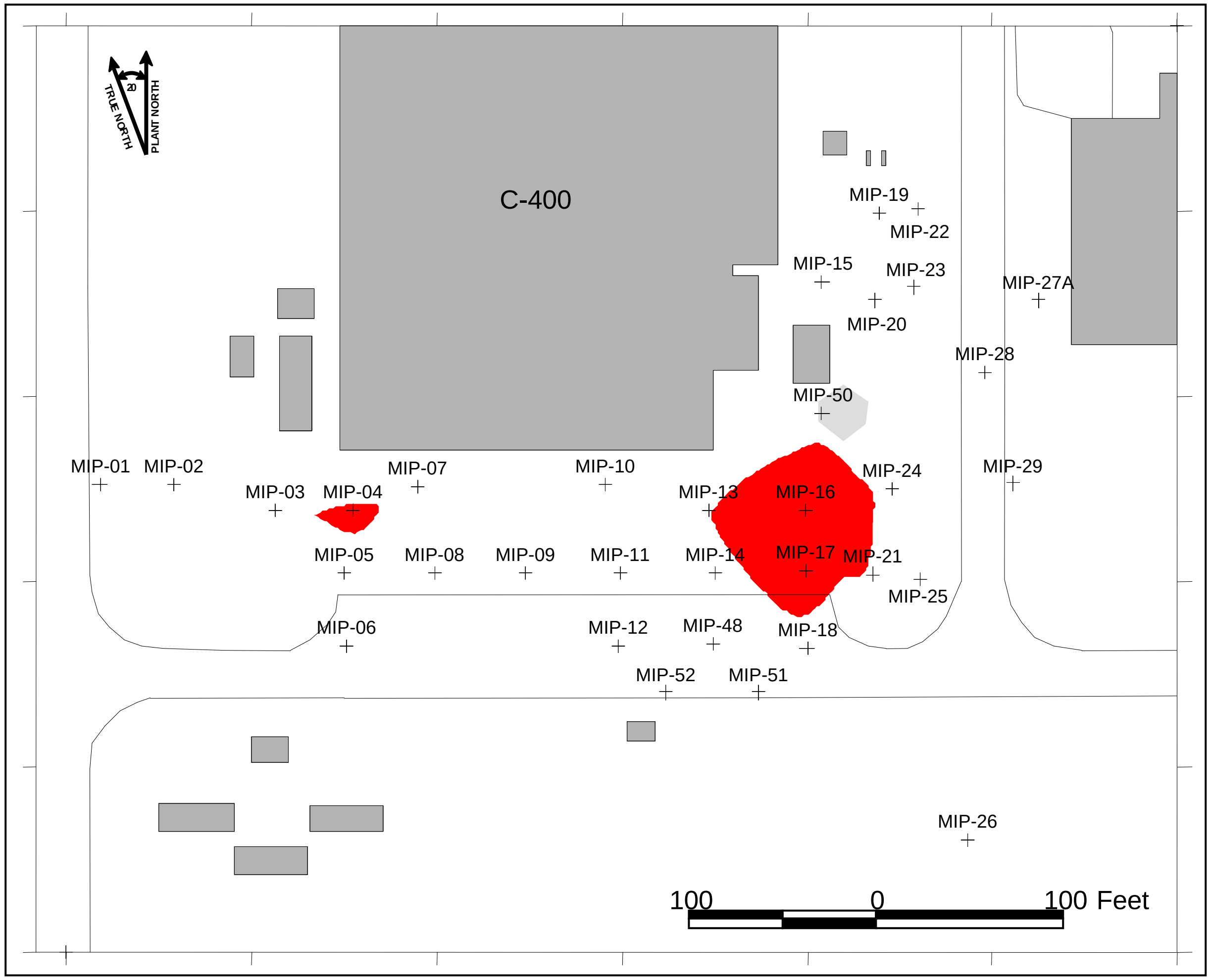

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Figure A.5. Composite Map of DNAPL Areas, 60-80 ft Depth Interval

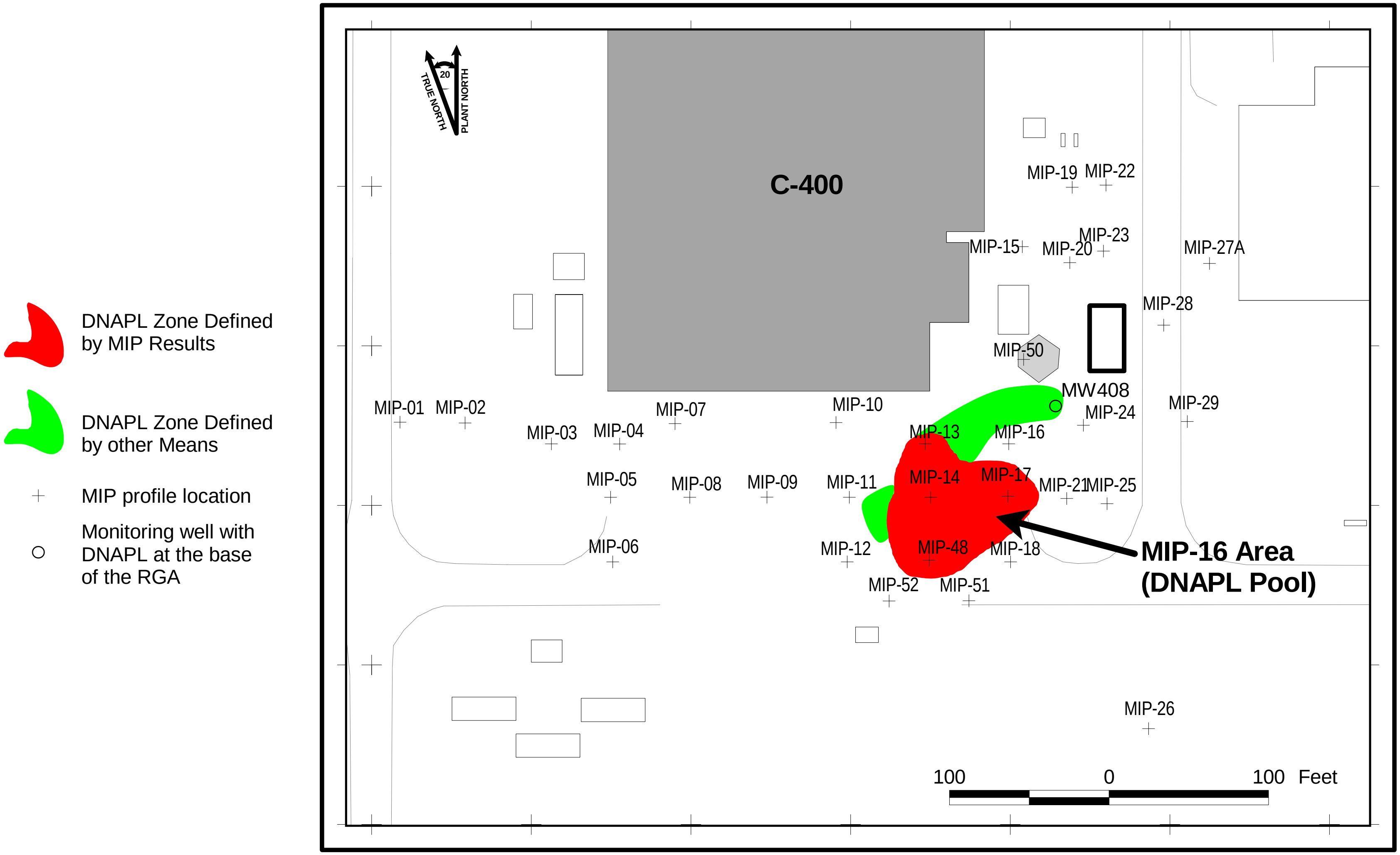

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Figure A.6. Composite Map of DNAPL Areas, 80-100 ft Depth Interval

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For the purposes of these volume calculations, the zone of vertical migration of DNAPL is approximated as a vertical cylinder with a central core of greater DNAPL saturation[7] surrounded by a zone of lesser DNAPL saturation, the DNAPL saturation diminishing with distance from the core.

DNAPL saturation never will reach 100% because some groundwater always will be trapped in the pore spaces. Typical DNAPL saturation of a porous soil in the core of the zone of vertical migration, after the migration has ceased, is approximately 30%.[8] In coarse sand and gravel, typical of the Lower Continental Deposits, DNAPL saturation of the core may be significantly less.

The spatial distribution of TCE within the DNAPL zones of the Upper Continental Deposits (primarily a silt) at the PGDP suggests TCE concentrations decline logarithmically with distance from the core (see *Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, volume 4, DOE/OR/07-1857&D2, issued August 2001). The calculations assume that the minimum DNAPL saturation at the outer perimeter of the DNAPL zone, as defined by MIP and WAG 6 RI data, is one percent (1%) (approximately 2,550,000 µg/kg[9]); see Attachment A5 for the conversion of DNAPL saturation to TCE level in soil. The average DNAPL saturation is a function of the radius of the vertical cylinder used to approximate the zone of vertical migration.[10]

DNAPL Pool: At the land surface of the original spill site or at subsurface barriers to vertical DNAPL migration, a small DNAPL spill will pool. With additional spill, the pool will expand laterally until the pool encounters a pathway for downward migration and the DNAPL mass is sufficient to overcome capillary barriers to migration.

The primary area of interest for assessing a DNAPL pool is the base of the Lower Continental Deposits. Here, sand and gravel unconformably rest upon the fine sand and silt and clay units of the McNairy Formation. This contact represents a barrier to downward migration of DNAPL due to the significantly smaller grain/pore sizes. Previous assessment (*Final Report, Feasibility of Using Enhanced Recovery Techniques at the C-400 Site for DNAPL Removal*, issued April 1995) determined that a DNAPL pool of approximately 5.4 ft thickness would be required for downward migration below the base of the Lower Continental Deposits. Thus, low areas in the base of the Lower Continental Deposits (where DNAPL could accumulate) in the vicinity of a zone of vertical DNAPL migration are of singular interest as a trap for a DNAPL pool.

The electrical conductivity and gamma ray logs of 33 of the MIP borings provide significant additional detail to the database of the depth of the Lower Continental Deposits/McNairy Formation contact. Only eight previous soil borings have penetrated the contact in the area of the RDSI. Figure A.7 illustrates the depth of the base of the Lower Continental Deposits, contoured to define a structural trap (closed low spot) in the area of a significant DNAPL pool as defined by PID profiles of several adjacent MIP borings.

The DNAPL saturation of a pool is poorly constrained. At a minimum, the DNAPL saturation must be at least equal to the saturation expected in the core of vertical migration. For the Lower Continental

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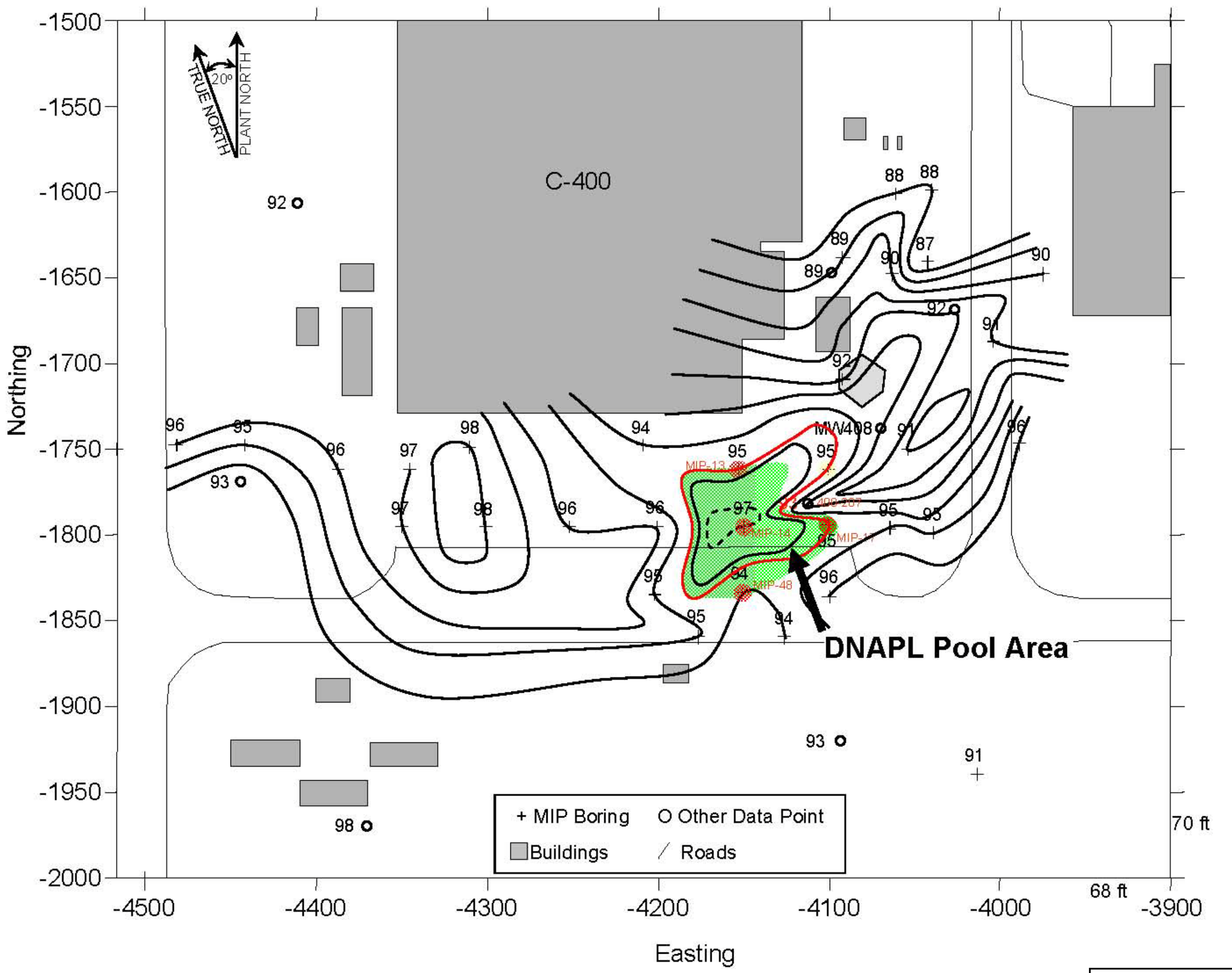
[7] DNAPL saturation is the percentage of porosity occupied by DNAPL (e.g., where soil pores are 1/3 filled with DNAPL on average, the DNAPL saturation is 33%).

[8] Dr. B.H. Kueper in *The Occurrence of Dense, Non-Aqueous Phase Liquids in the Subsurface at the Paducah Gaseous Diffusion Plant, Final Report*, KY/ER/Sub/0815-1015/91/2, November 25, 1991 reported, “On average, residual DNAPL will occupy between 5 % and 30 % of pore space.” The upper bound was used for the core of the DNAPL zone.

[9] The assumption of 1% DNAPL saturation at the edge of the defined source zone is an assumed small mass ratio factor, which is biased to the calculation of greater mass than may be present. Previous DNAPL mass estimates for the C-400 source zones in the *Feasibility Study for the Groundwater Operable Unit* (DOE/OR/07-1857&D2) used 0.1% DNAPL saturation, based on WAG 6 RI soil analyses.

[10] For the purpose of this evaluation, the radius of the DNAPL zones was uniformly estimated in one ft increments. Larger DNAPL zone radii segregated into more units, which resulted in calculation of a lower average DNAPL saturation.



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

Figure A.7. Depth to Base of the Continental Deposits (ft)

Deposits, it was assumed that the DNAPL saturation in a pool of significant thickness is governed predominately by hydraulic potential and would be greater than the DNAPL saturation remaining in the zone of vertical migration. The DNAPL saturation within the pool may be as much as 60%.

Zone of Residual Contamination: The south C-400 area contains several discrete areas of soil containing lesser TCE contamination, that appear to be the residual of DNAPL zones that have become depleted by percolating water or may be the outer, diffuse fringe of a small DNAPL zone. The soil TCE concentrations typically range from 1,000 to 100,000 µg/kg. These contaminant levels equate to exceedingly small DNAPL saturations, 0.000004 and 0.0004 (0.0004 and 0.04%), respectively according to equation A.4 in Attachment A.5.

The vadose zone at PGDP exists primarily in a loess unit (silt). A high percentage of the porosity between 20 and 30 ft bgs is expected to be filled with water. The following DNAPL volume calculations do not include a correction for reduced water saturation in the vadose zone.

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ATTACHMENT A1

PHOTOIONIZATION DETECTOR LOGS FOR THE MEMBRANE INTERFACE PROBE BORINGS OF THE REMEDIAL DESIGN SUPPORT INVESTIGATION

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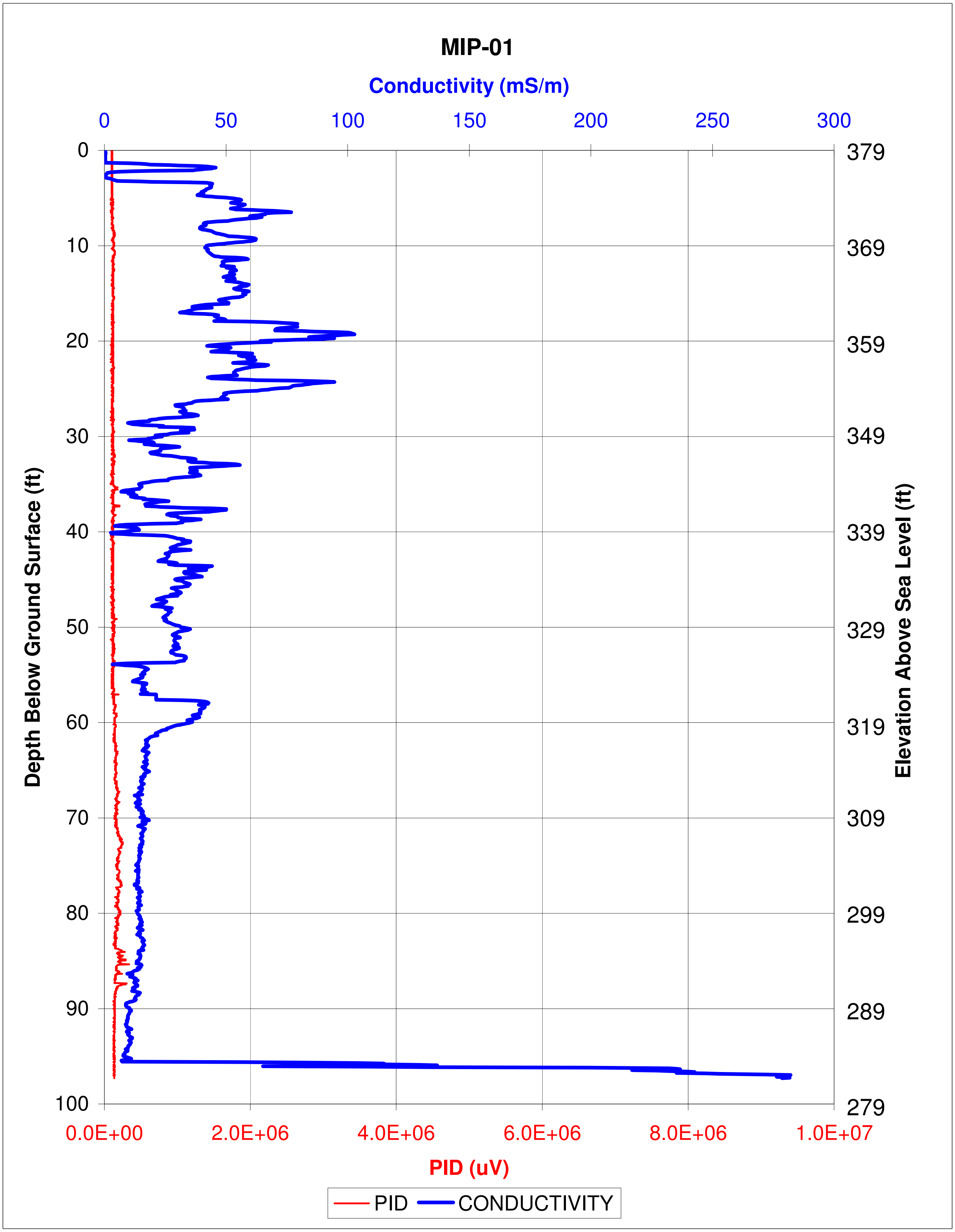
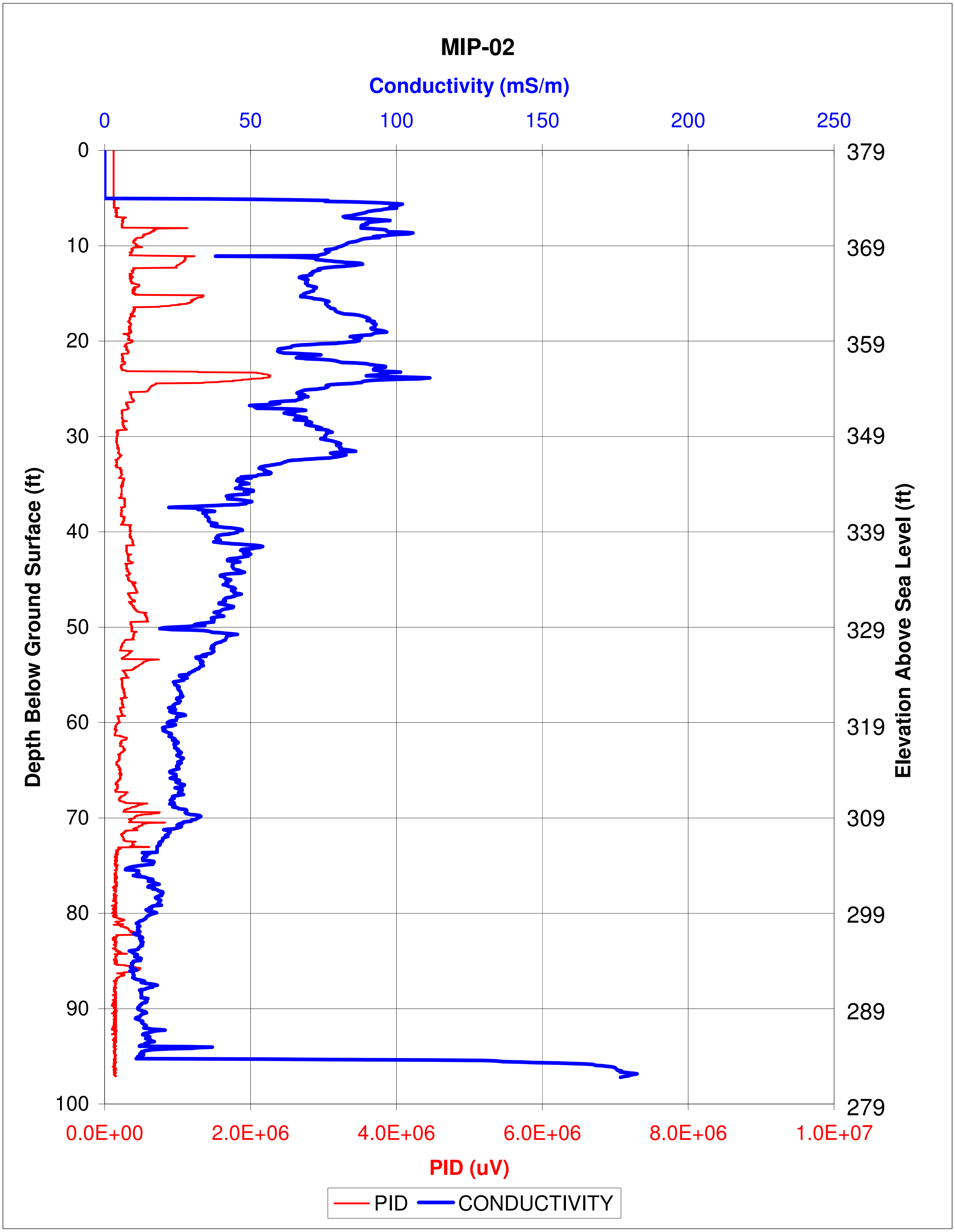
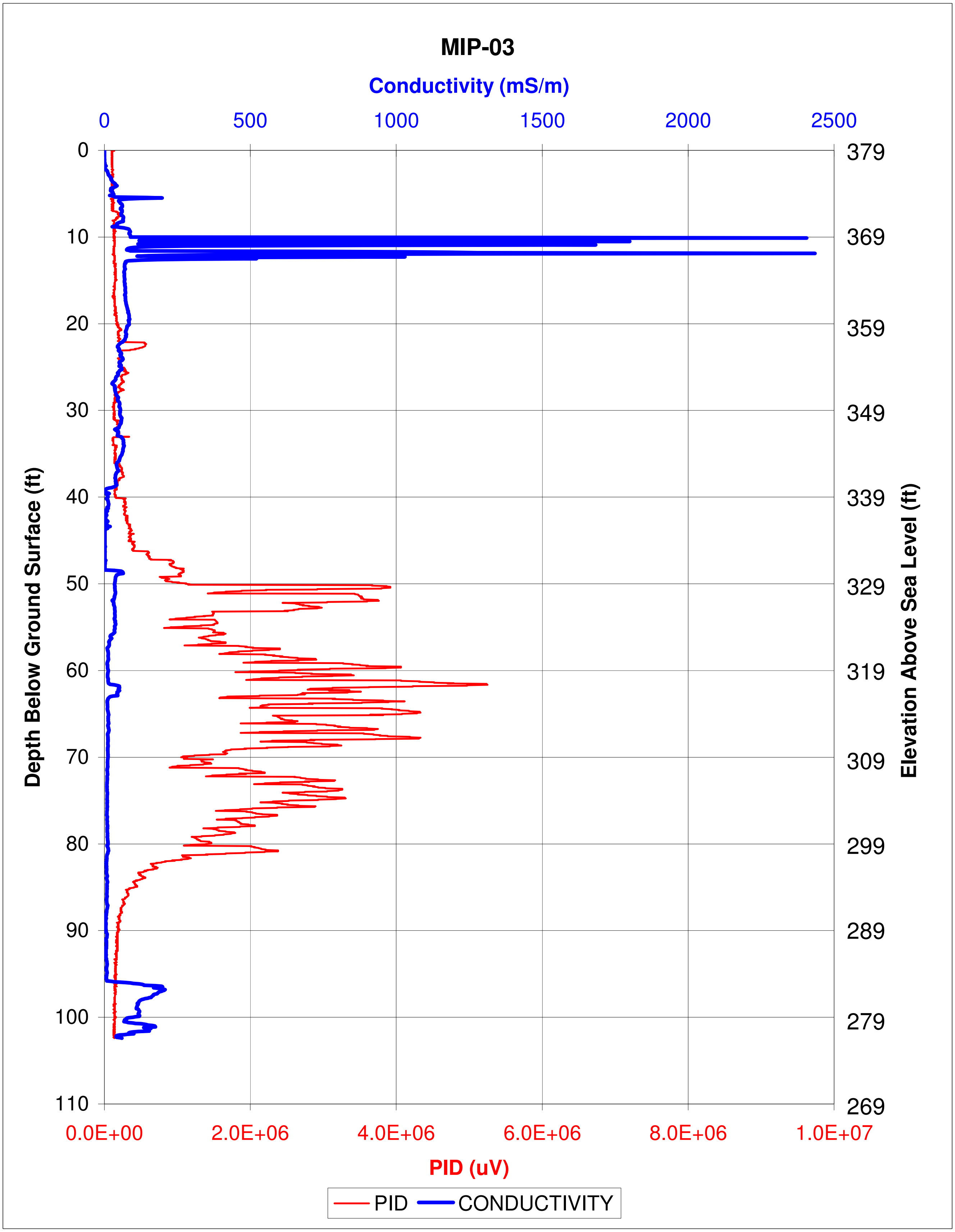
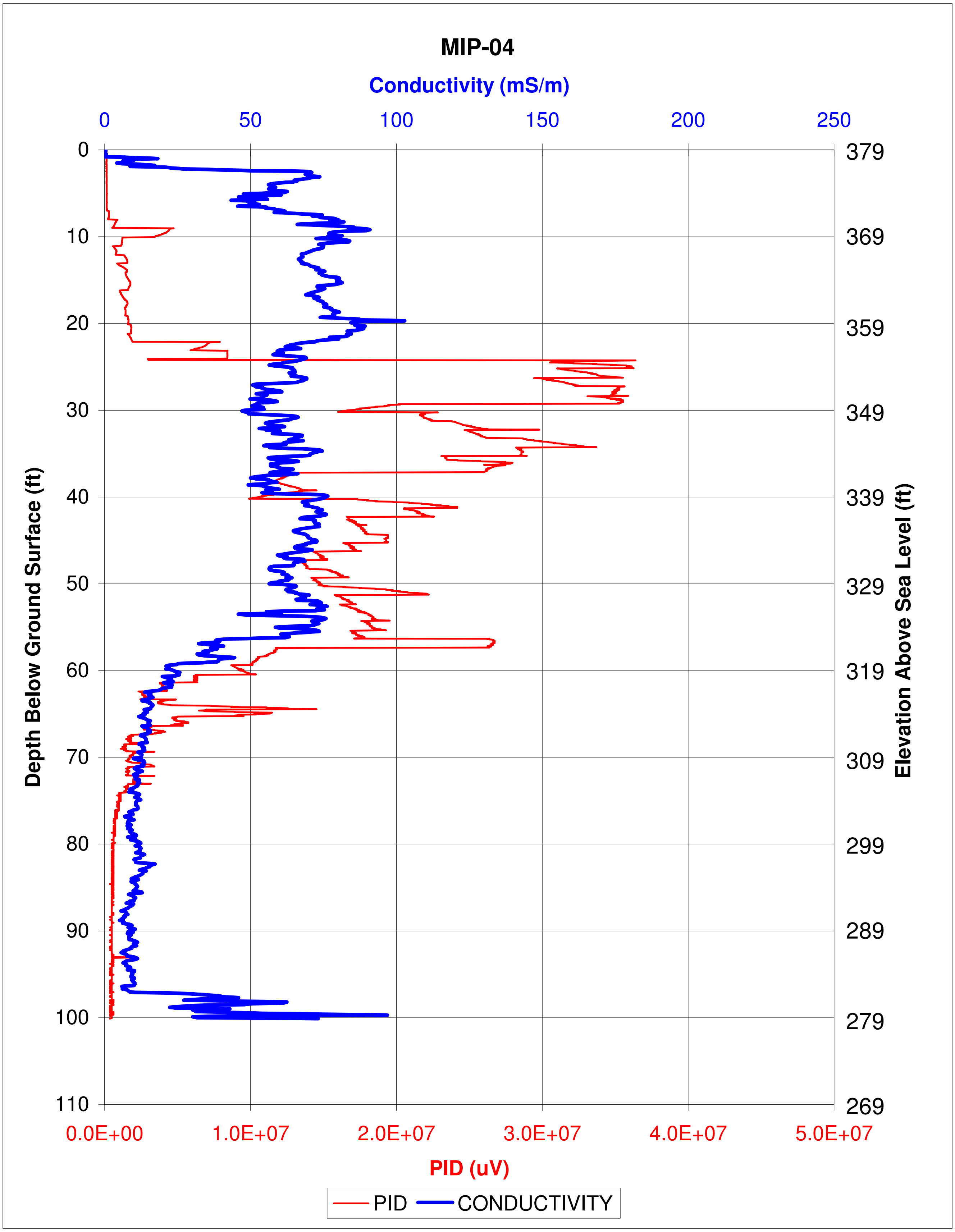
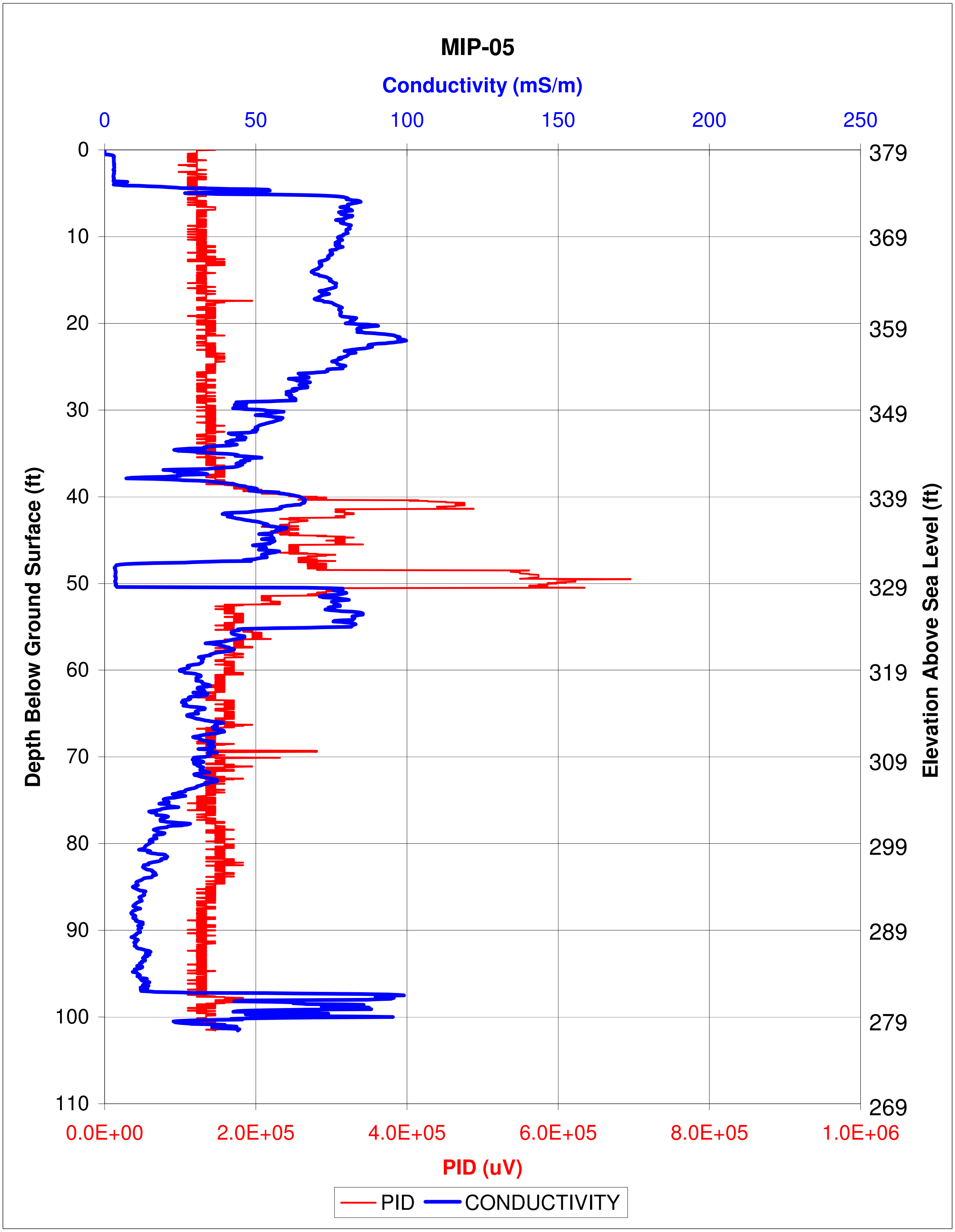

MIP-01
Conductivity (mS/m)
0
50
100
150
200
250
300
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

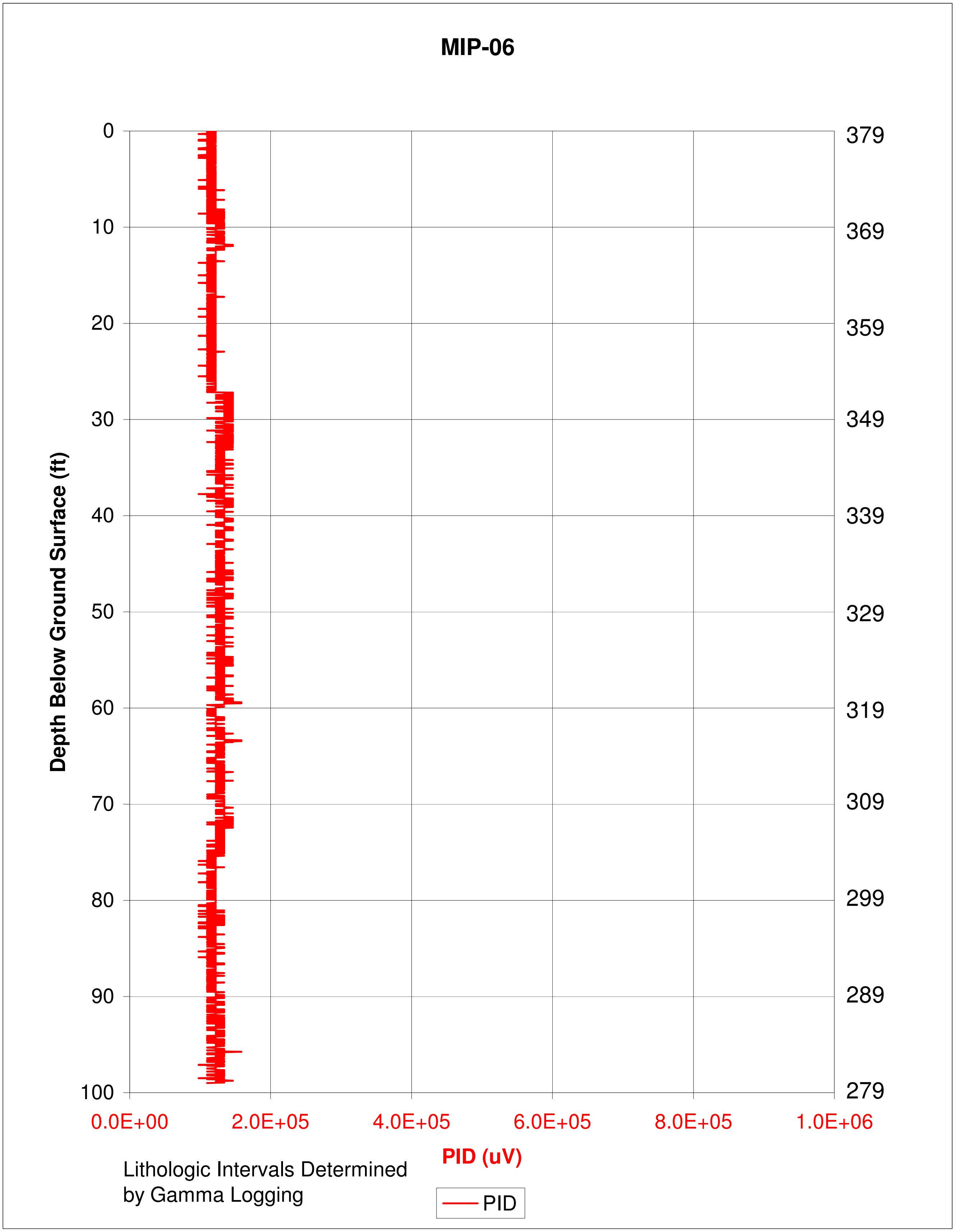

MIP-02
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

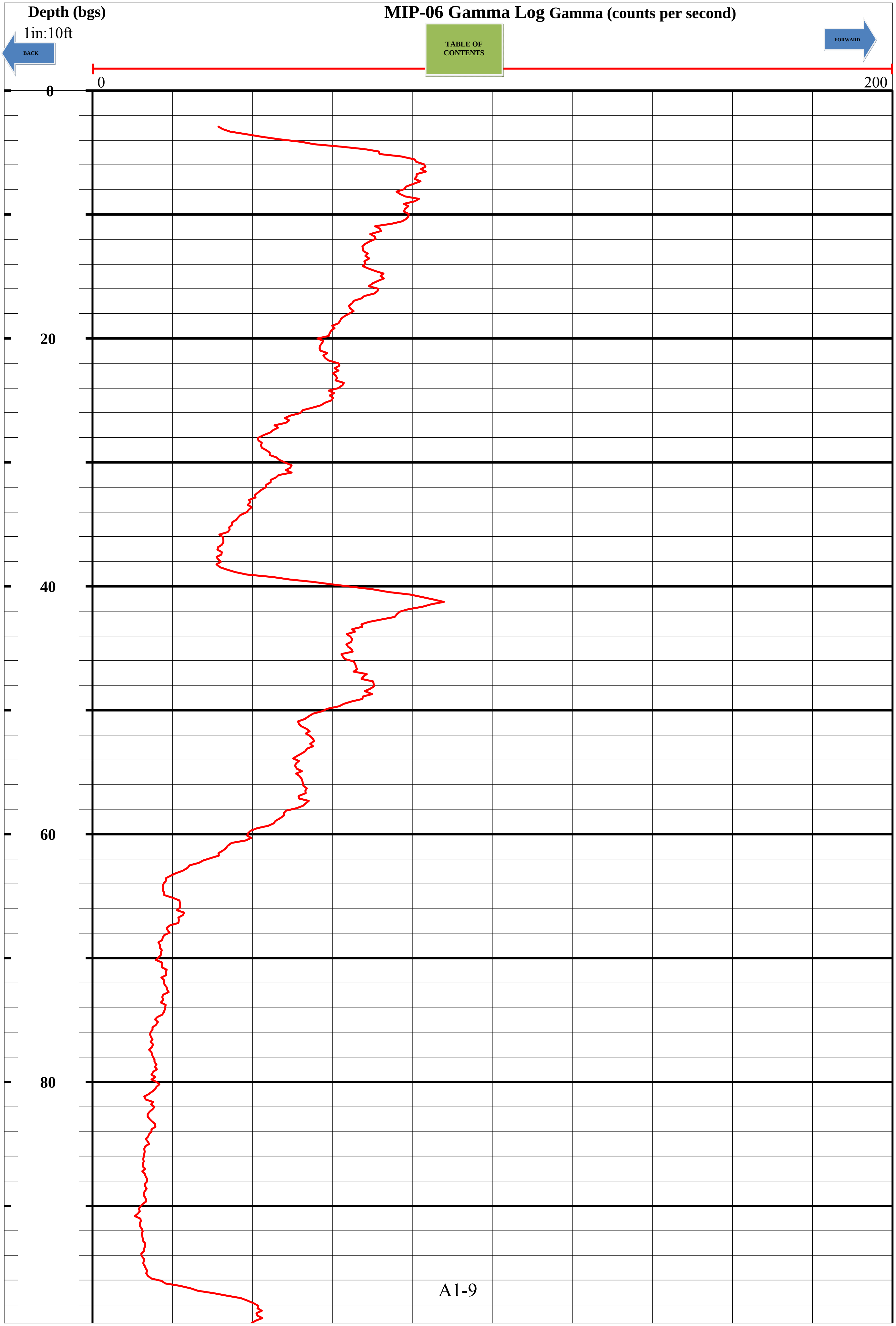


Conductivity logs for the approximately 10-12.5 feet range are anomalous readings because of expected detector contact with subsurface equipment.

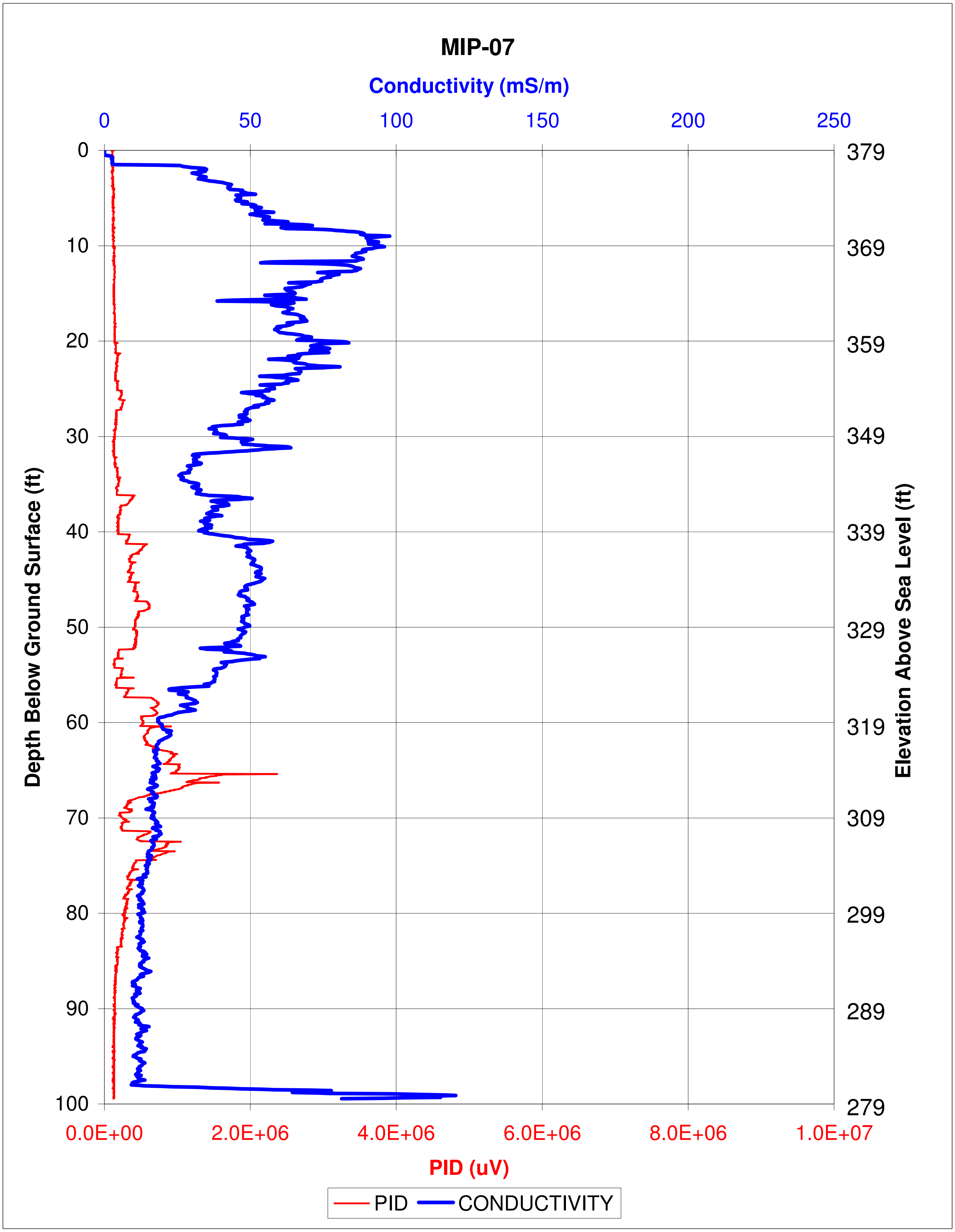

MIP-04
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
110
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
269
0.0E+00
1.0E+07
2.0E+07
3.0E+07
4.0E+07
5.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-05
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
110
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
269
0.0E+00
2.0E+05
4.0E+05
6.0E+05
8.0E+05
1.0E+06
PID (uV)
PID
CONDUCTIVITY


MIP-06
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+05
4.0E+05
6.0E+05
8.0E+05
1.0E+06
PID (uV)
Lithologic Intervals Determined by Gamma Logging
PID



Depth (bgs)
1in:10ft
MIP-06 Gamma Log Gamma (counts per second)
BACK
TABLE OF CONTENTS
FORWARD
0
200
0
20
40
60
80


MIP-07
Conductivity (mS/m)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90
100
Depth Below Ground Surface (ft)
379
369
359
349
339
329
319
309
299
289
279
Elevation Above Sea Level (ft)
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

BACK

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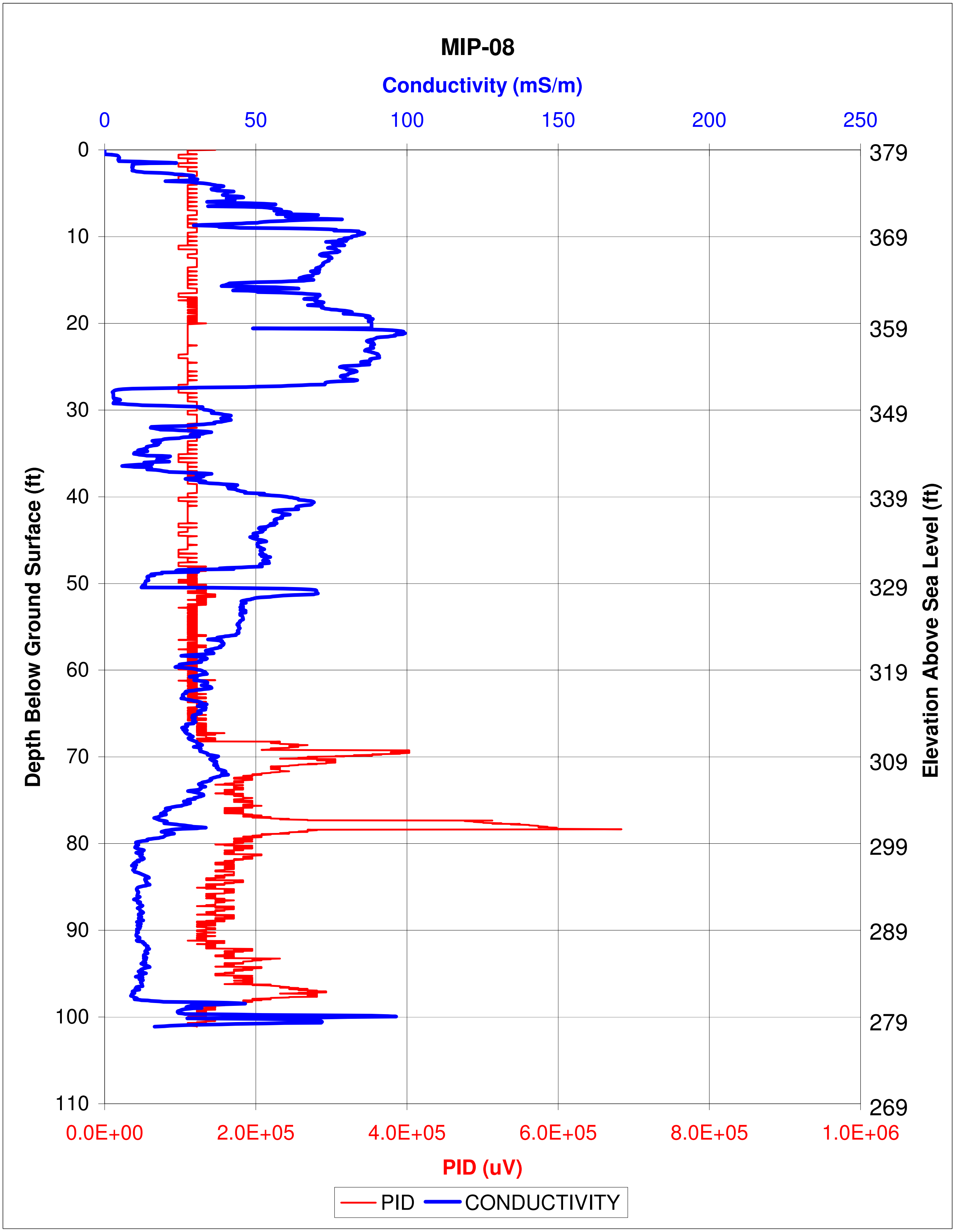
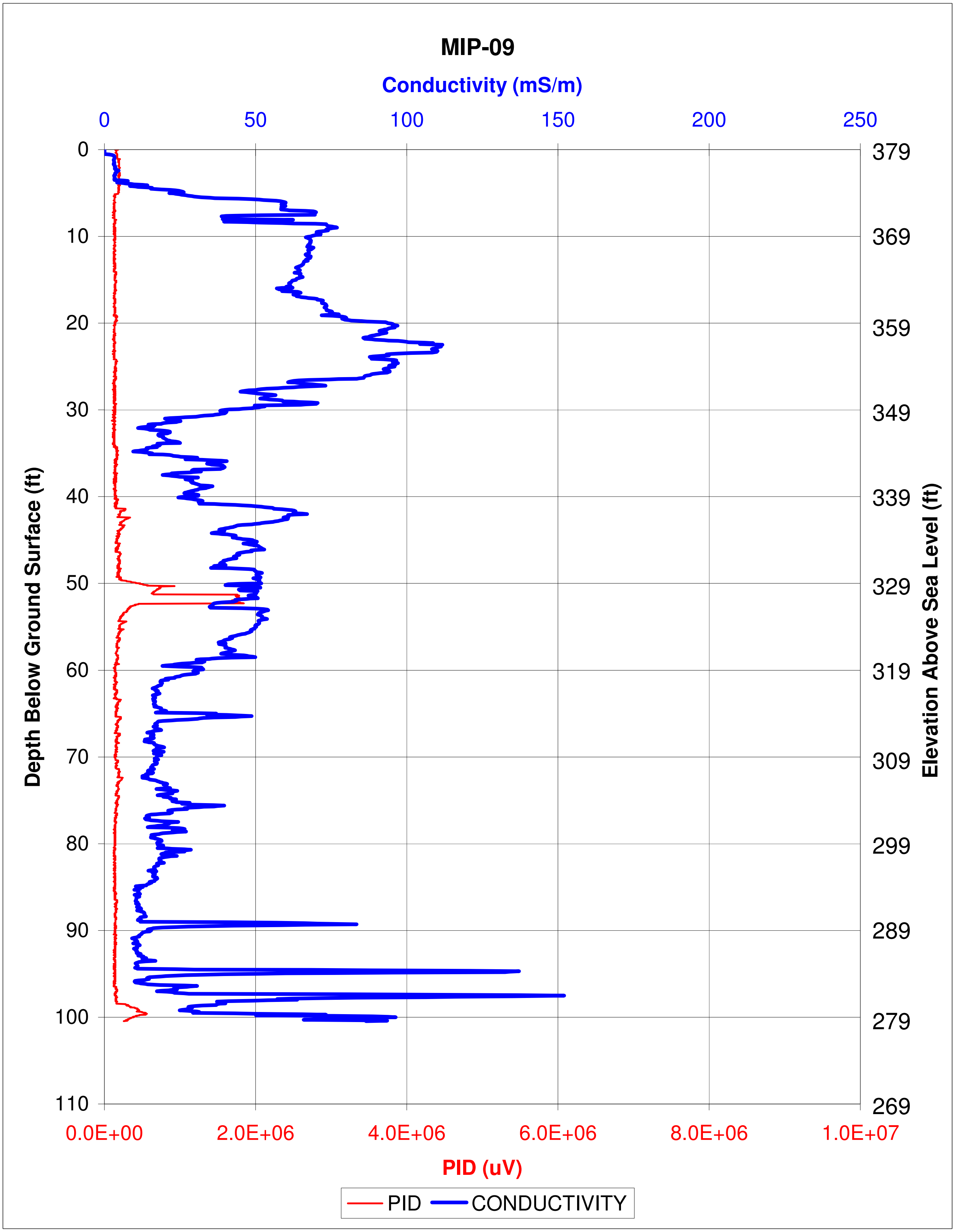
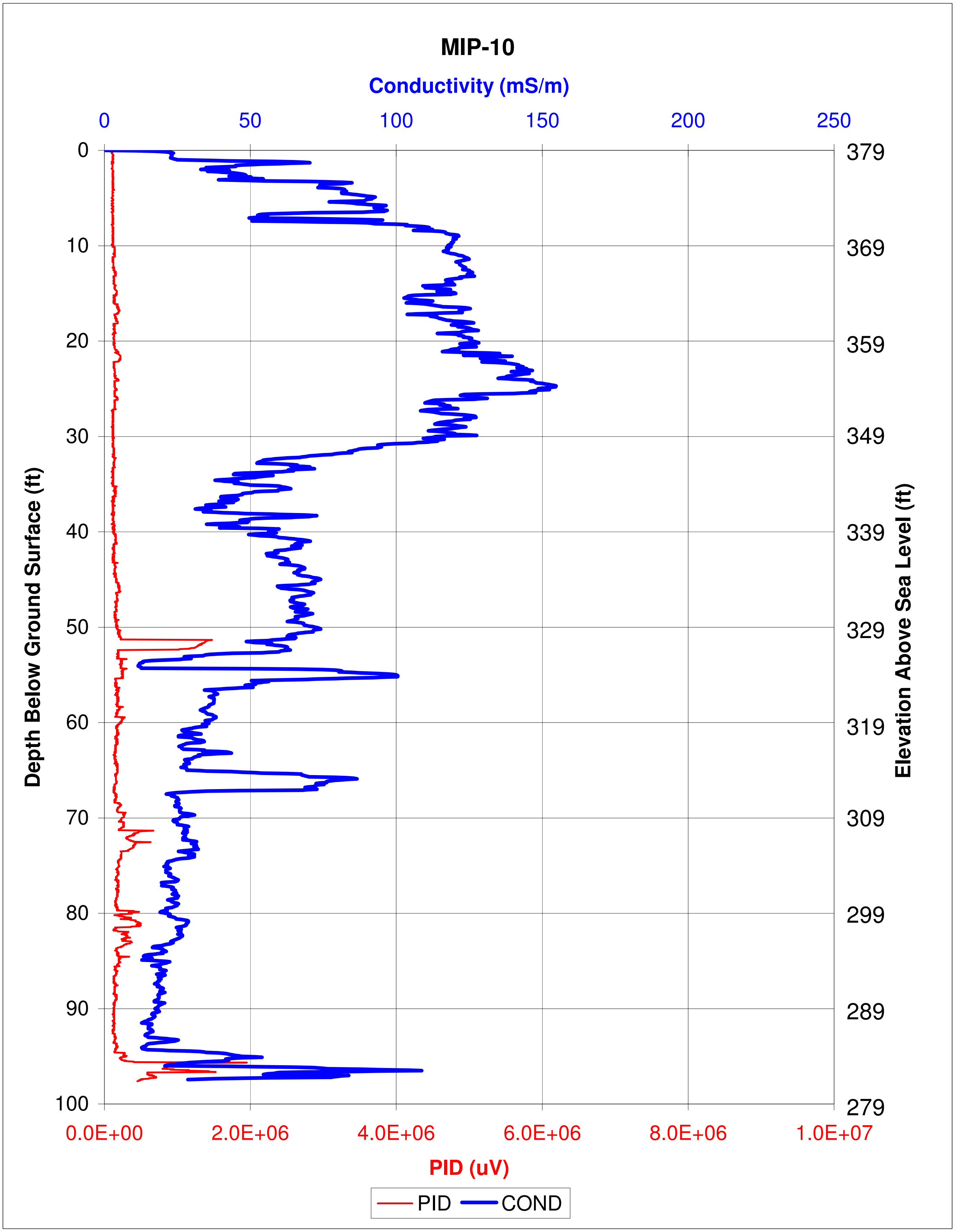
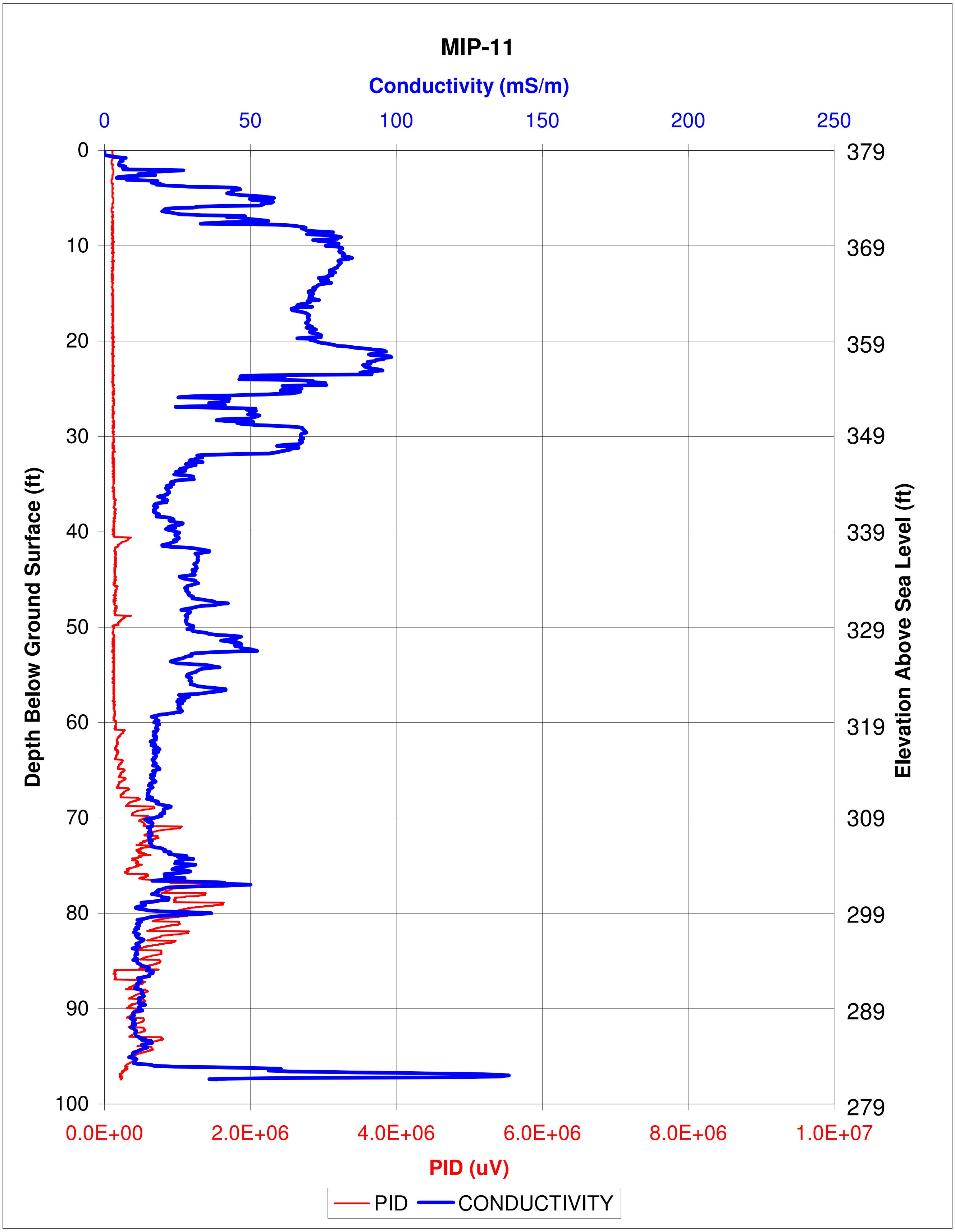
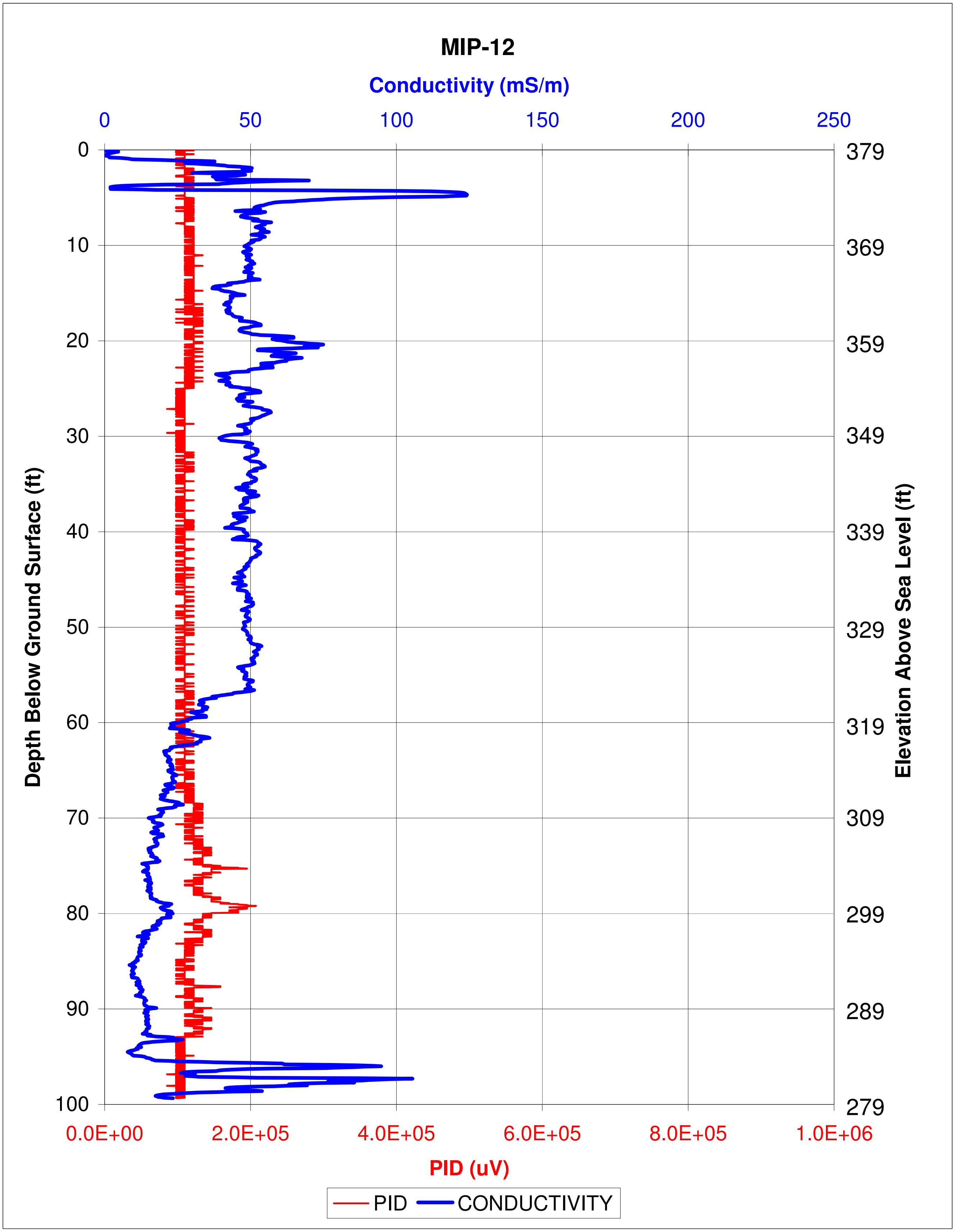
FORWARD

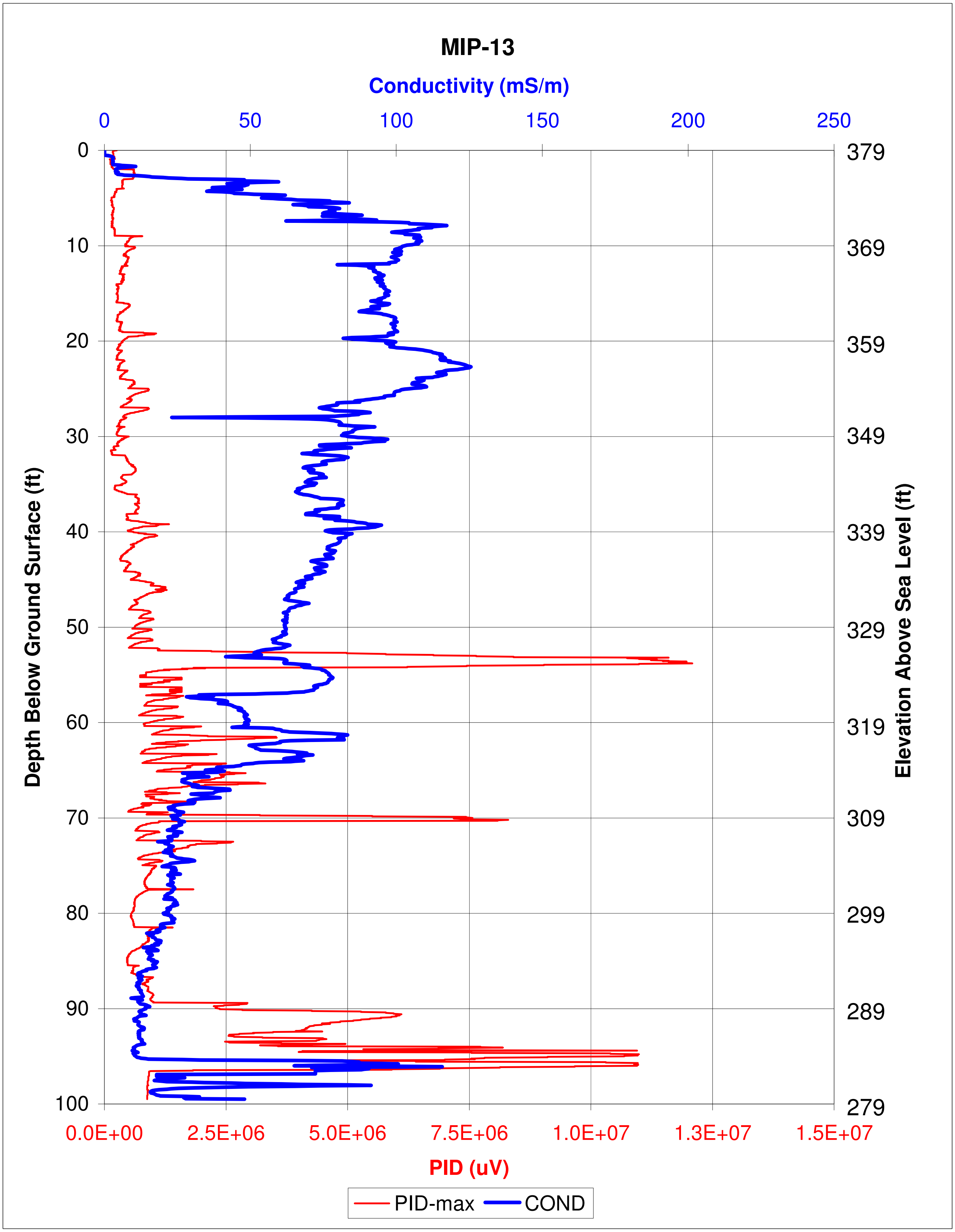


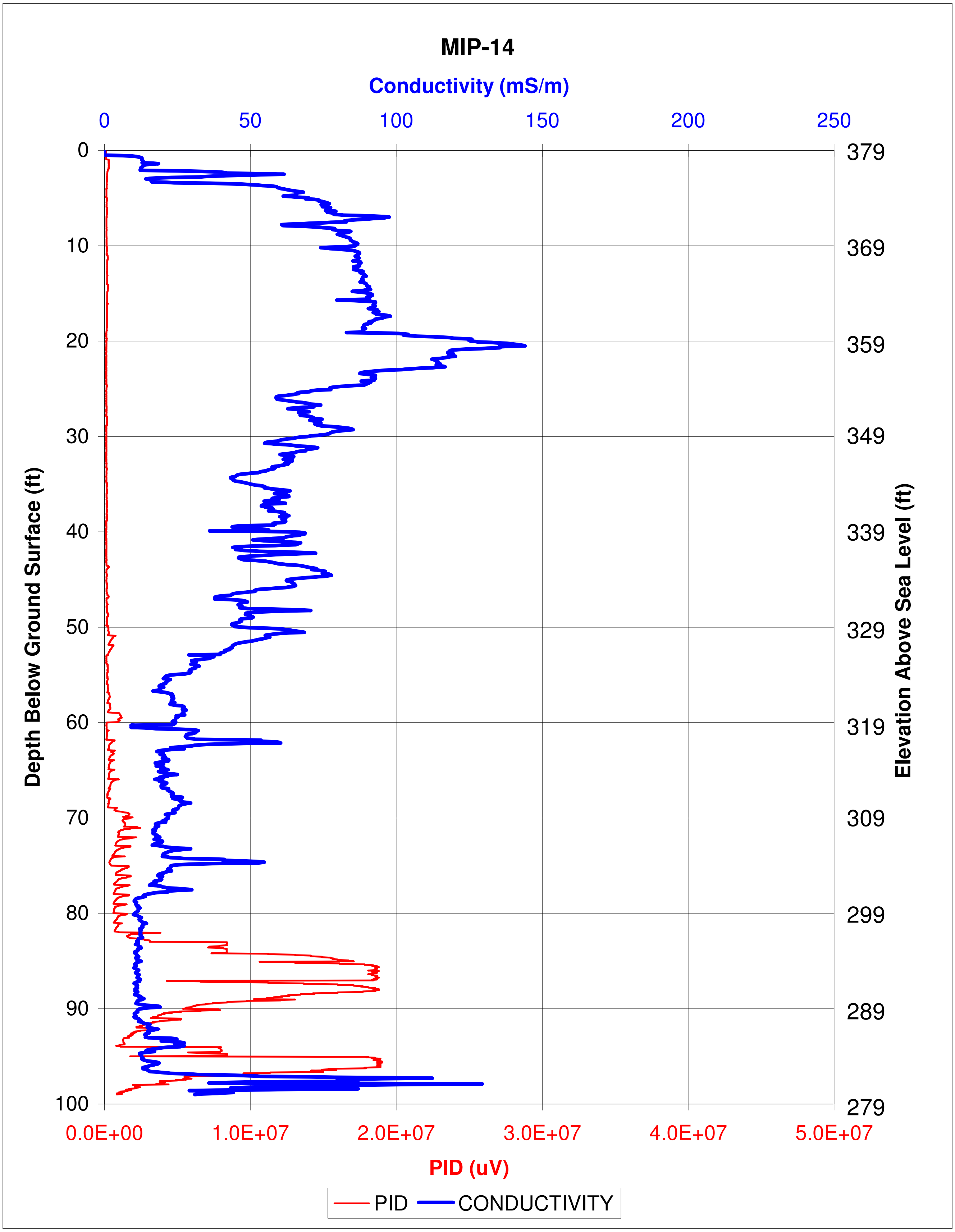

MIP-09
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
110
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
269
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-10
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
COND


MIP-11
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-12
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+05
4.0E+05
6.0E+05
8.0E+05
1.0E+06
PID (uV)
PID
CONDUCTIVITY


MIP-13
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.5E+06
5.0E+06
7.5E+06
1.0E+07
1.3E+07
1.5E+07
PID (uV)
PID-max
COND


MIP-14
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
1.0E+07
2.0E+07
3.0E+07
4.0E+07
5.0E+07
PID (uV)
PID
CONDUCTIVITY

BACK

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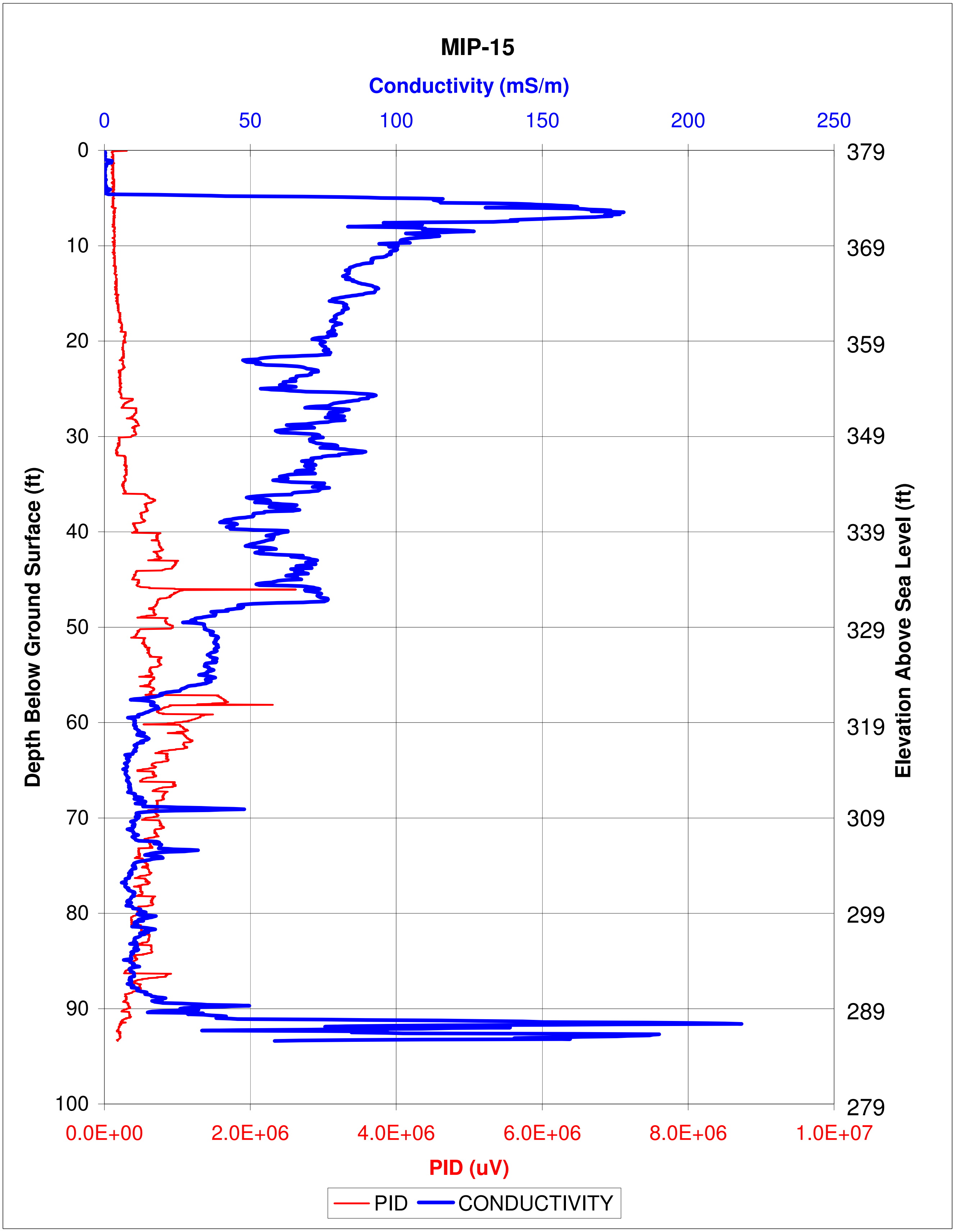
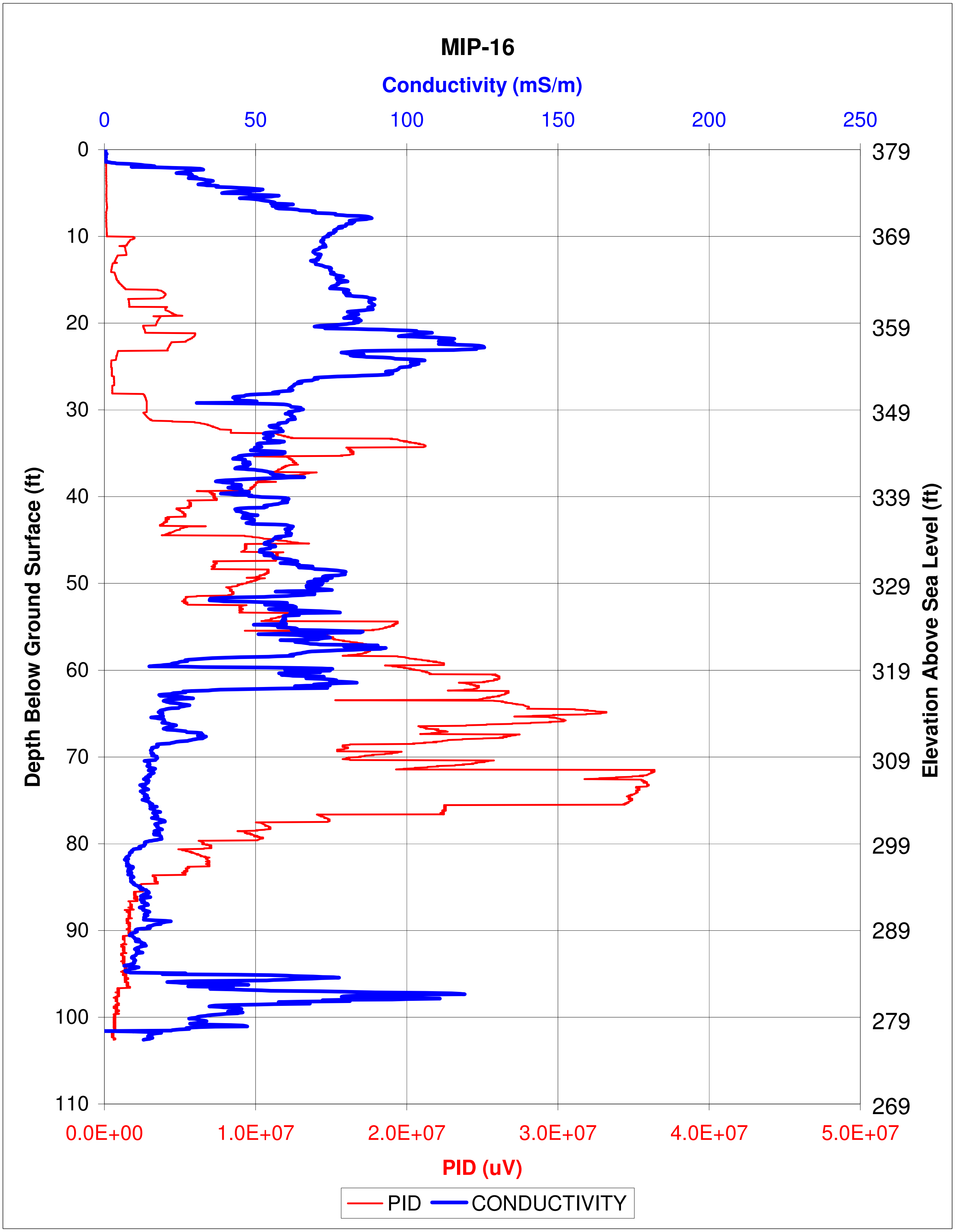
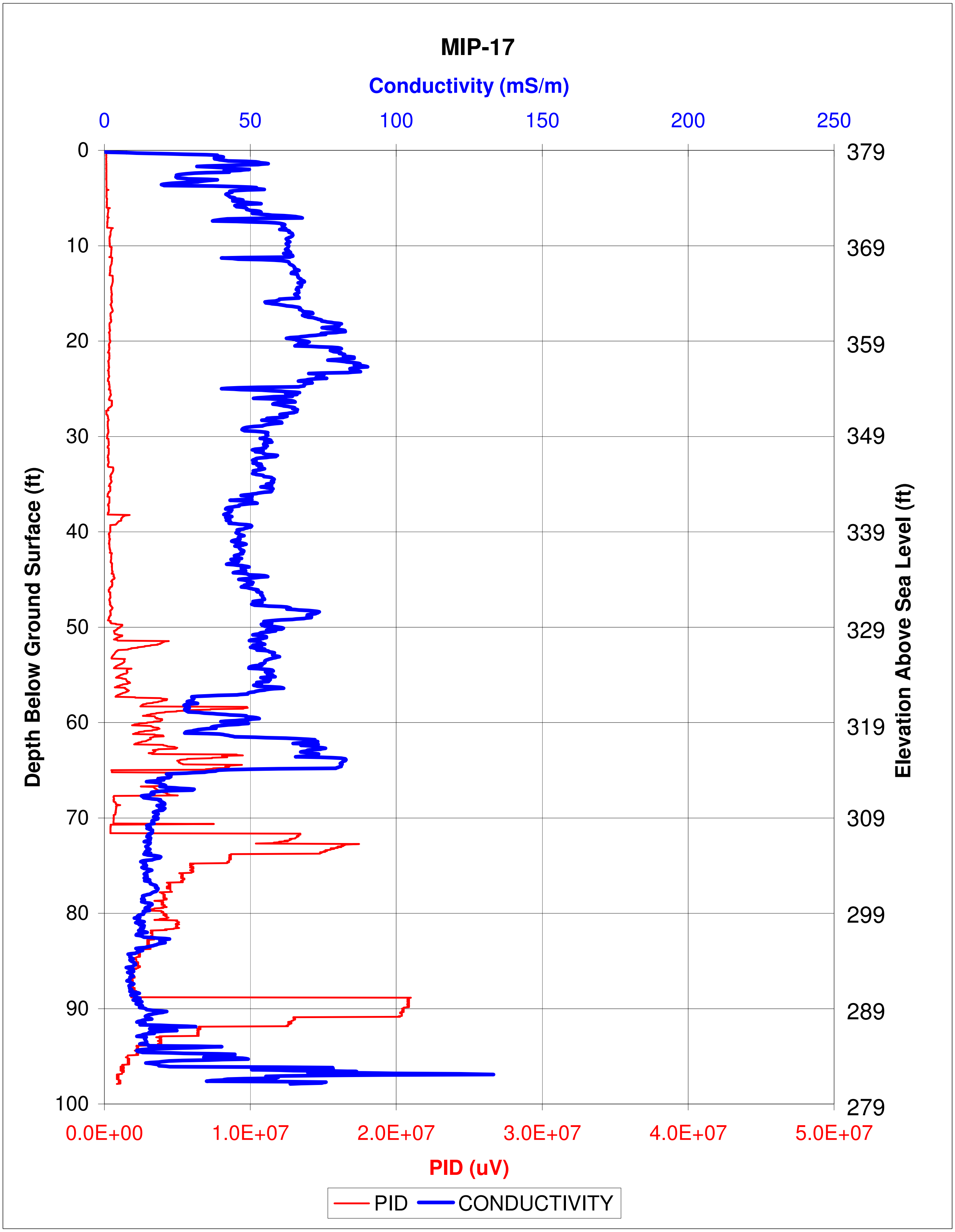
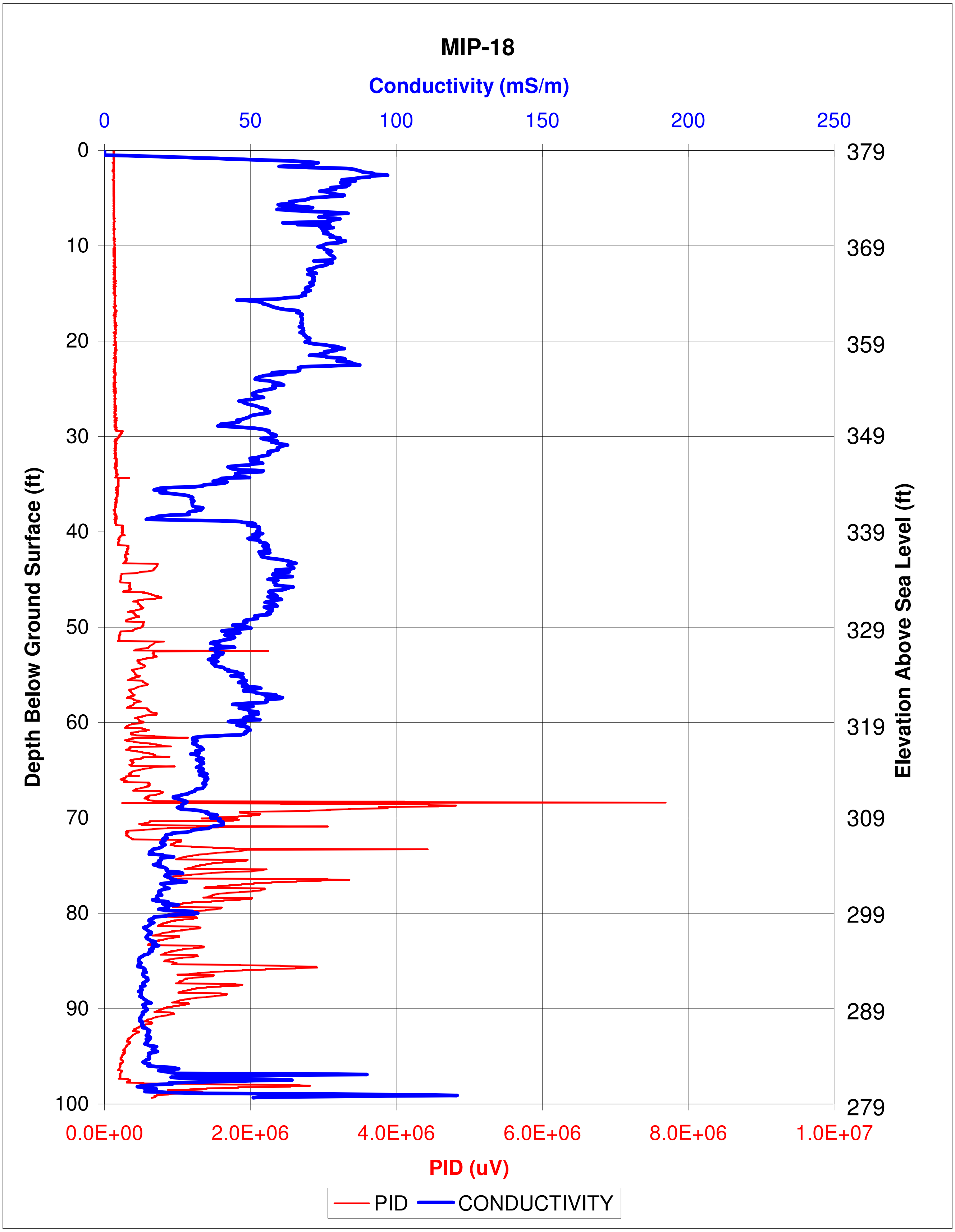
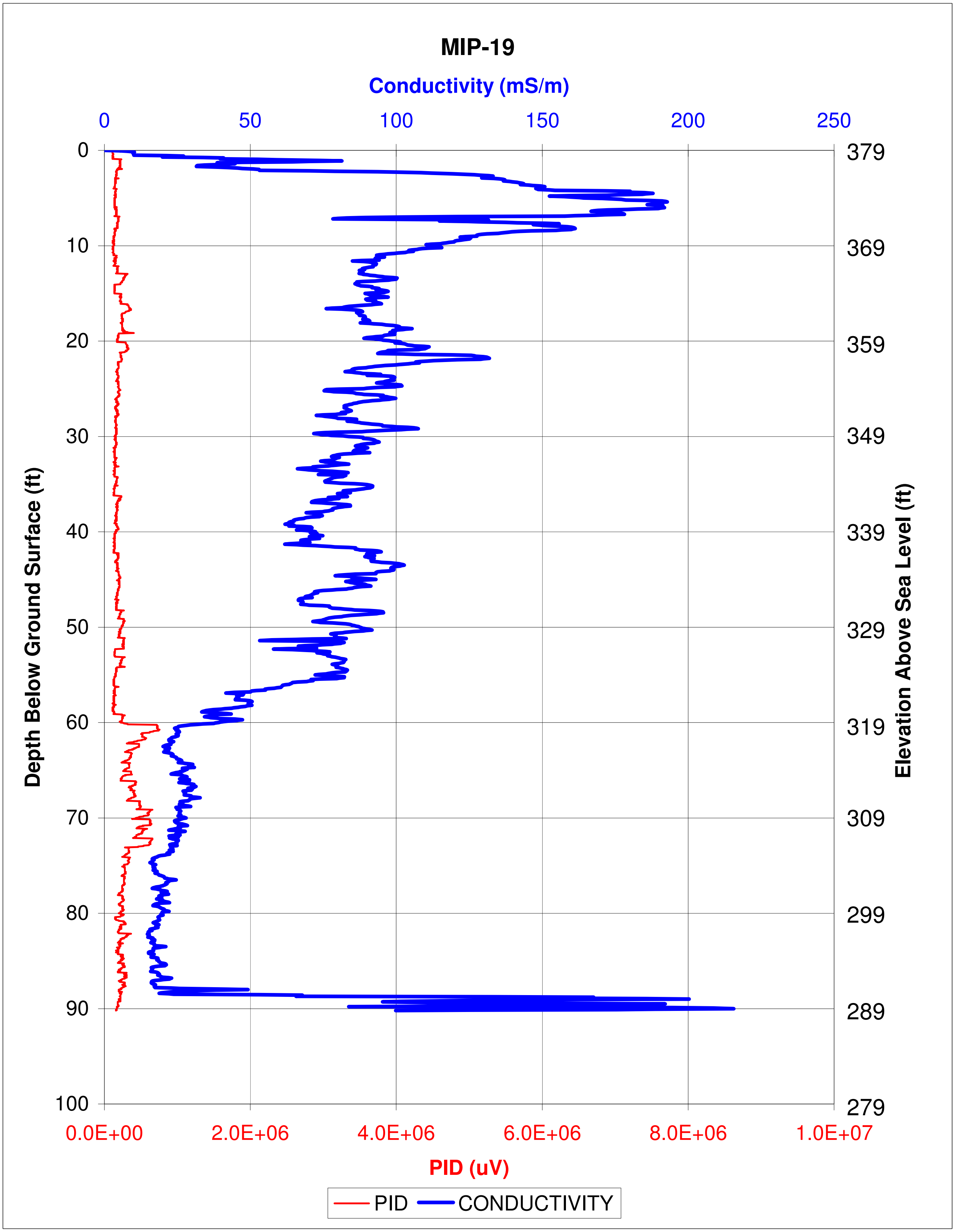
FORWARD

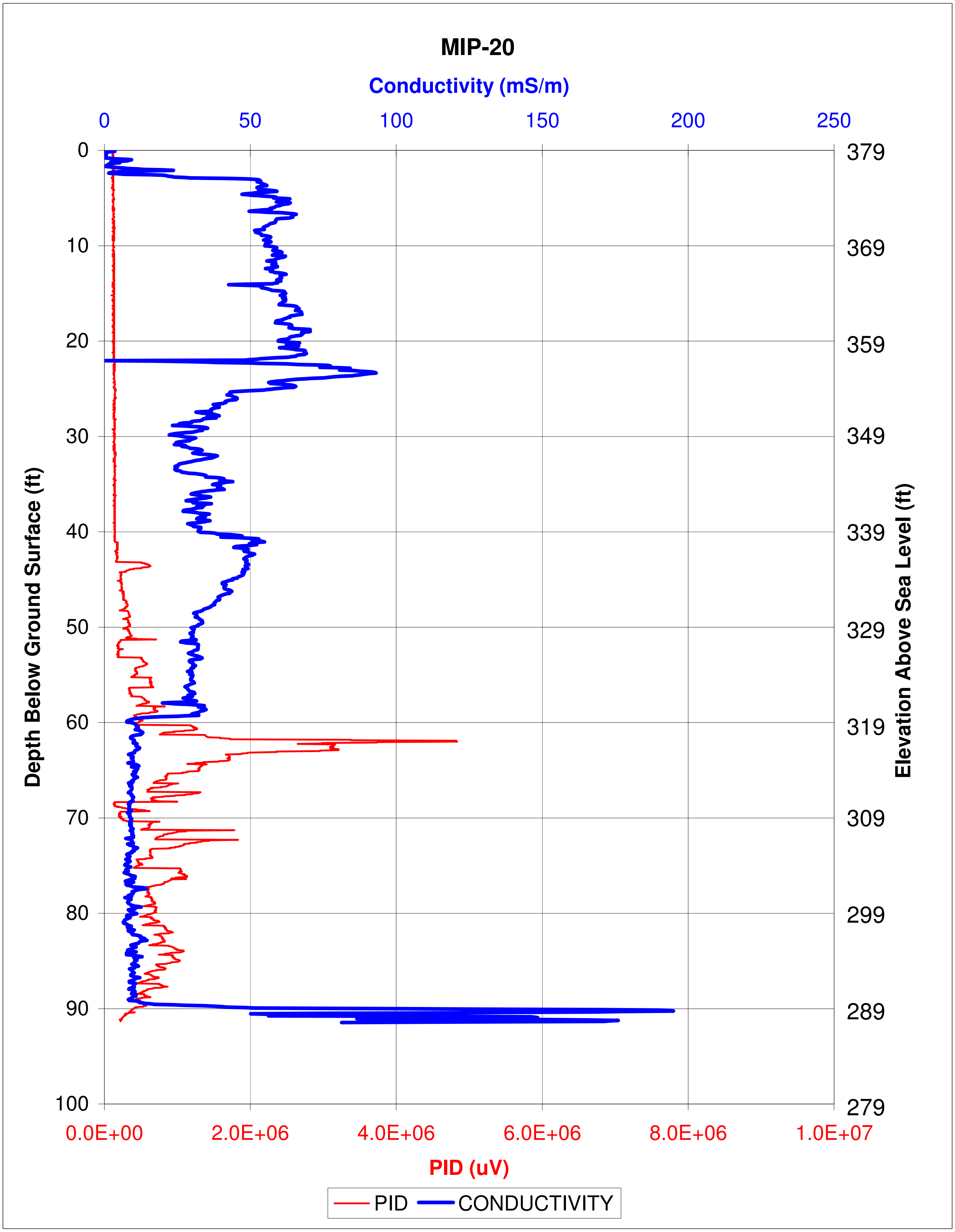


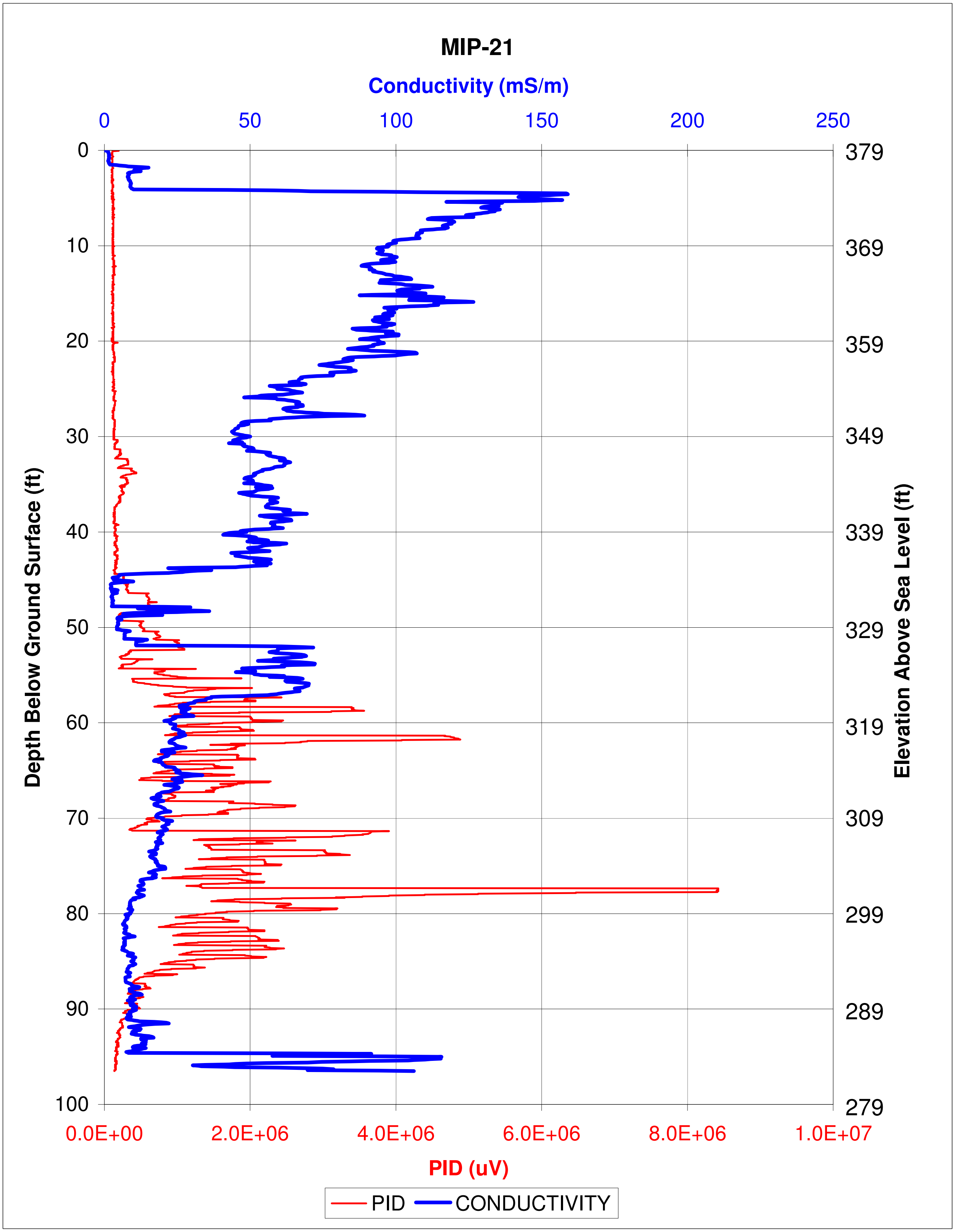

MIP-16
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
110
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
269
0.0E+00
1.0E+07
2.0E+07
3.0E+07
4.0E+07
5.0E+07
PID (uV)
PID
CONDUCTIVITY

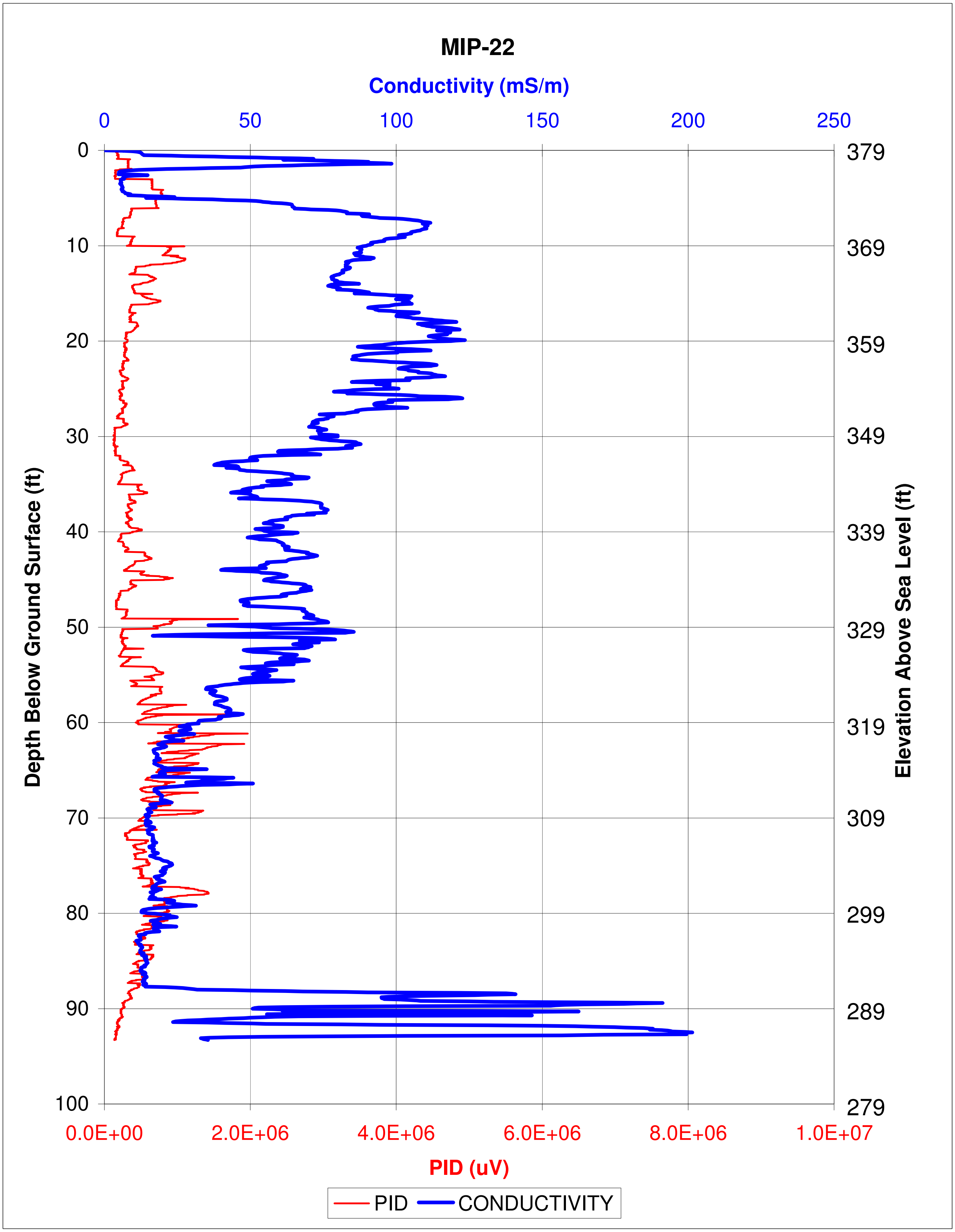

MIP-17
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
1.0E+07
2.0E+07
3.0E+07
4.0E+07
5.0E+07
PID (uV)
PID
CONDUCTIVITY

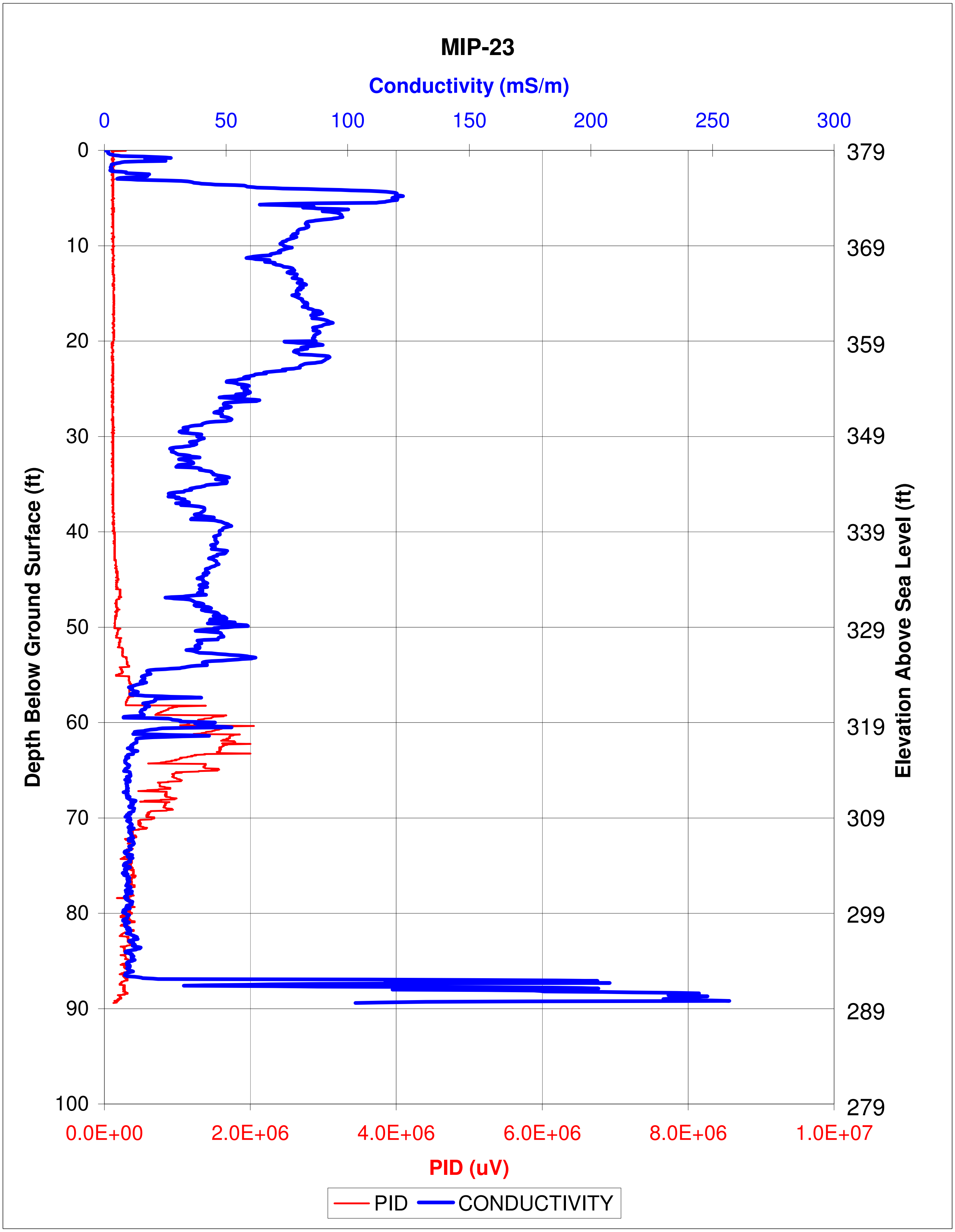

MIP-18
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

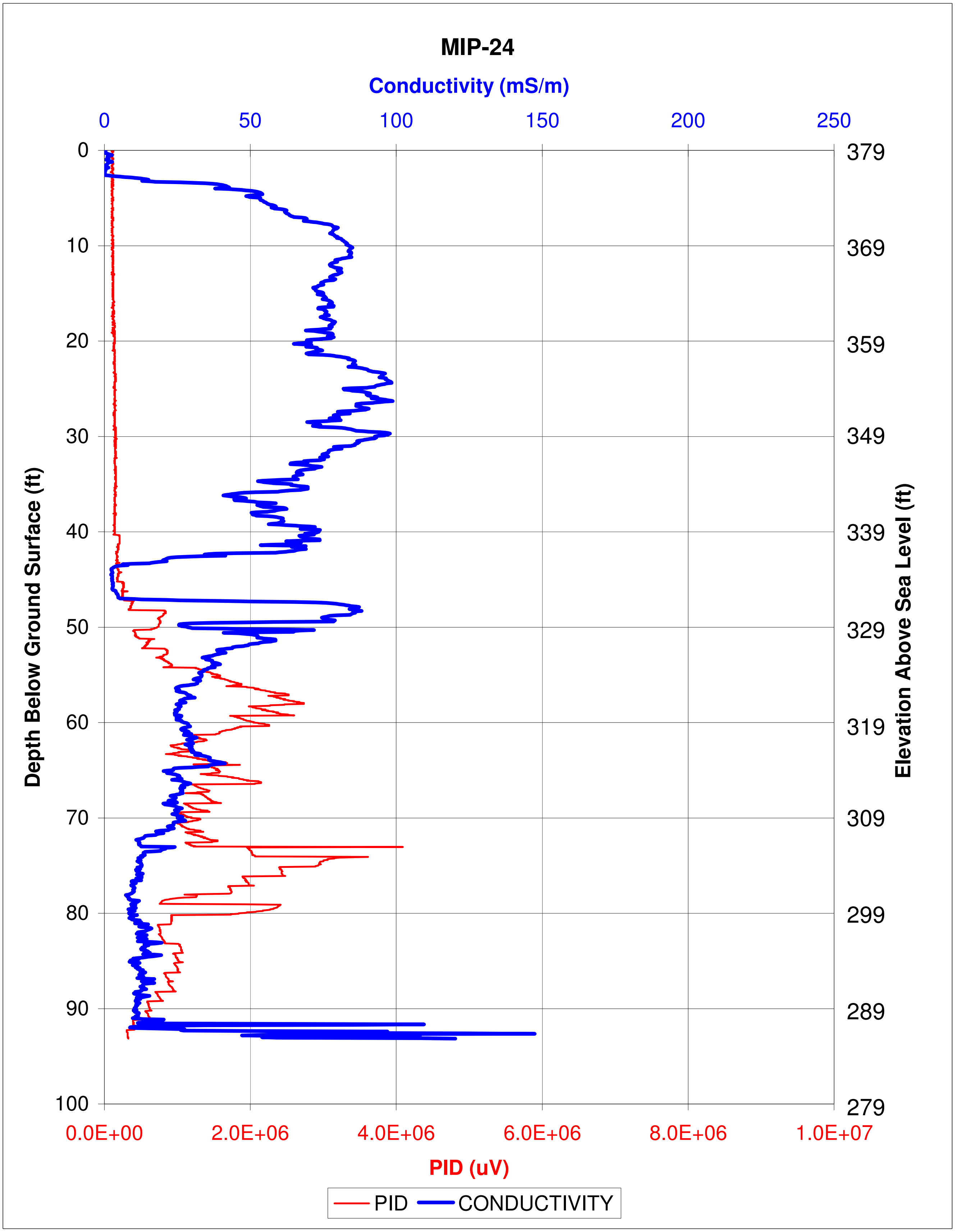

MIP-19
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

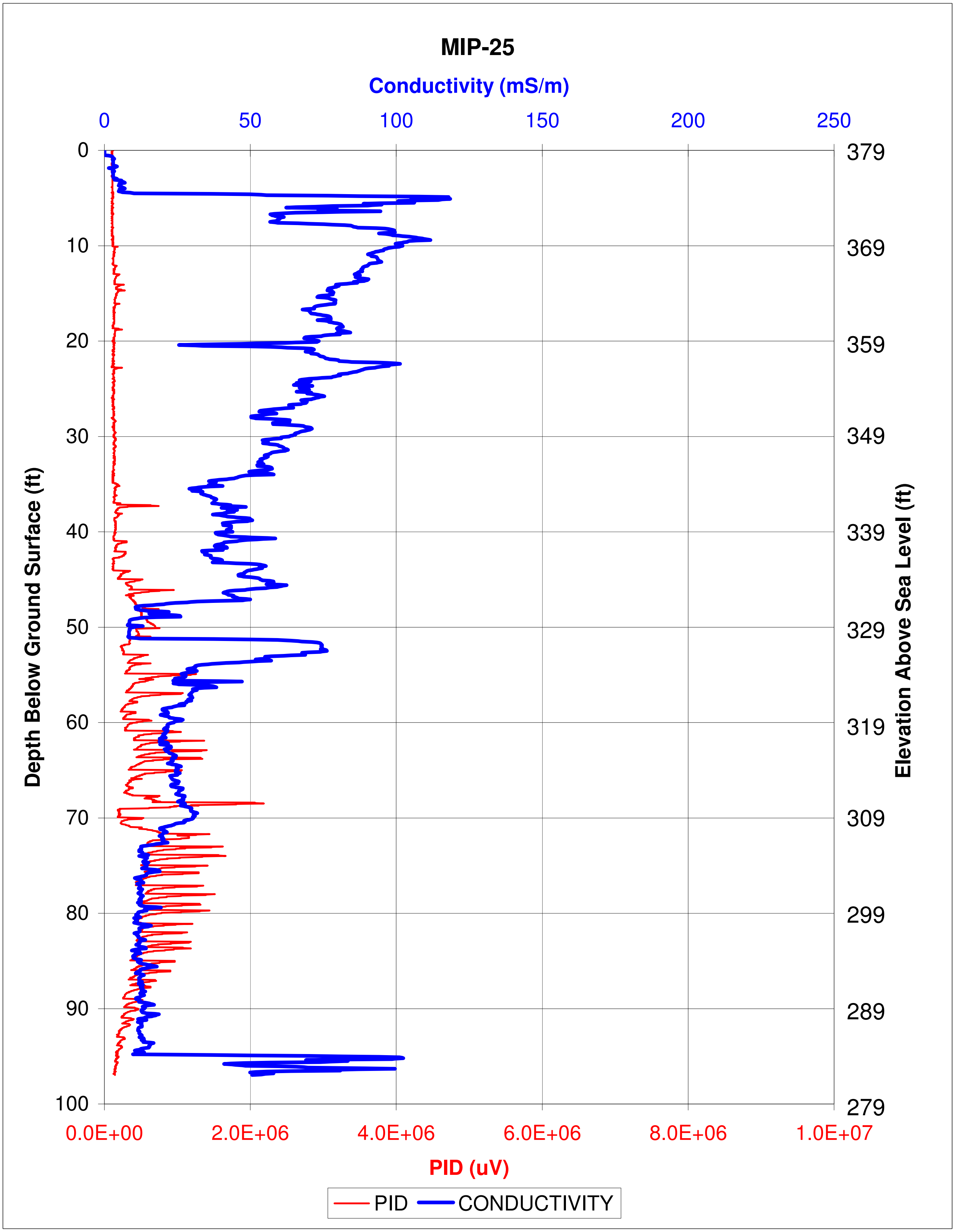

MIP-20
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

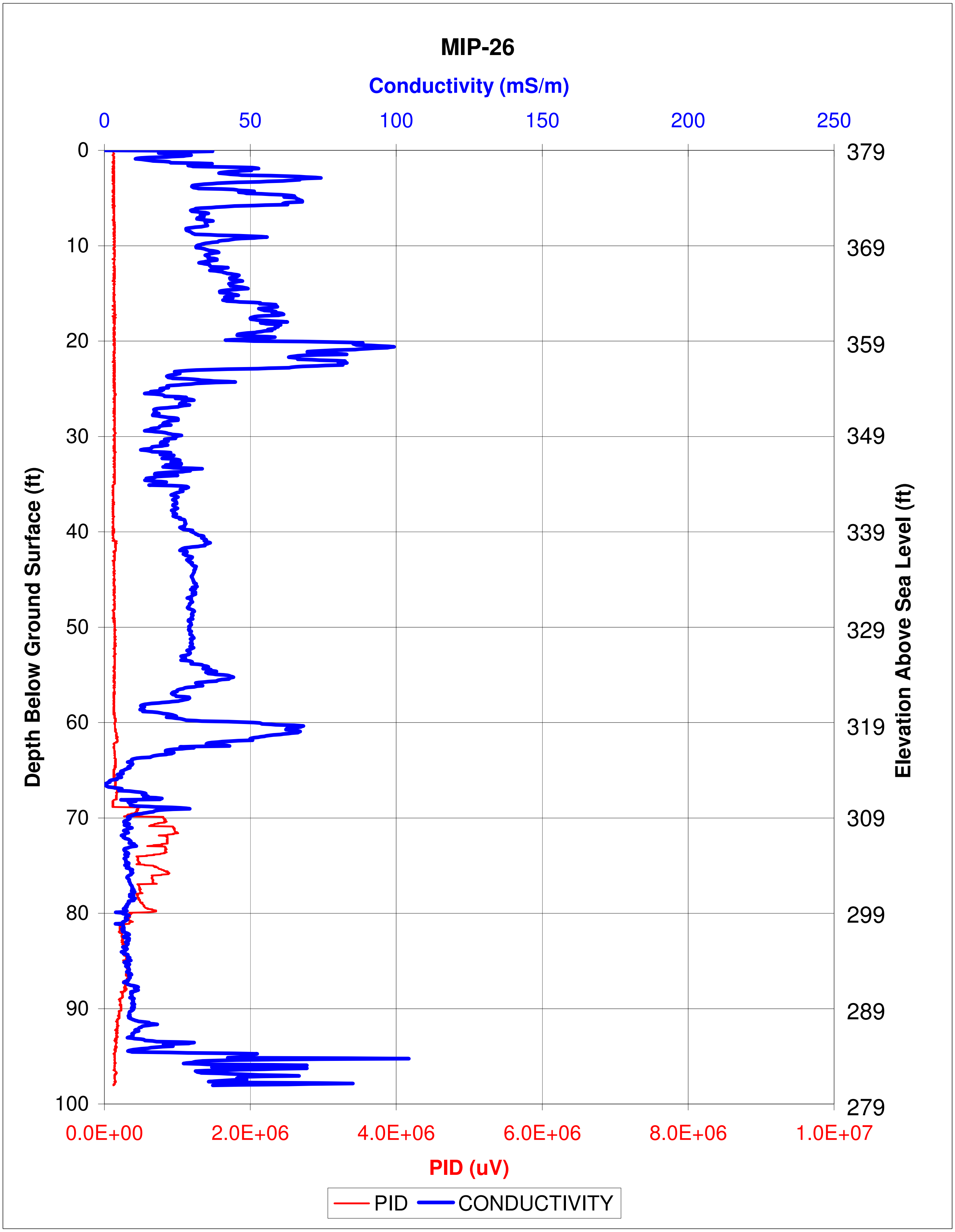

MIP-21
Conductivity (mS/m)
0
50
100
150
200
250
0
10
20
30
40
50
60
70
80
90
100
Depth Below Ground Surface (ft)
379
369
359
349
339
329
319
309
299
289
279
Elevation Above Sea Level (ft)
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

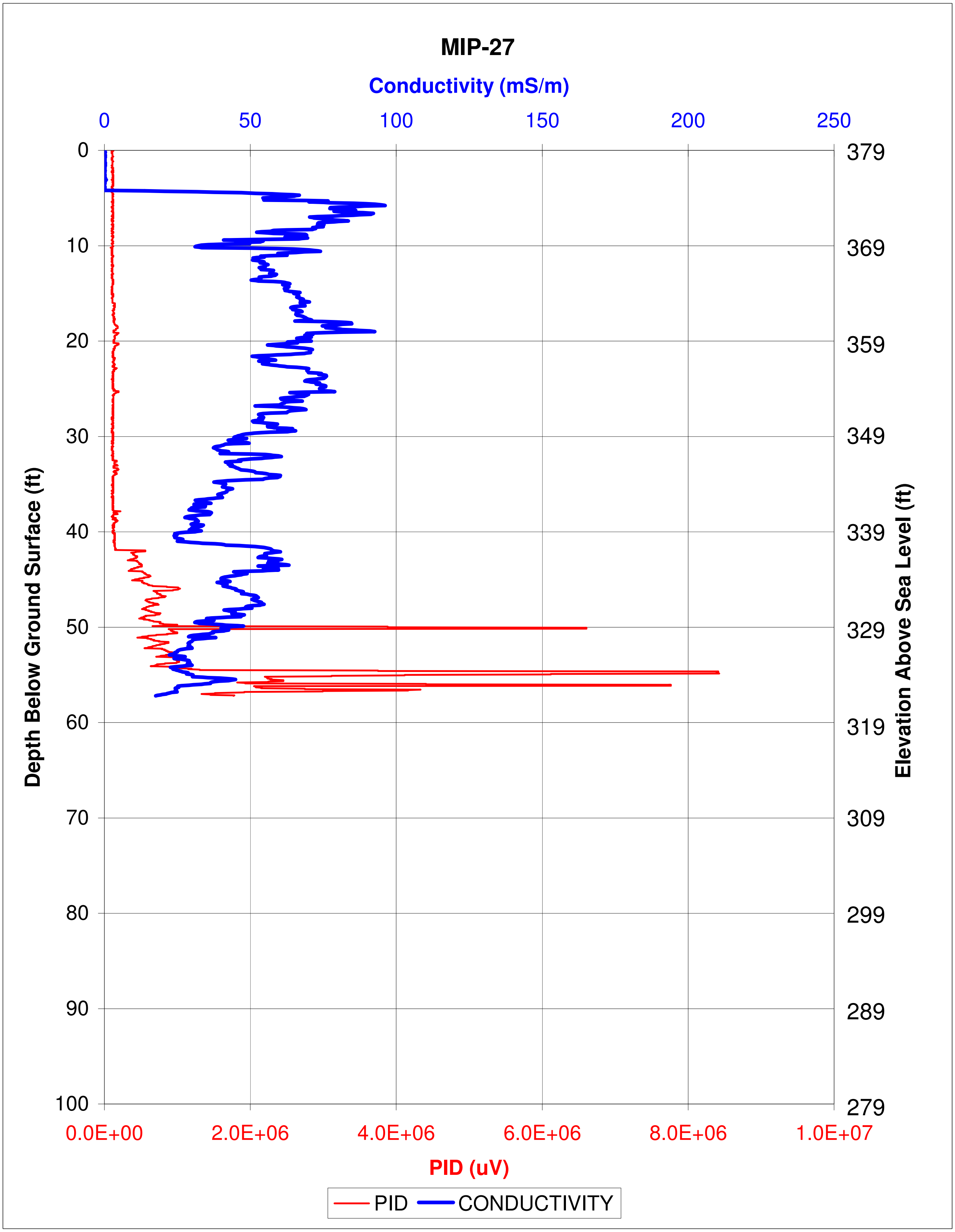

MIP-22
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-23
Conductivity (mS/m)
0
50
100
150
200
250
300
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-24
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-25
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-26
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-27
Conductivity (mS/m)
0
50
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
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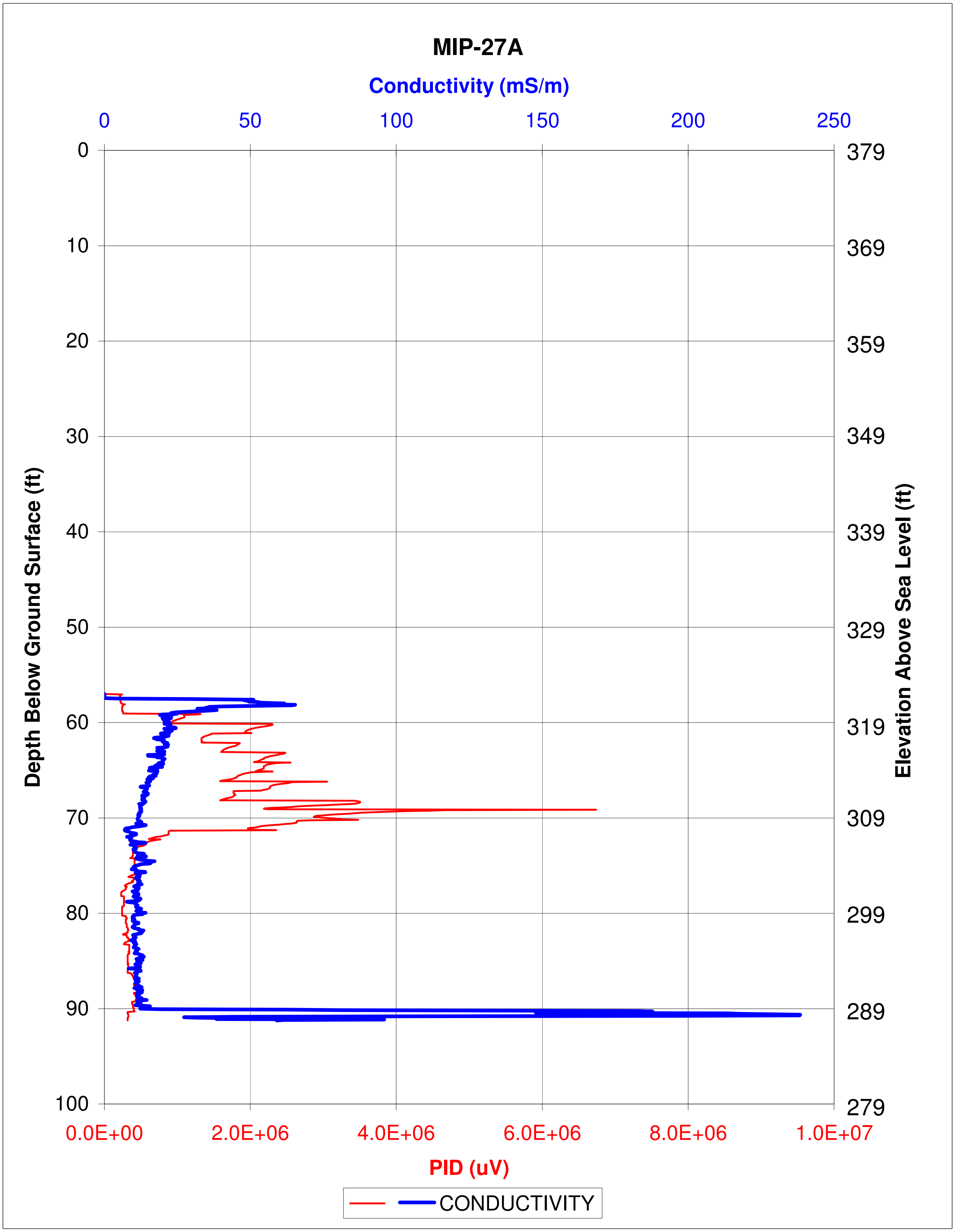
CONDUCTIVITY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Conductivity (mS/m)
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50
100
150
200
250
Depth Below Ground Surface (ft)
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10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
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PID (uV)
CONDUCTIVITY

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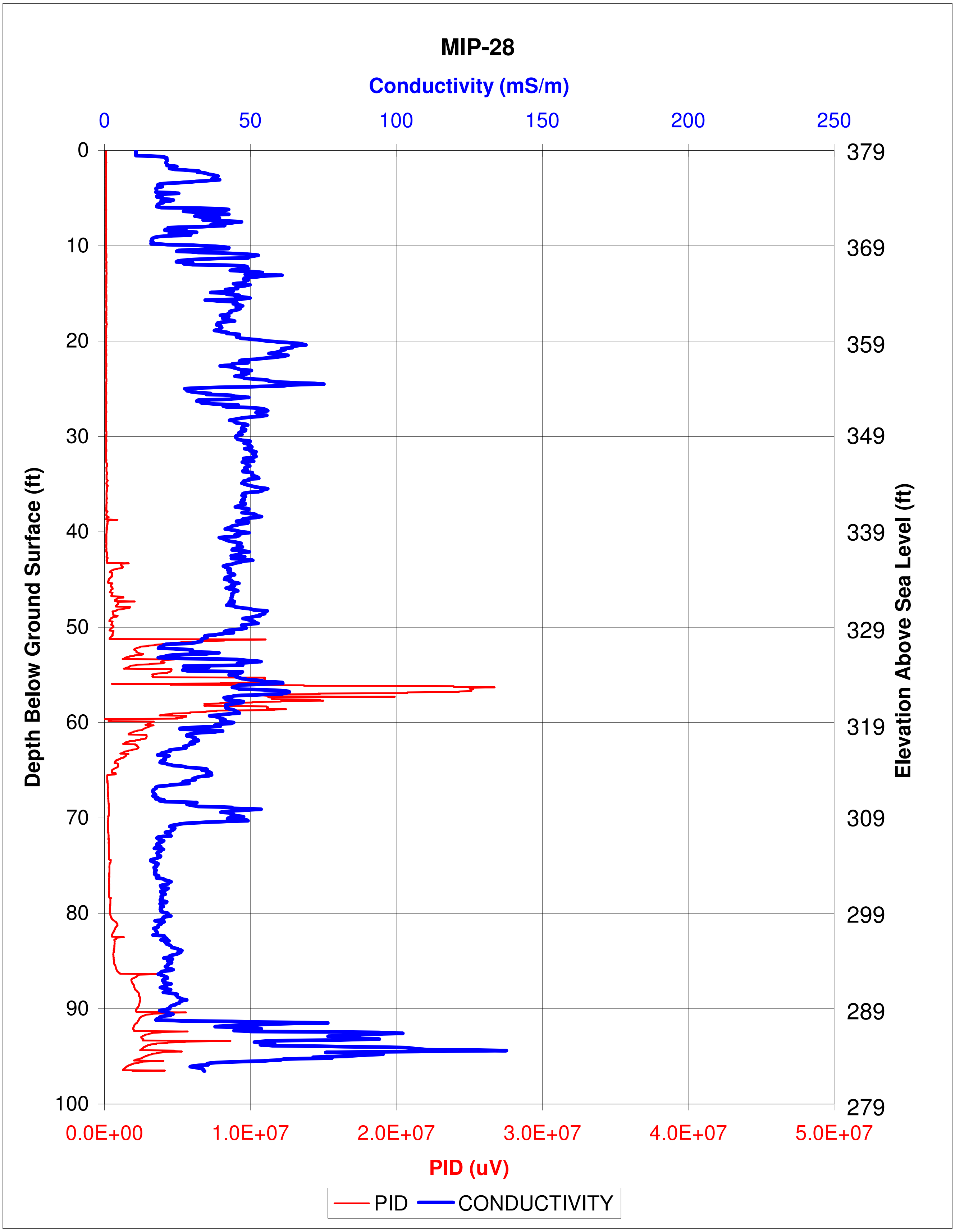

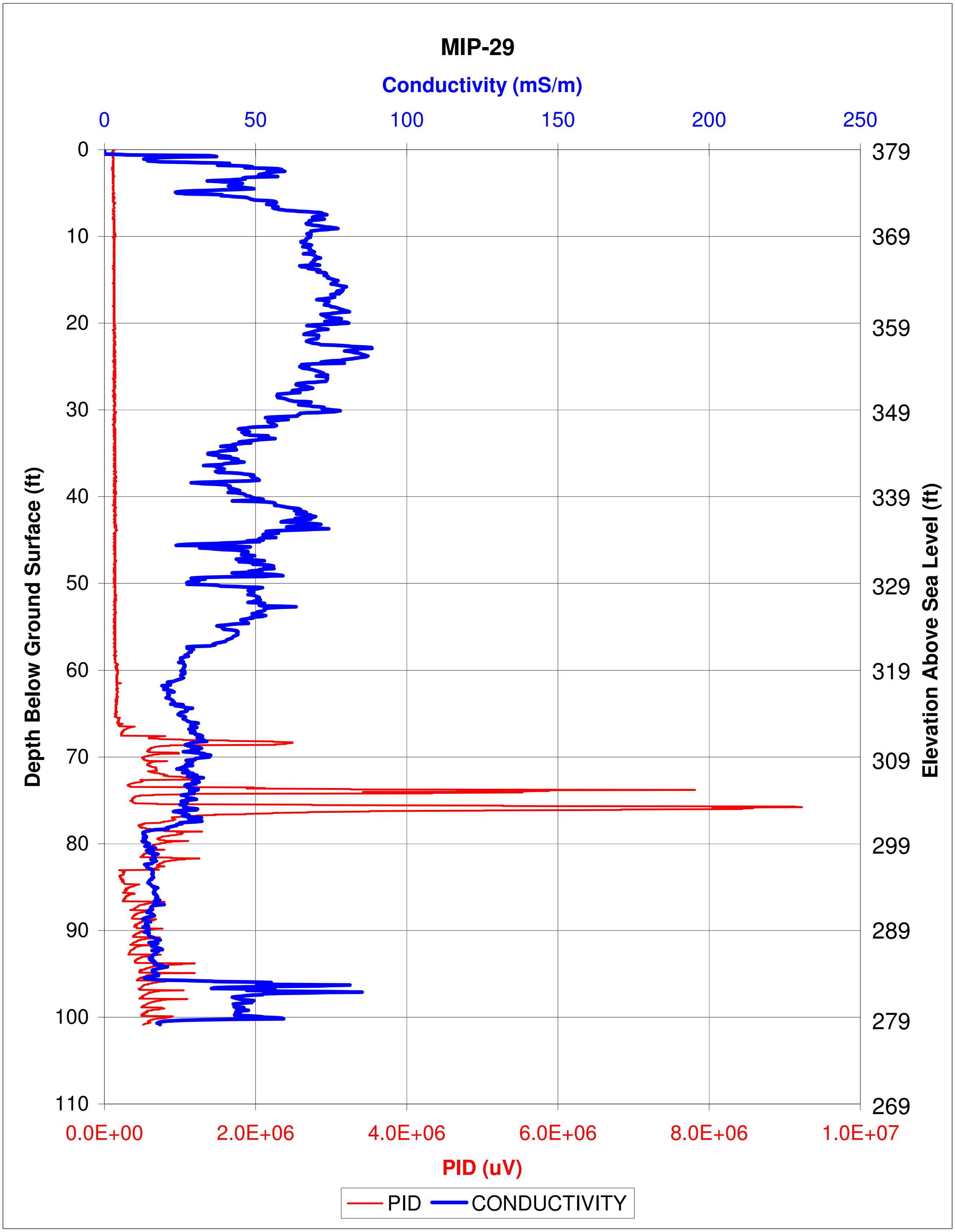
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Conductivity (mS/m)
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100
150
200
250
Depth Below Ground Surface (ft)
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90
100
110
Elevation Above Sea Level (ft)
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369
359
349
339
329
319
309
299
289
279
269
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6.0E+06
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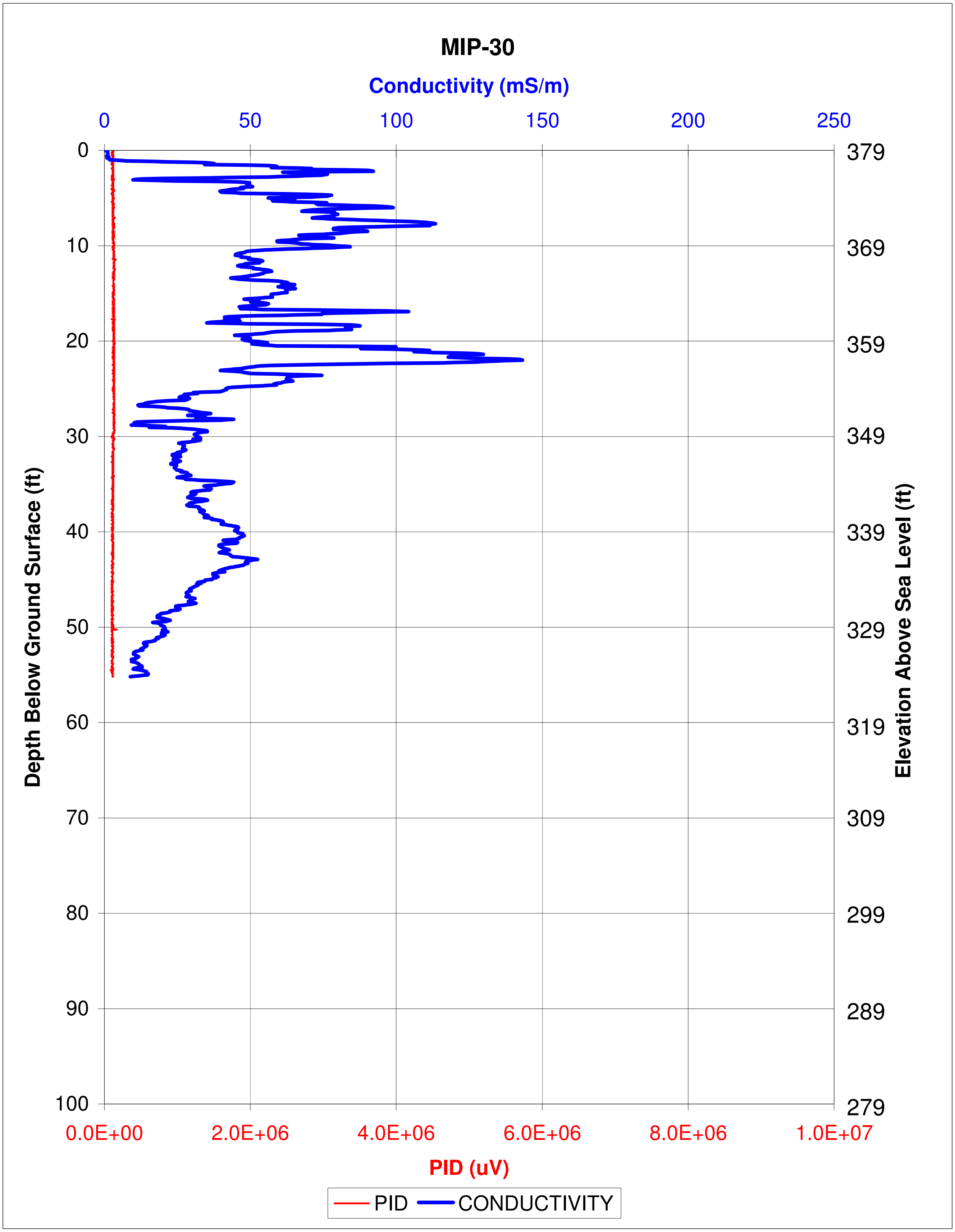
PID
CONDUCTIVITY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200
250
Depth Below Ground Surface (ft)
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50
60
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80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
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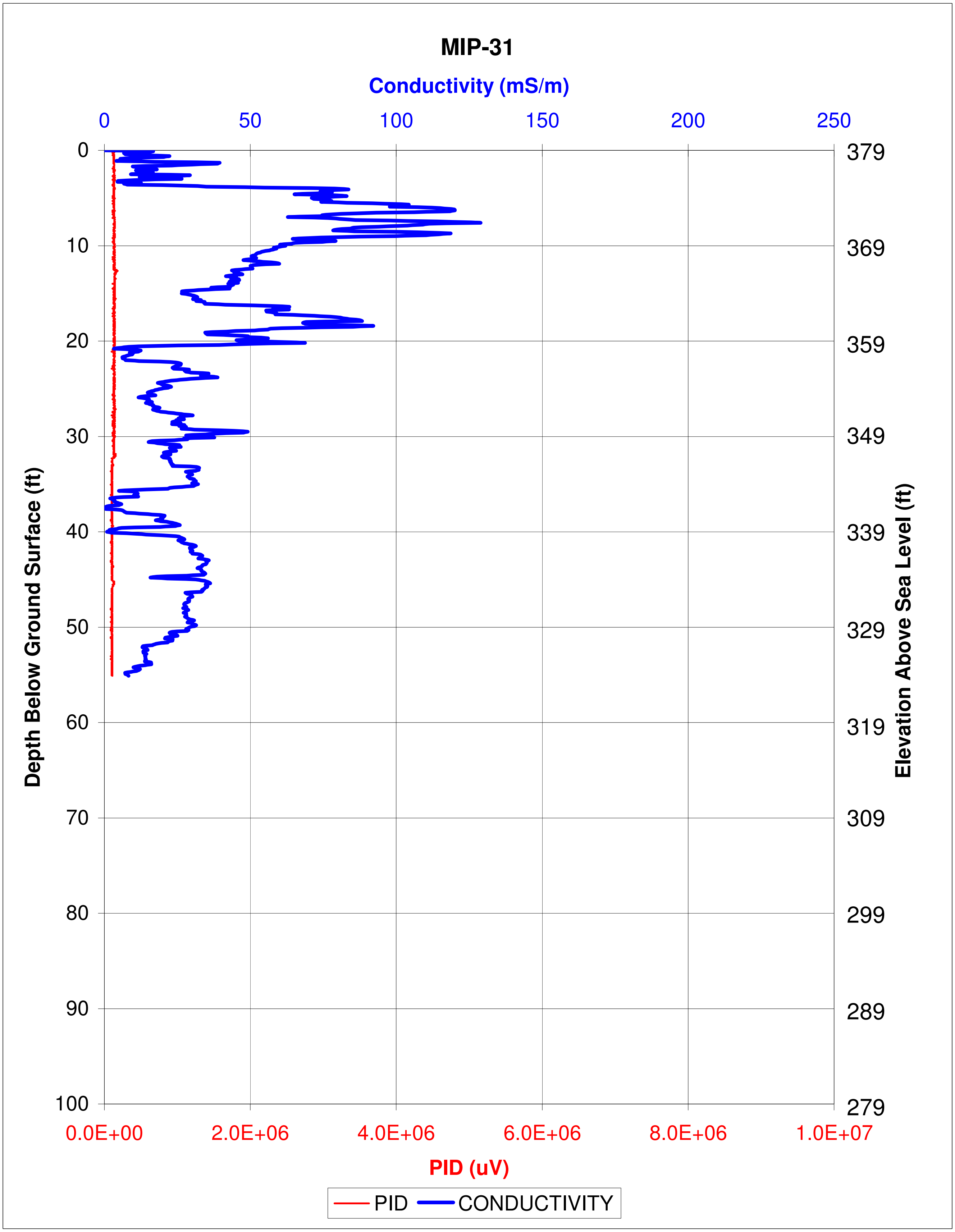
PID (uV)
PID
CONDUCTIVITY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60
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90
100
Elevation Above Sea Level (ft)
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369
359
349
339
329
319
309
299
289
279
0.0E+00
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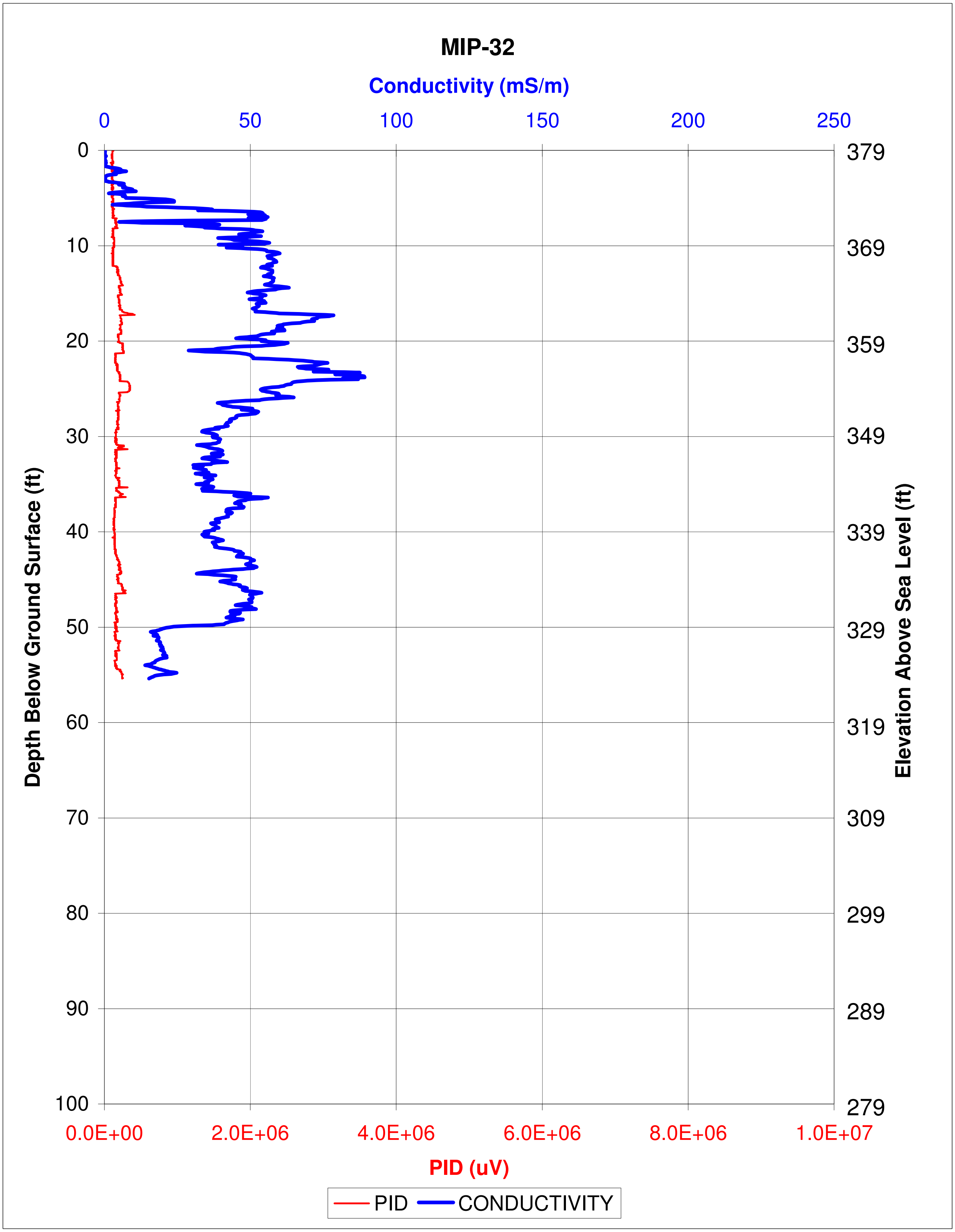
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY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Conductivity (mS/m)
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200
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Depth Below Ground Surface (ft)
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50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
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4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
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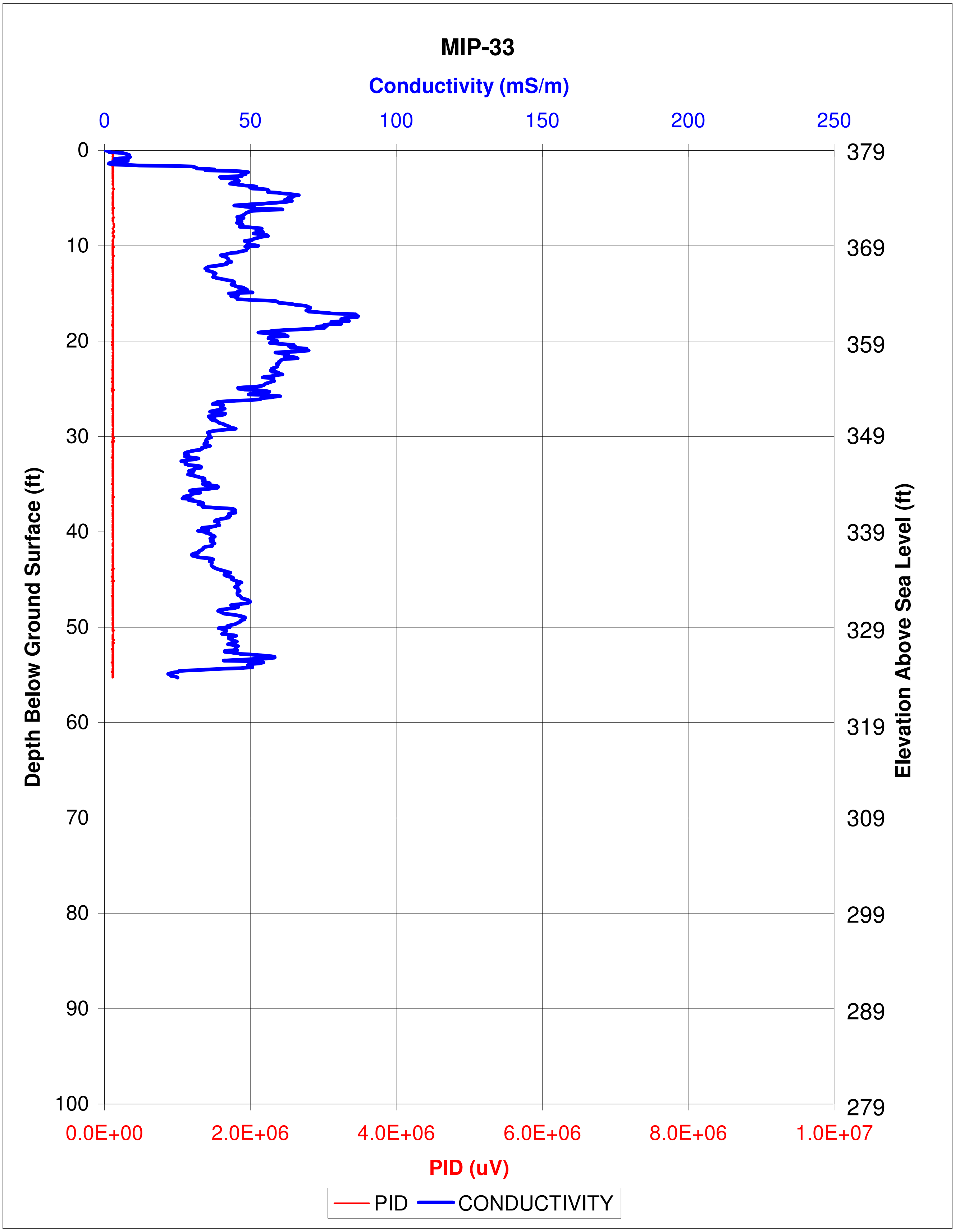
CONDUCTIVITY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Conductivity (mS/m)
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50
60
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80
90
100
Elevation Above Sea Level (ft)
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369
359
349
339
329
319
309
299
289
279
0.0E+00
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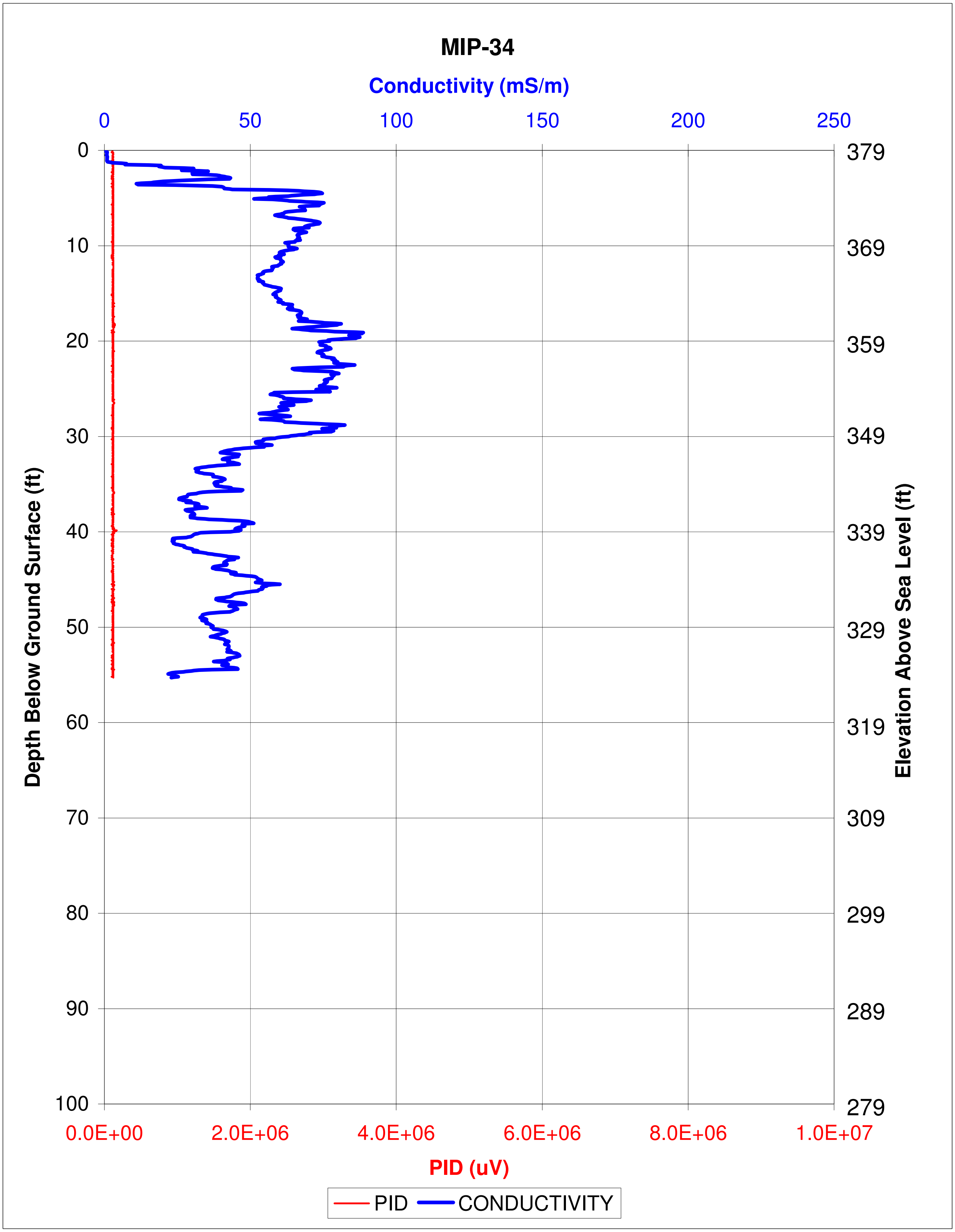
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-34
Conductivity (mS/m)
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200
250
Depth Below Ground Surface (ft)
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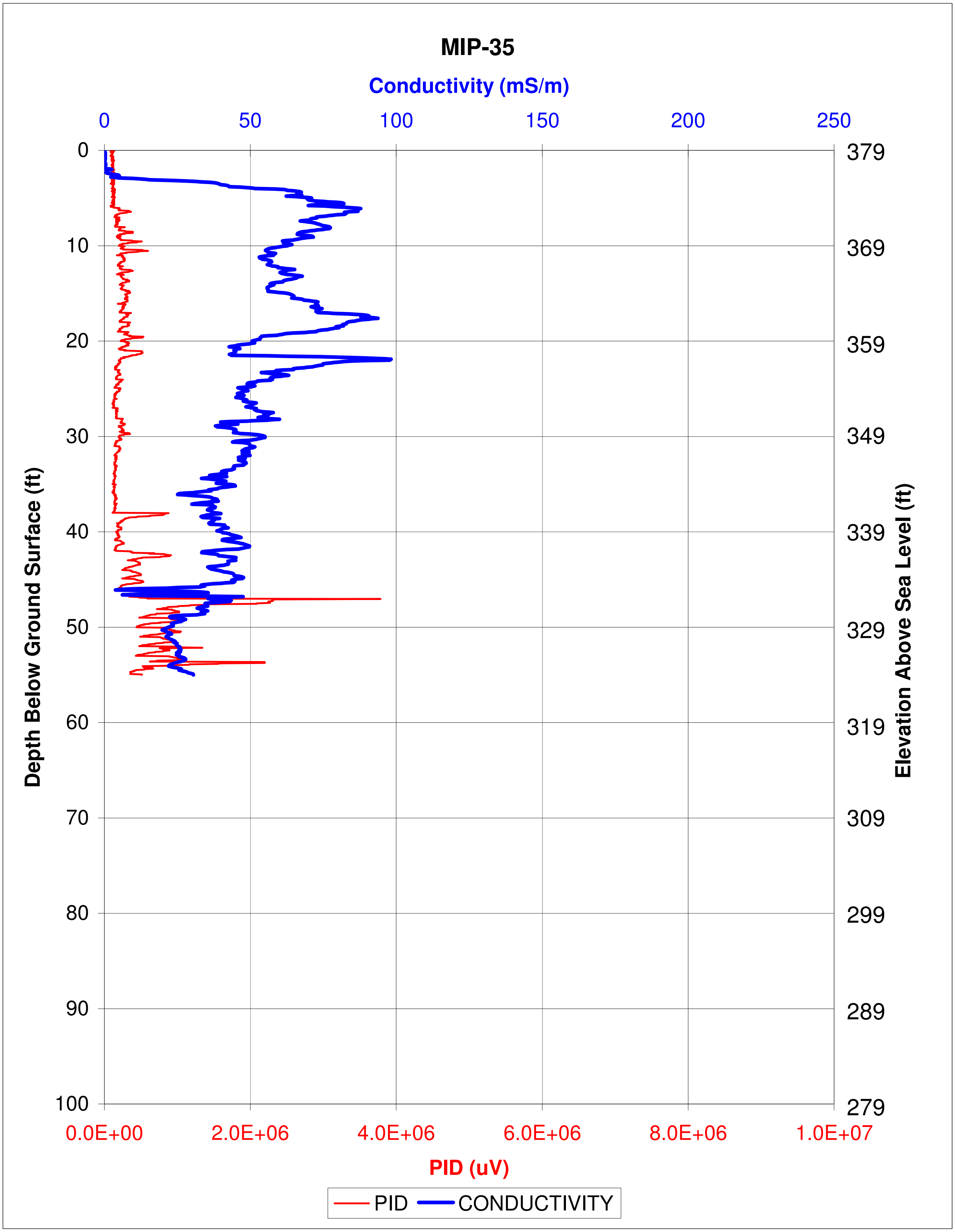
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-35
Conductivity (mS/m)
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100
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250
Depth Below Ground Surface (ft)
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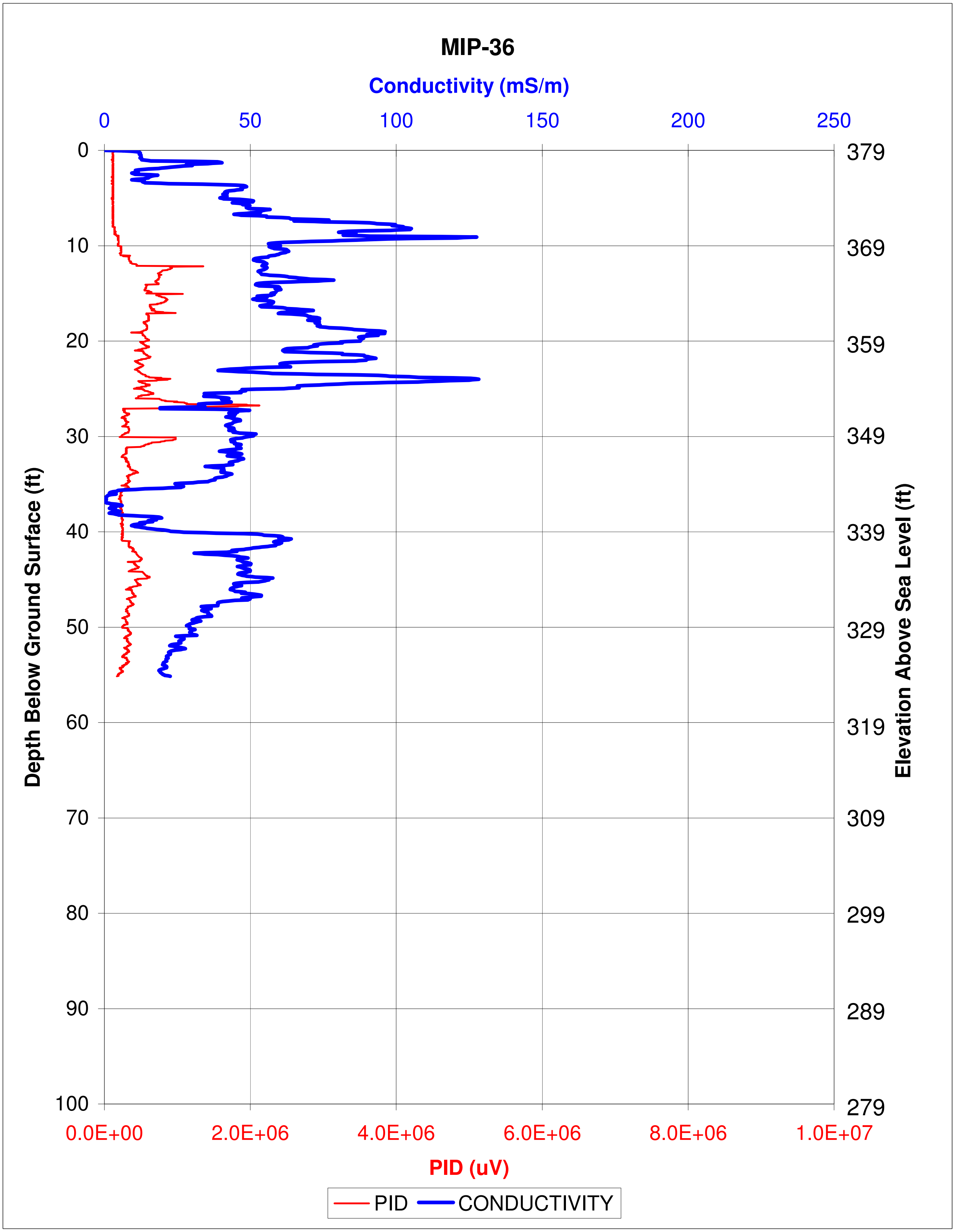
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-36
Conductivity (mS/m)
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100
150
200
250
Depth Below Ground Surface (ft)
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10
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30
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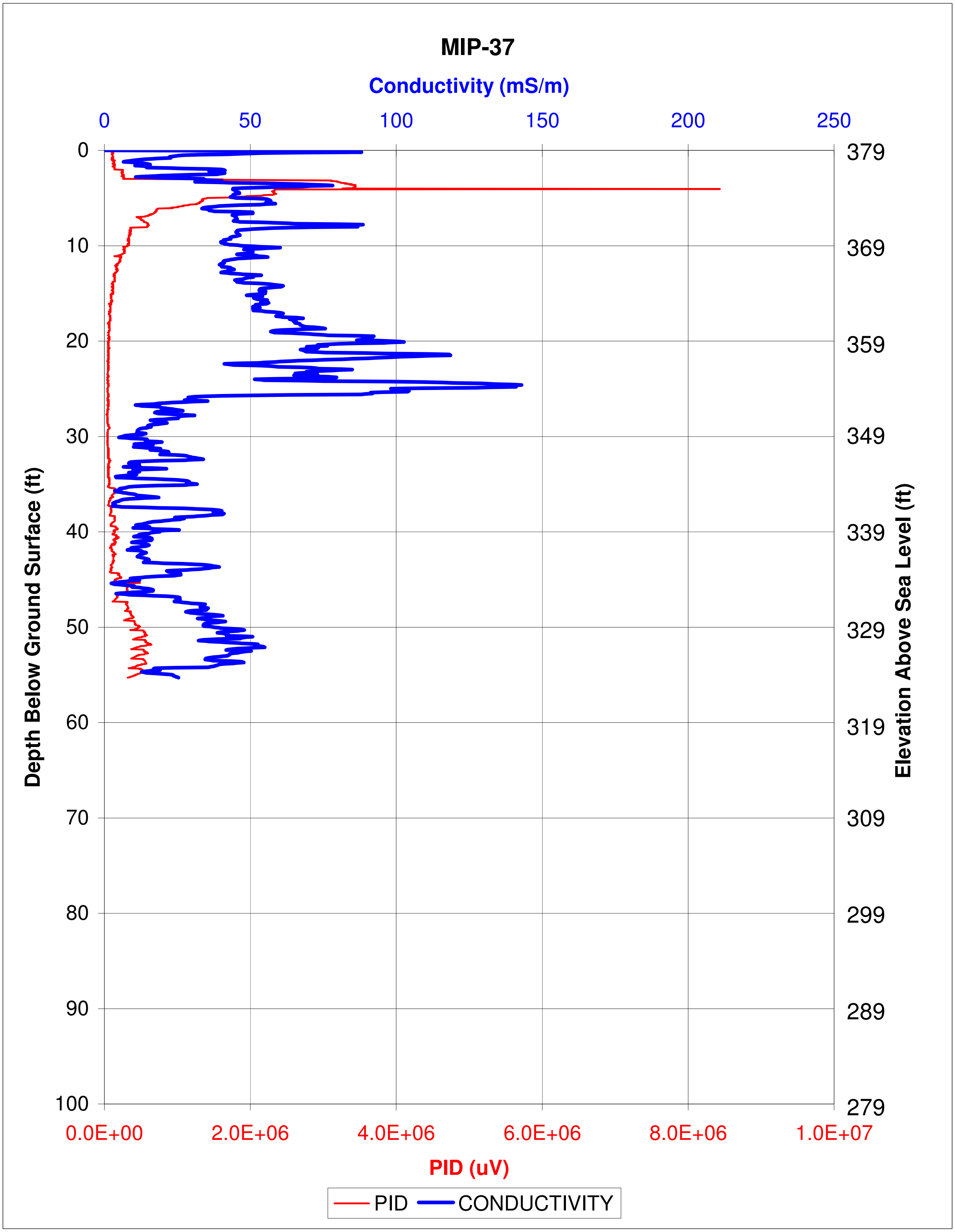
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-37
Conductivity (mS/m)
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100
150
200
250
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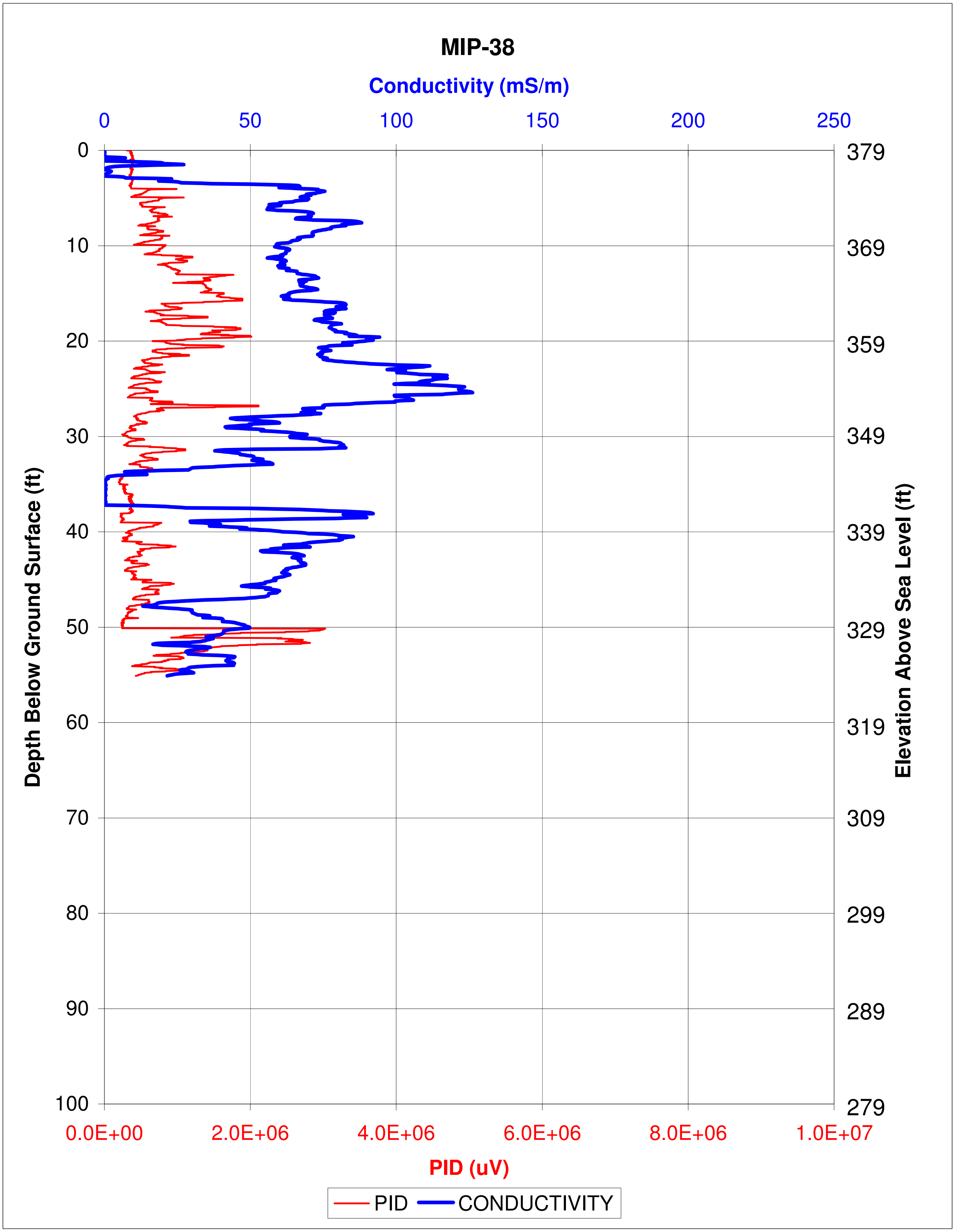
10
20
30
40
50
60
70
80
90
100
379
369
359
349
339
329
319
309
299
289
279
Depth Below Ground Surface (ft)
Elevation Above Sea Level (ft)
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-38
Conductivity (mS/m)
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100
150
200
250
Depth Below Ground Surface (ft)
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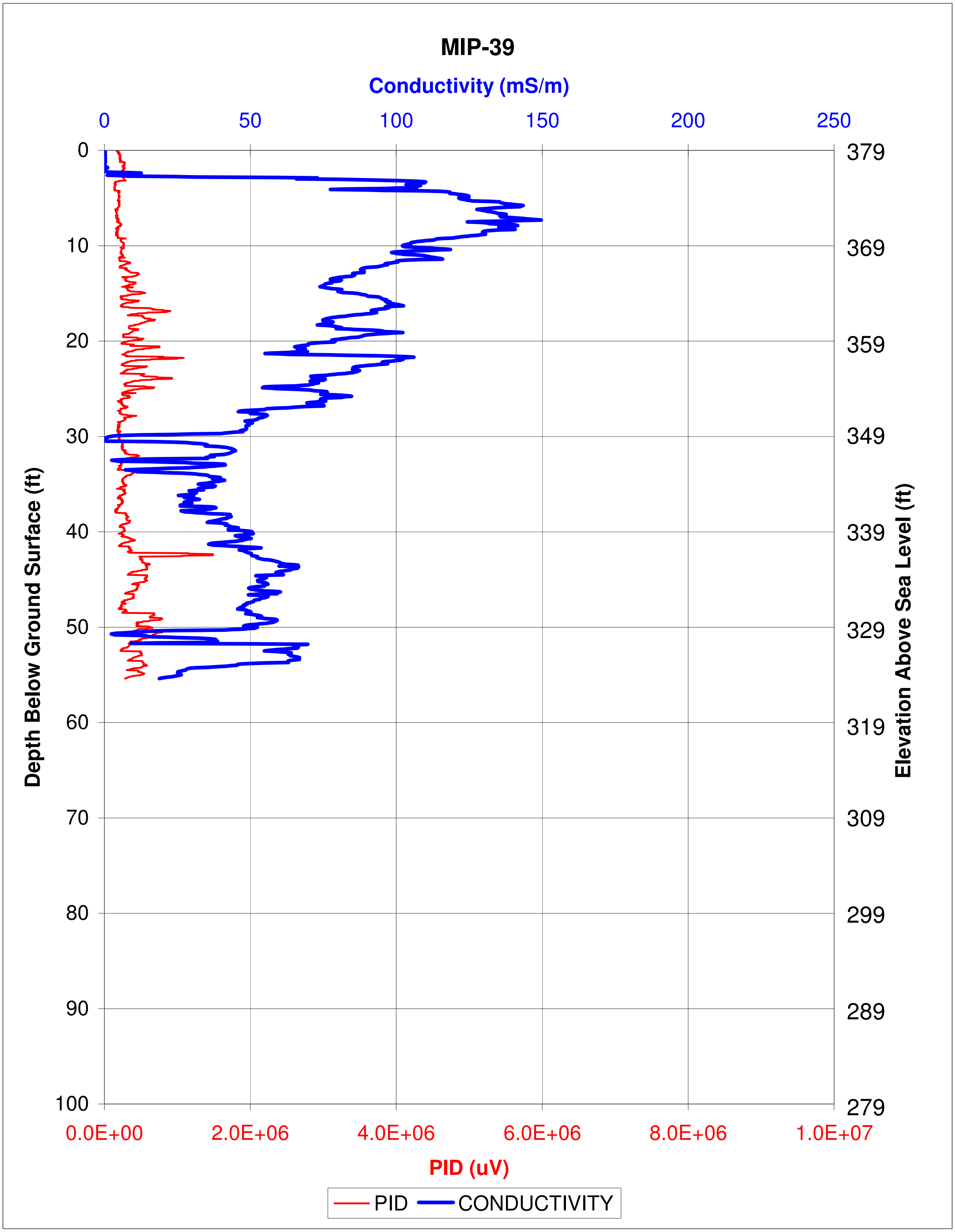
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-39
Conductivity (mS/m)
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150
200
250
Depth Below Ground Surface (ft)
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50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

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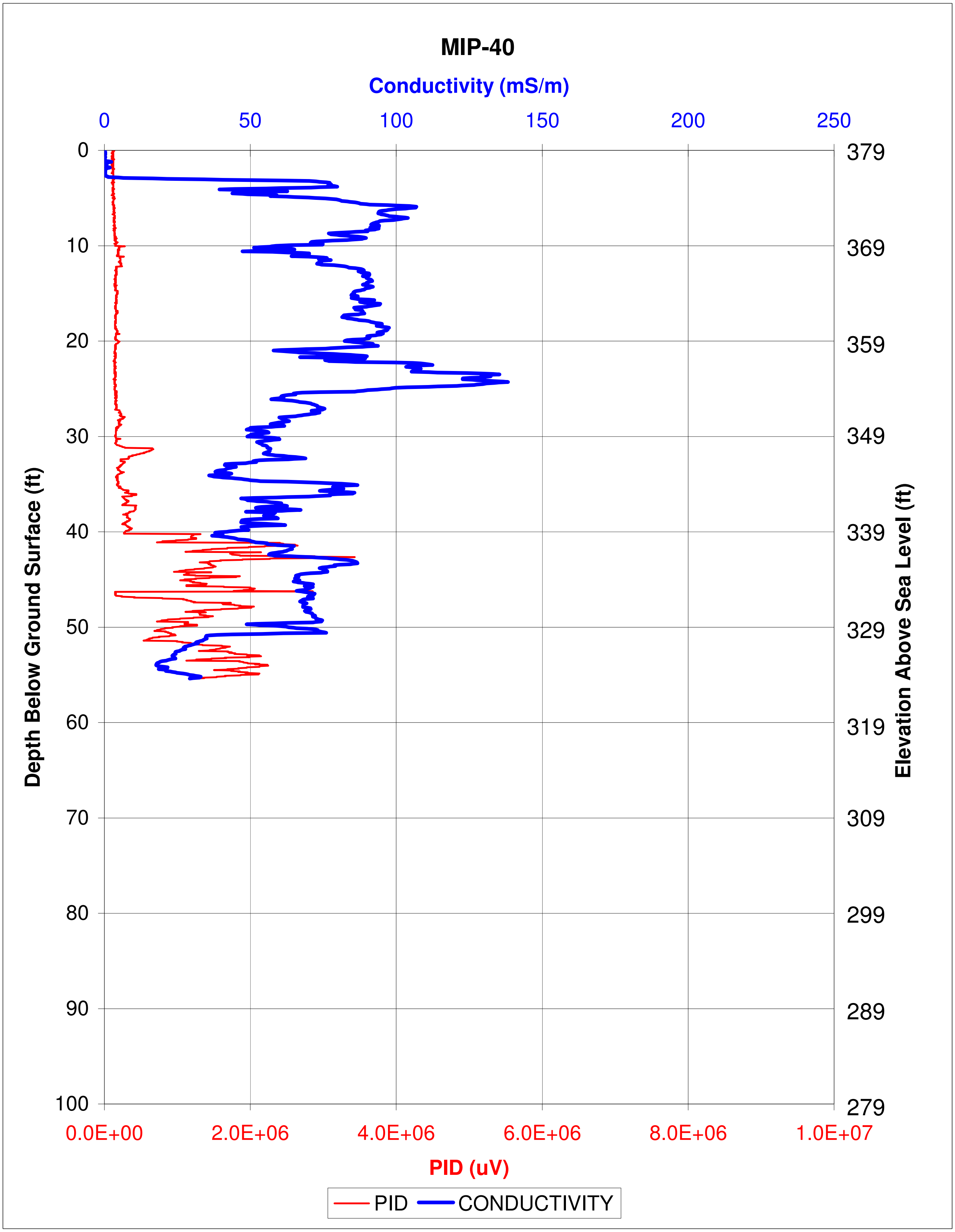

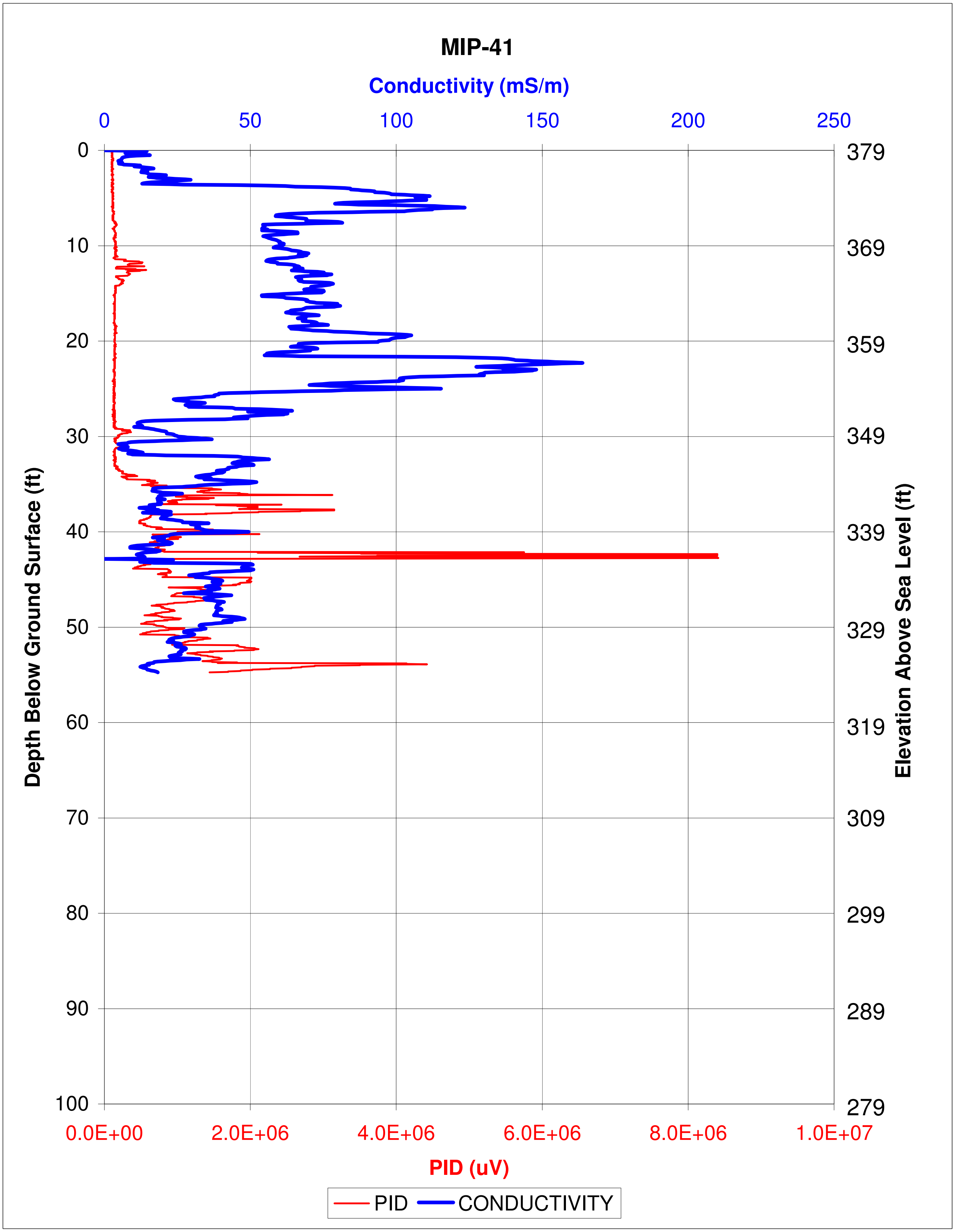
MIP-41
Conductivity (mS/m)
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100
150
200
250
Depth Below Ground Surface (ft)
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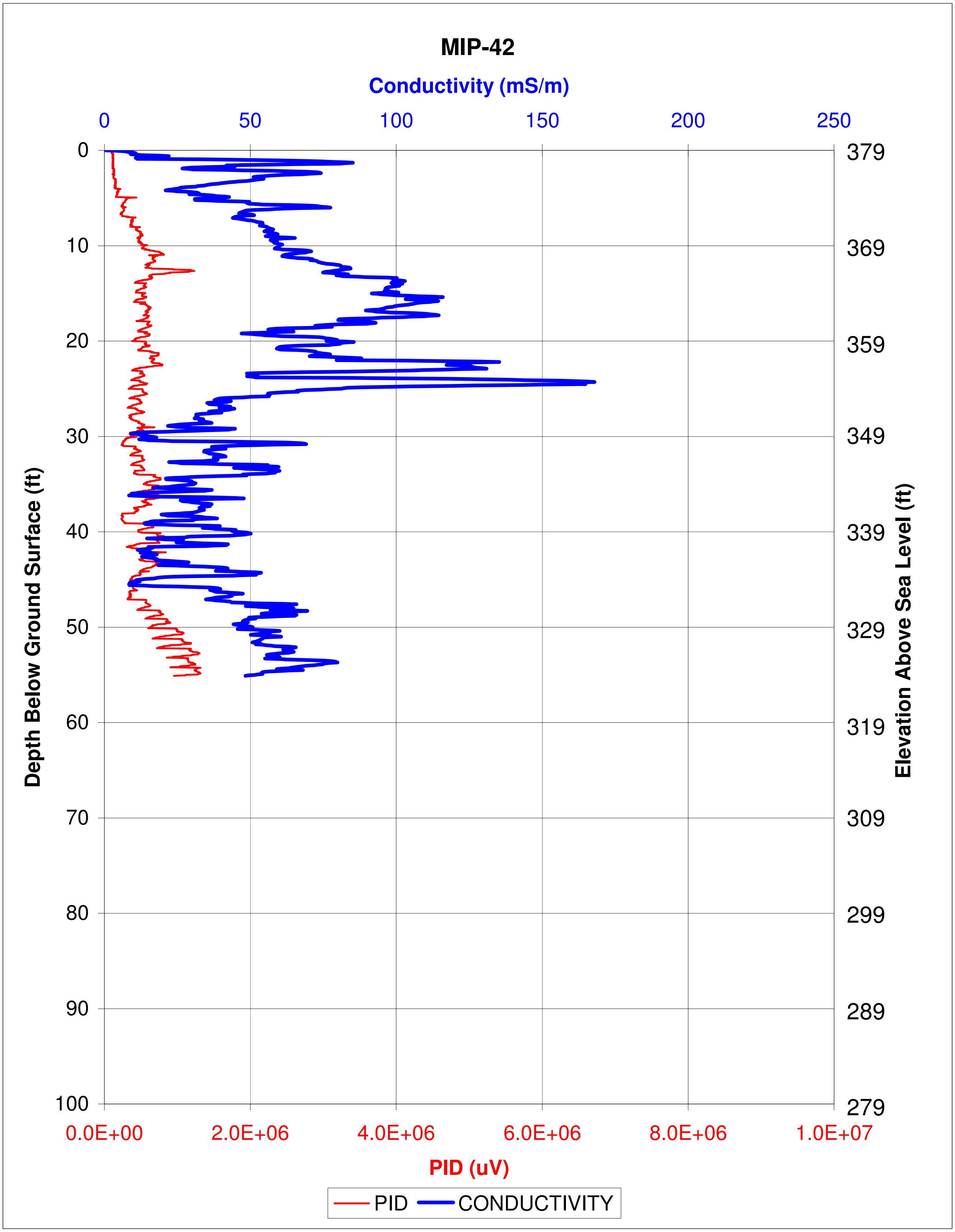
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-42
Conductivity (mS/m)
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100
150
200
250
Depth Below Ground Surface (ft)
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20
30
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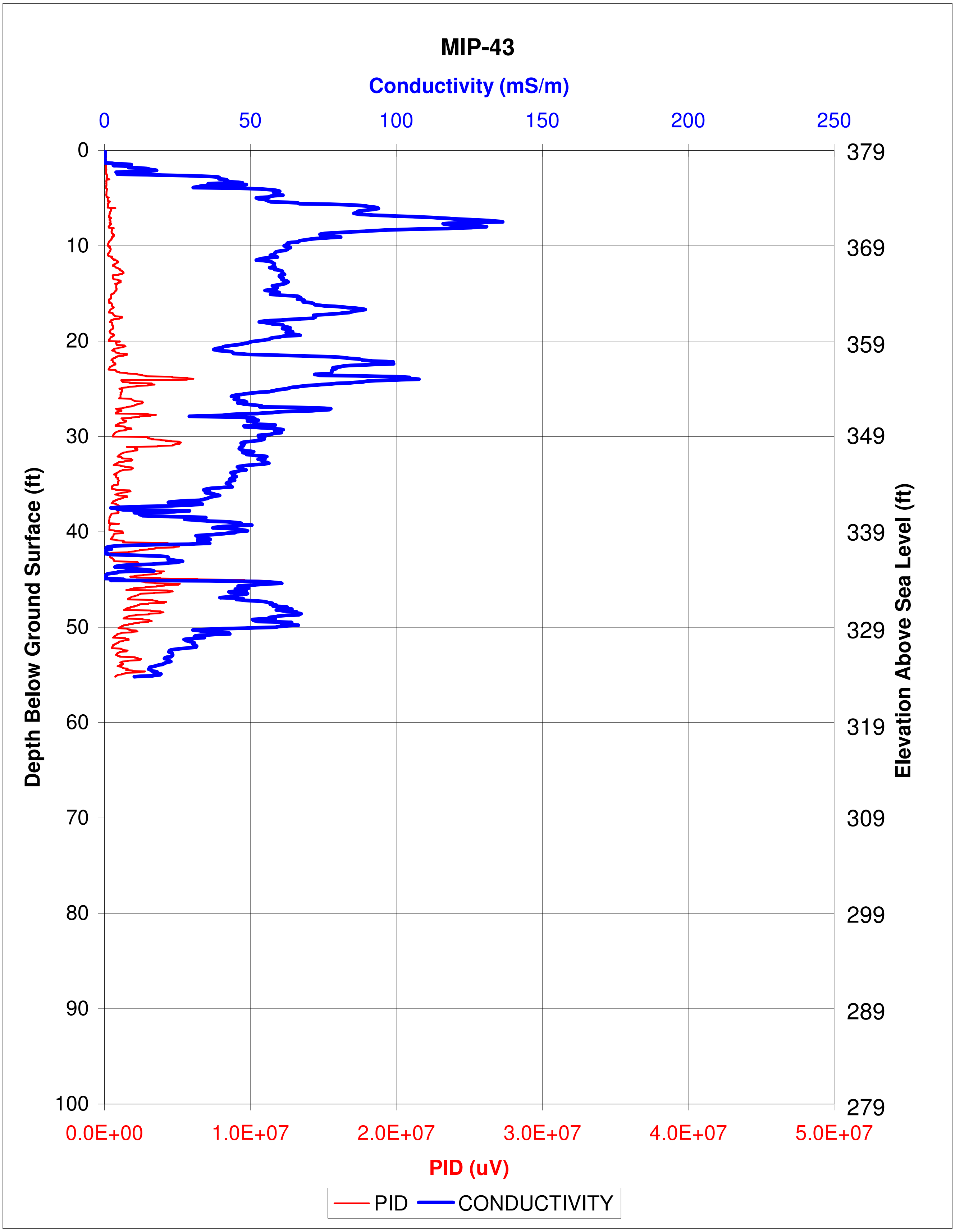
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY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Conductivity (mS/m)
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200
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Depth Below Ground Surface (ft)
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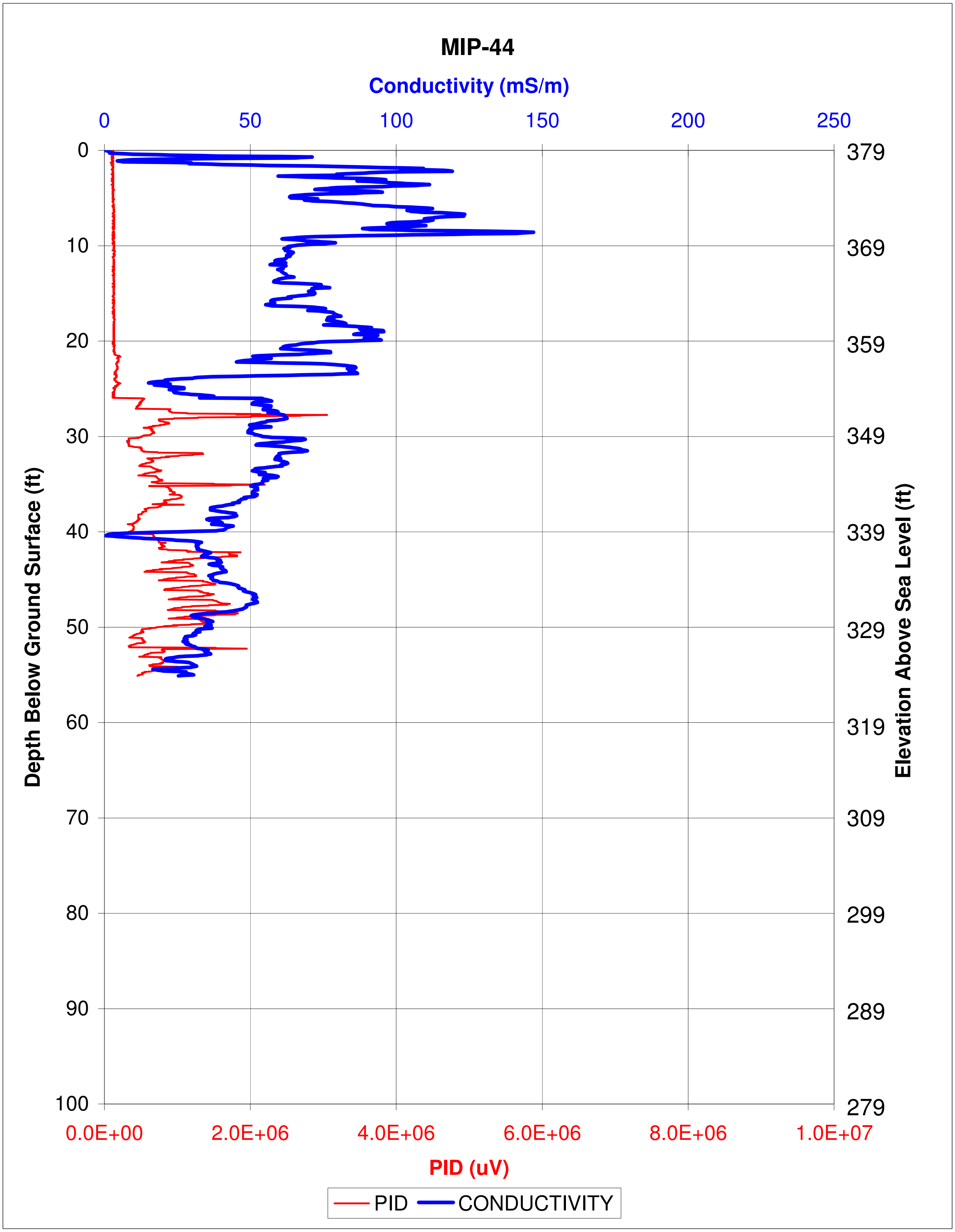
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
1.0E+07
2.0E+07
3.0E+07
4.0E+07
5.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-44
Conductivity (mS/m)
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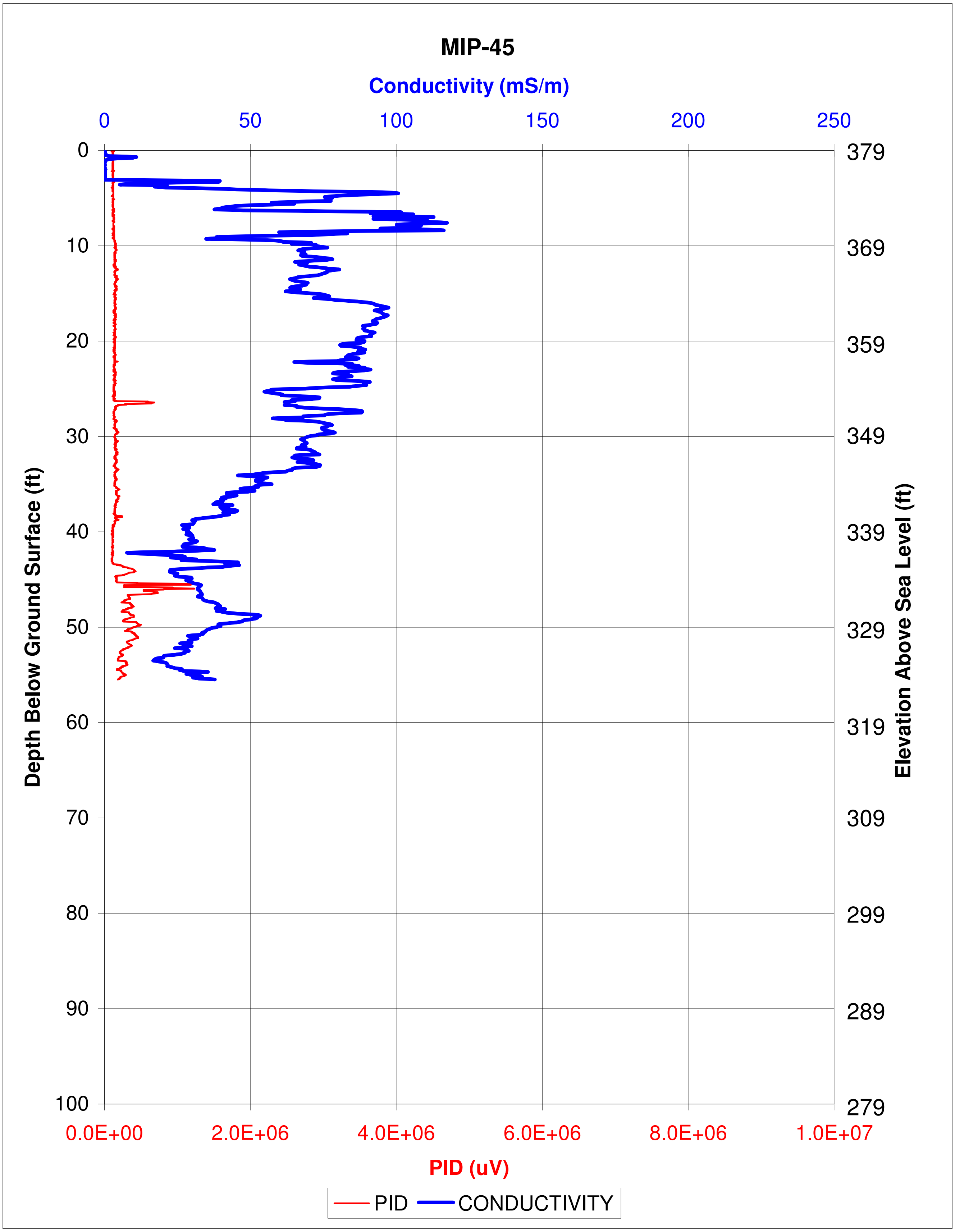
100
150
200
250
Depth Below Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-45
Conductivity (mS/m)
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150
200
250
Depth Below Ground Surface (ft)
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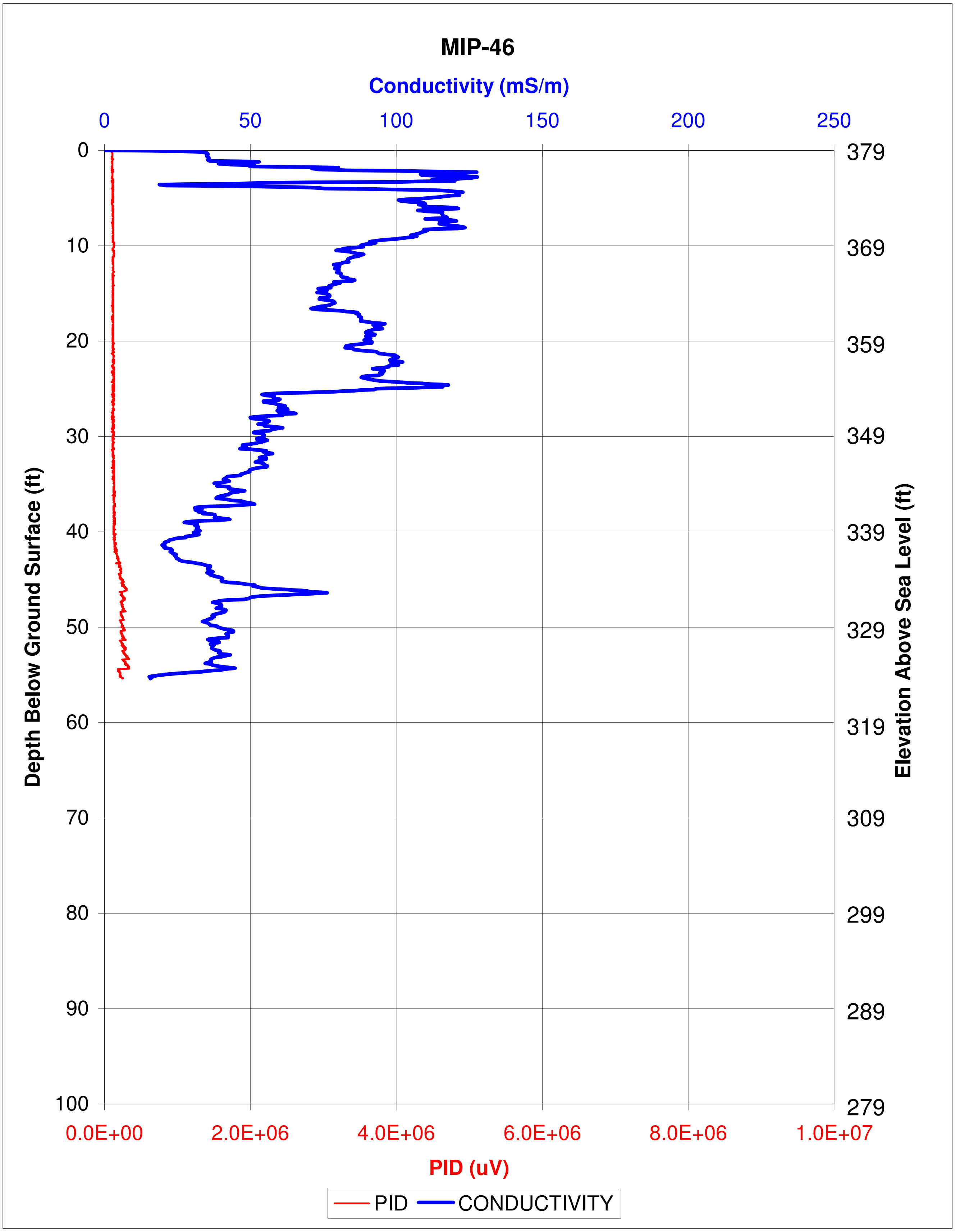
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-46
Conductivity (mS/m)
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100
150
200
250
Depth Below Ground Surface (ft)
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30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

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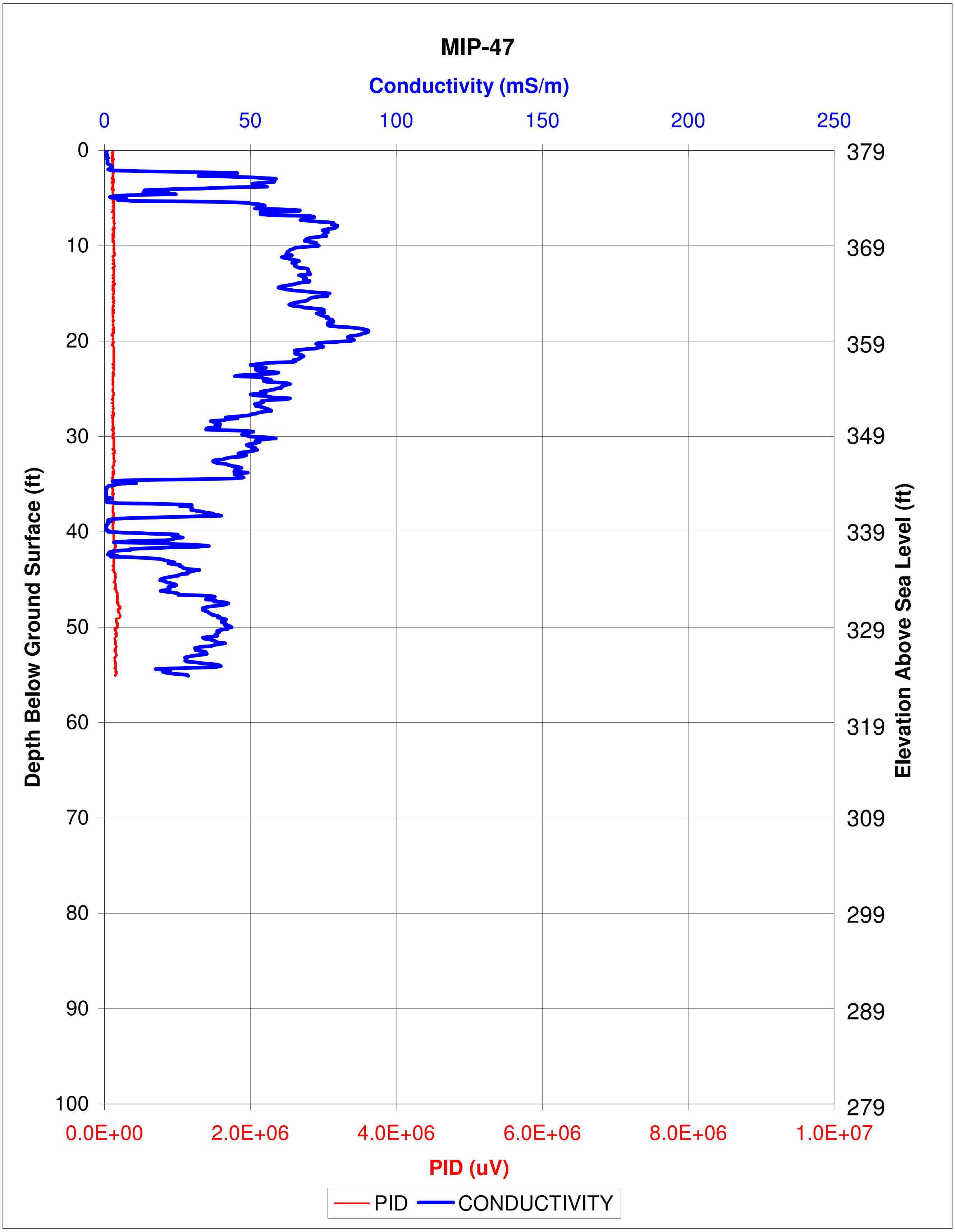

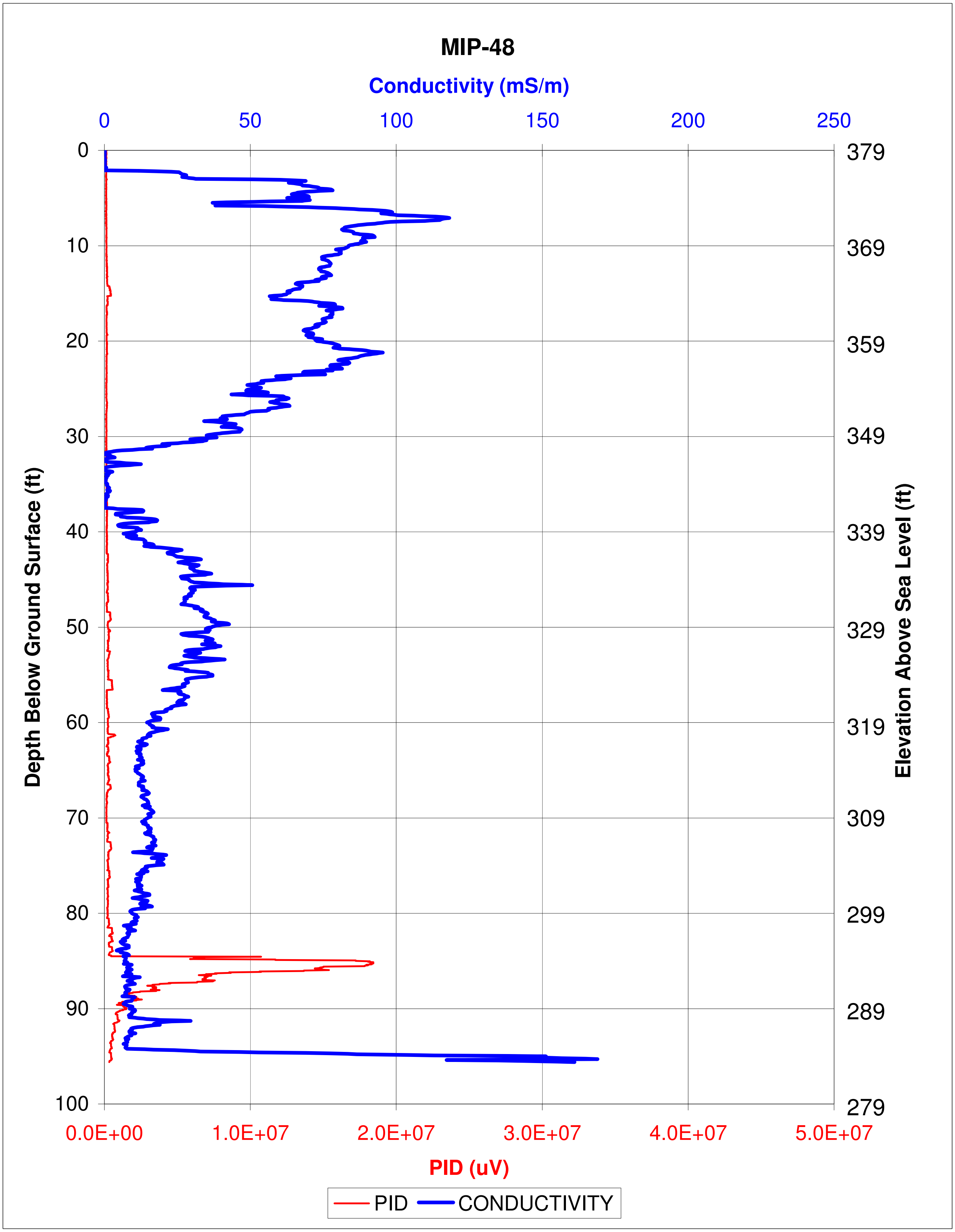
MIP-48
Conductivity (mS/m)
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150
200
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Depth Below Ground Surface (ft)
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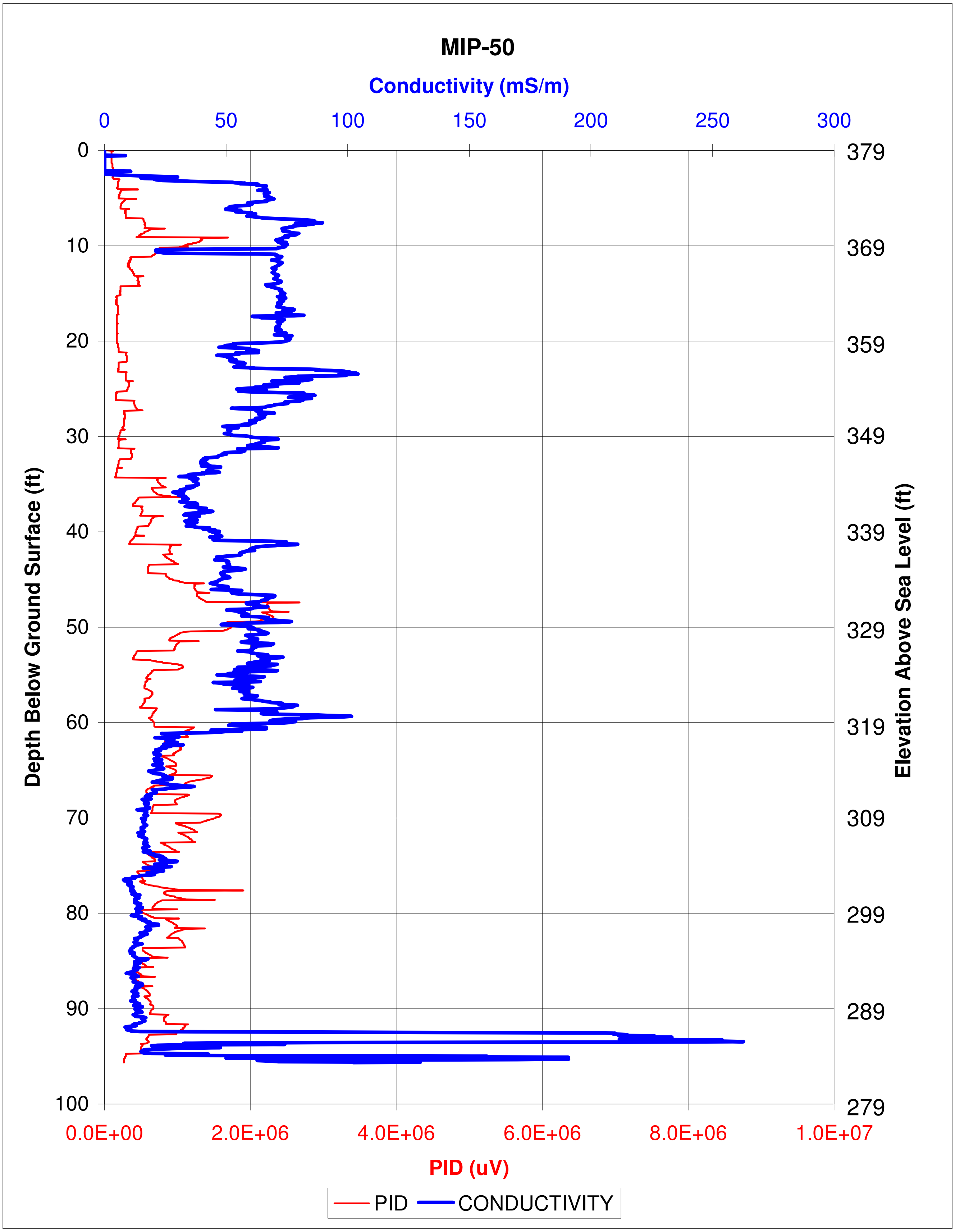
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
1.0E+07
2.0E+07
3.0E+07
4.0E+07
5.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-50
Conductivity (mS/m)
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100
150
200
250
300
Depth Below Ground Surface (ft)
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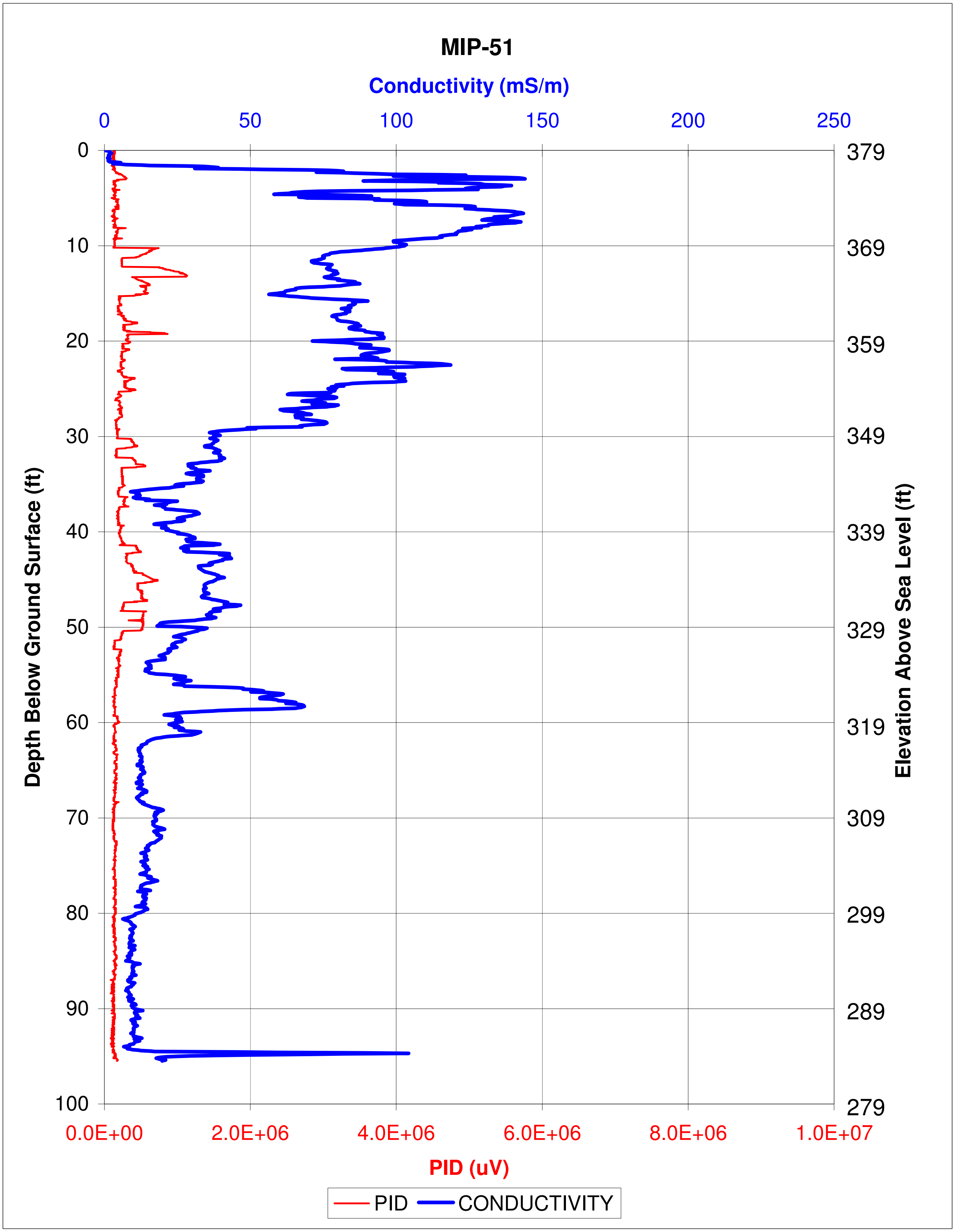
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-51
Conductivity (mS/m)
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150
200
250
Depth Below Ground Surface (ft)
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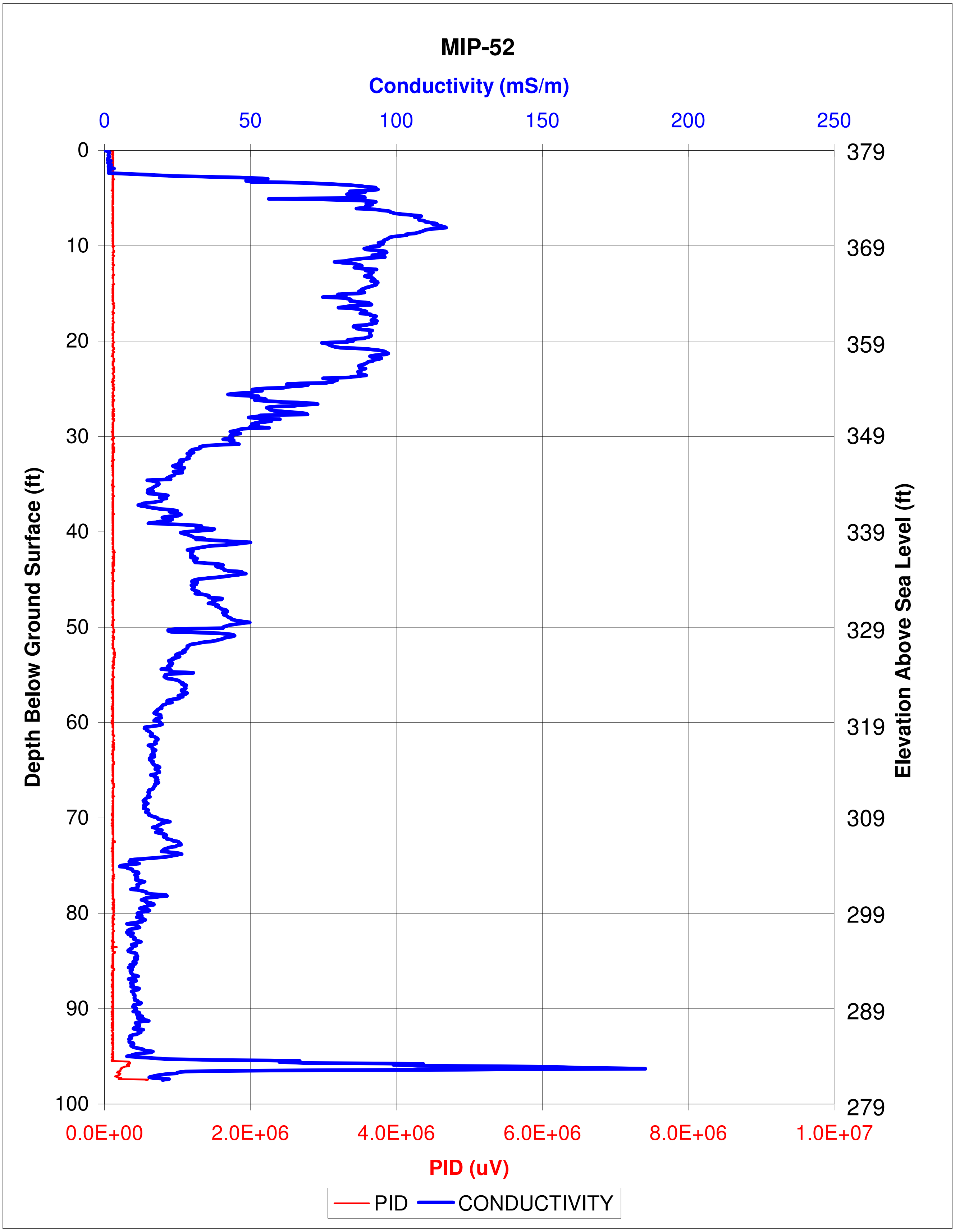
10
20
30
40
50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY


MIP-52
Conductivity (mS/m)
0
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150
200
250
Depth Below Ground Surface (ft)
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50
60
70
80
90
100
Elevation Above Sea Level (ft)
379
369
359
349
339
329
319
309
299
289
279
0.0E+00
2.0E+06
4.0E+06
6.0E+06
8.0E+06
1.0E+07
PID (uV)
PID
CONDUCTIVITY

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CD with Additional Logs of the ECD and FID Data of Each MIP Borehole

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ATTACHMENT A2

TCE ANALYSES OF SOIL AND GROUNDWATER FROM THE WASTE AREA GROUP 6 REMEDIAL INVESTIGATION FOR THE REMEDIAL DESIGN SUPPORT INVESTIGATION AREA

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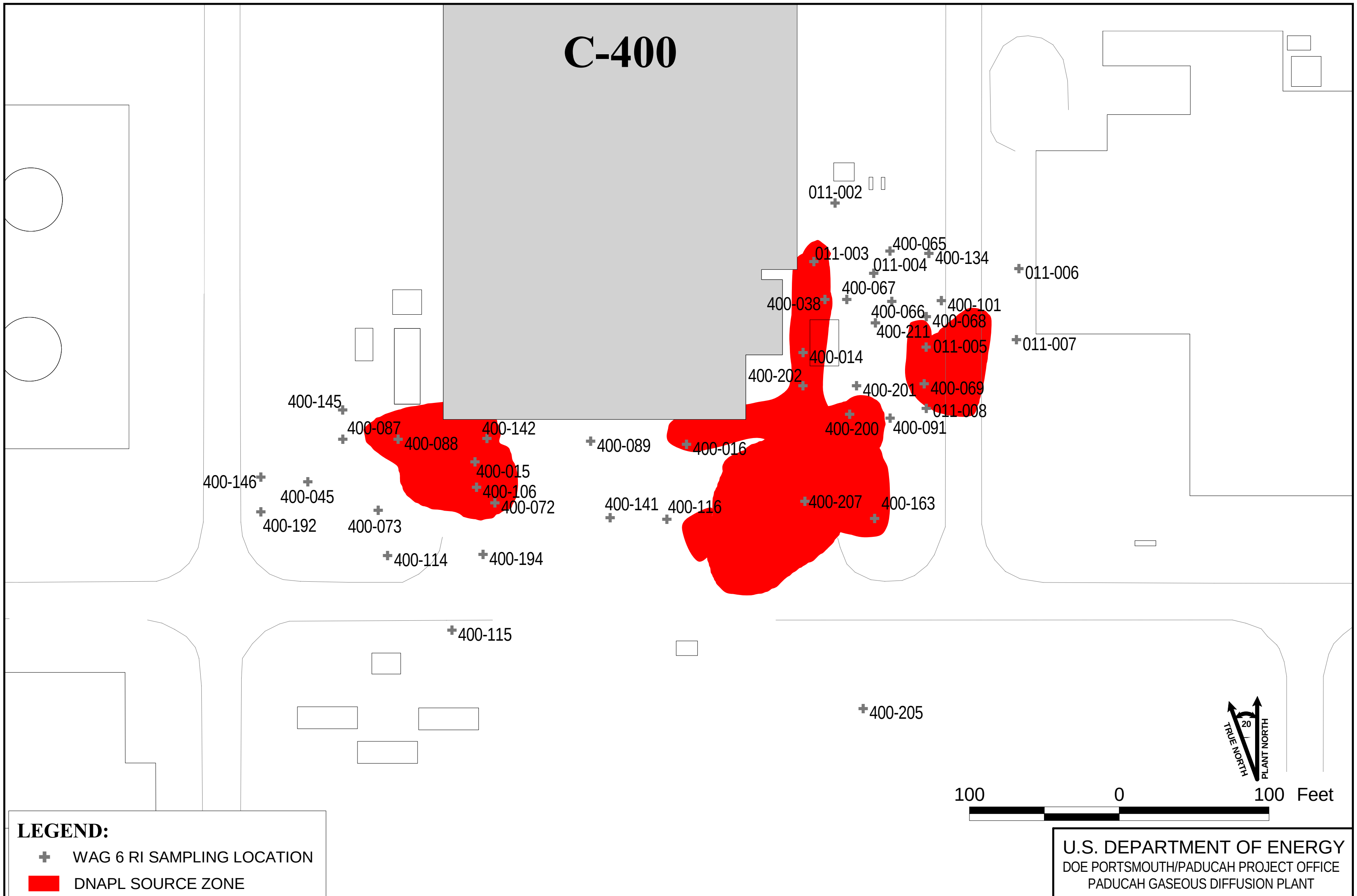

Attachment A2. Location of Waste Area Group 6 Remedial Investigation Soil Borings

LATA Environmental Services of Kentucky, LLC

Figure No. c5ac90005sk012basemap.apr
DATE 11-26-07

GROUNDWATER DATA OF MIP INVESTIGATION AREA

BORING	DEPTH (ft)	TCE (ug/L) SW846-8010M
400-037	61	79,078
400-037	66	172,858
400-037	74	701,184
400-037	76	638,576
400-037	81	419,380
400-037	86	42,072
400-037	91	39,096
400-037	96	85,597
400-038	61	60
400-038	66	3,656
400-038	71	4,464
400-038	76	745
400-038	87.5	1,352
400-038	81	1,010
400-038	86	19,373
400-045	64	24,473
400-045	69	13,549
400-045	74	630
400-045	79	246
400-045	84	129
400-045	89	137
MW155	89.5	6,900
MW156	66.5	26,000

Note, all groundwater samples except for boring 400-037 (96 ft depth) were collected from the RGA. The sample from boring 400-037, at 96 ft depth, represents the McNairy Formation.

SOIL DATA OF MIP INVESTIGATION AREA

	DEPTH (ft)		TCE (ug/kg)		DEPTH (ft)		TCE (ug/kg)
BORING	TOP	BOTTOM	SW846-8010M	BORING	TOP	BOTTOM	SW846-8010M
011-002	0	4	<800	011-006	0	4	<700
011-002	4	8	<1,000	011-006	4	8	<700
011-002	8	12	<700	011-006	8	12	<800
011-002	12	16	<800	011-006	12	16	<600
011-002	16	20	<900	011-006	16	20	<600
011-002	20	24	<700	011-006	20	24	<600
011-002	24	28	<800	011-006	24	28	<600
011-002	28	32	<1,100	011-006	28	32	<700
011-002	36	40	<1,000	011-006	32	36	<600
011-002	40	43	<1,000	011-006	36	40	<500
011-002	43	47	<700	011-006	40	44	<600
011-003	0	4	<1,000	011-006	44	48	7,800
011-003	8	11	<700	011-007	24	28	<600
011-003	14	17	<1,000	011-007	36	40	<600
011-003	17	20	<800	011-008	13	17	<700
011-003	20	24	<800	400-014	0	4	2,200
011-003	24	28	<800	400-014	4	8	23,000
011-003	28	32	<700	400-014	8	12	52,000
011-003	32	36	<700	400-014	12	16	66,000
011-003	36	40	6,200	400-014	16	20	65,600
011-003	40	44	29,000	400-014	20	24	64,000
011-003	44	48	13,000	400-014	24	28	16,100
011-004	0	4	<700	400-014	28	31	2,200
011-004	4	8	<1,000	400-014	31	35	1,300
011-004	8	12	<700	400-014	35	38	14,900
011-004	12	16	<700	400-014	38	42	100,000
011-004	16	20	<700	400-014	42	45	42,000
011-004	20	24	<800	400-014	45	49	200,000
011-004	24	27	<800	400-015	3	8	<1,100
011-004	27	31	<800	400-015	8	12	35,000
011-004	31	34	<800	400-015	19	23	200,000
011-004	34	38	<800	400-015	19	23	200,000
011-004	38	41	<800	400-015	30	33	94,400
011-004	41	45	<600	400-015	40	43	28,000
011-004	45	48	<1,000	400-016	5	8	<800
011-005	4	8	<800	400-016	8	12	<500
011-005	20	24	12,800	400-016	16	20	1,500
011-005	24	28	57,200	400-016	20	24	1,800
011-005	28	32	8,000,000	400-016	30	34	1,900
011-005	32	35	1,700				
011-005	35	39	<700				
011-005	39	42	<600				
011-005	42	45	500 J				
011-005	45	49	1,500				

SOIL DATA OF MIP INVESTIGATION AREA

	DEPTH (ft)		TCE (ug/kg)		DEPTH (ft)		TCE (ug/kg)
BORING	TOP	BOTTOM	SW846-8010M	BORING	TOP	BOTTOM	SW846-8010M
400-038	5	5	<700	400-145	0	4	<600
400-038	10	11	4,600	400-145	4	8	<700
400-038	15	15	6,300	400-145	8	12	<600
400-038	20	20	6,300	400-145	10	10	<900
400-038	25	25	6,400	400-145	12	16	<700
400-038	30	30	1,400	400-145	16	20	<600
400-038	35	35	<800	400-145	18	18	<800
400-038	39	39	9,600	400-145	20	24	<700
400-038	46	49	30,000	400-145	22	22	<600
400-038	49	49	26,000	400-145	24	28	<600
400-038	53	53	<800	400-145	26	26	<800
400-045	6	10	18,200	400-145	28	32	<700
400-065	9	13	<500	400-145	32	34	<800
400-066	13	17	<700	400-145	34	34	<700
400-067	8	12	5,600	400-145	36	40	<1200
400-068	13	17	11,400	400-145	38	38	<500
400-069	13	17	4,100	400-145	40	44	<600
400-072	13	17	<500	400-145	42	42	<400
400-073	13	17	3,000	400-146	15	19	8,800
400-087	4	8	2,900	400-163	21	25	22,100
400-088	6	10	<1,000	400-163	24	28	11,000
400-089	6	10	12,000	400-163	28	32	46,000
400-091	8	12	2,000	400-163	32	36	15,000
400-101	7	11	<600	400-163	36	40	60,000
400-106	13	17	9,500	400-163	40	44	75,000
400-114	6	10	<500	400-163	44	48	36,000
400-115	14	18	<600	400-192	4	8	<900
400-116	8	12	<600	400-192	8	12	<900
400-134	12	16	8,200	400-192	12	16	<700
400-141	0	4	<900	400-192	16	20	<900
400-141	4	8	<700	400-192	20	24	<700
400-141	8	12	<700	400-192	24	28	<700
400-141	12	16	<900	400-192	28	32	<1,000
400-141	16	20	<800	400-192	32	36	<1,000
400-141	20	24	<800	400-192	36	40	<900
400-141	24	28	<700	400-192	40	44	<700
400-141	28	32	<700	400-192	44	48	<800
400-141	32	36	<700				
400-141	36	40	<1,000				
400-141	40	44	<700				
400-141	44	48	<600				
400-142	7	11	25,000				

SOIL DATA OF MIP INVESTIGATION AREA

	DEPTH (ft)		TCE (ug/kg)		DEPTH (ft)		TCE (ug/kg)
BORING	TOP	BOTTOM	SW846-8010M	BORING	TOP	BOTTOM	SW846-8010M
400-194	0	4	<700	400-207	28	30	<600
400-194	4	8	<800	400-207	66	67	4,500
400-194	8	12	<1,000	400-207	82	83	24,000
400-194	12	16	<800	400-207	97	99	<800
400-194	16	20	<800	400-207 Duplicate	43	44	800
400-194	20	24	<800	400-207 Duplicate	71	72	65,000
400-194	24	28	<900	400-207 Duplicate	94	95	25,000
400-194	28	32	<700	400-207 Duplicate	102	103	<700
400-194	32	36	<800	400-211	0	4	<800
400-194	36	40	<1,100	400-211	4	8	<1,000
400-194	40	44	<800	400-211	8	12	<800
400-200	1	5	55,000	400-211	12	16	<800
400-200	5	9	10,000,000	400-211	16	20	<700
400-200	9	13	1,000,000	400-211	20	24	<900
400-200	13	17	40,000	400-211	24	28	<700
400-200	17	21	2,000,000	400-211	28	32	<800
400-200	17	21	2,000,000	400-211	32	36	<700
400-200	25	29	3,000,000	400-211	36	40	<1,400
400-201	20	24	200,000	400-211	40	44	<800
400-201	24	28	100,000	400-211	44	48	<700
400-201	28	32	93,000				
400-201	32	36	61,000				
400-201	36	40	1,900				
400-201	40	44	<1,100				
400-201	44	48	15,000				
400-202	0	4	200,000				
400-202	4	8	52,500				
400-202	8	12	49,700				
400-202	12	16	62,300				
400-202	16	20	62,900				
400-202	20	24	33,000				
400-202	24	28	14,200				
400-204	0	4	<700				
400-204	4	8	<900				
400-204	8	12	<800				
400-204	12	16	<800				
400-204	16	20	<800				
400-204	20	24	<800				
400-204	24	28	<900				
400-204	28	32	<700				
400-204	32	36	<1,000				
400-204	36	40	<800				
400-205	20	24	<700				
400-205	32	36	<700				
400-205	36	40	<800				
400-205	40	44	<800				
400-205	44	48	<700				

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ATTACHMENT A3

CONTOURED MAPS OF THE RESPONSES OF THE PHOTOIONIZATION DETECTOR, MAXIMUM FOR FIVE FT DEPTH INTERVALS

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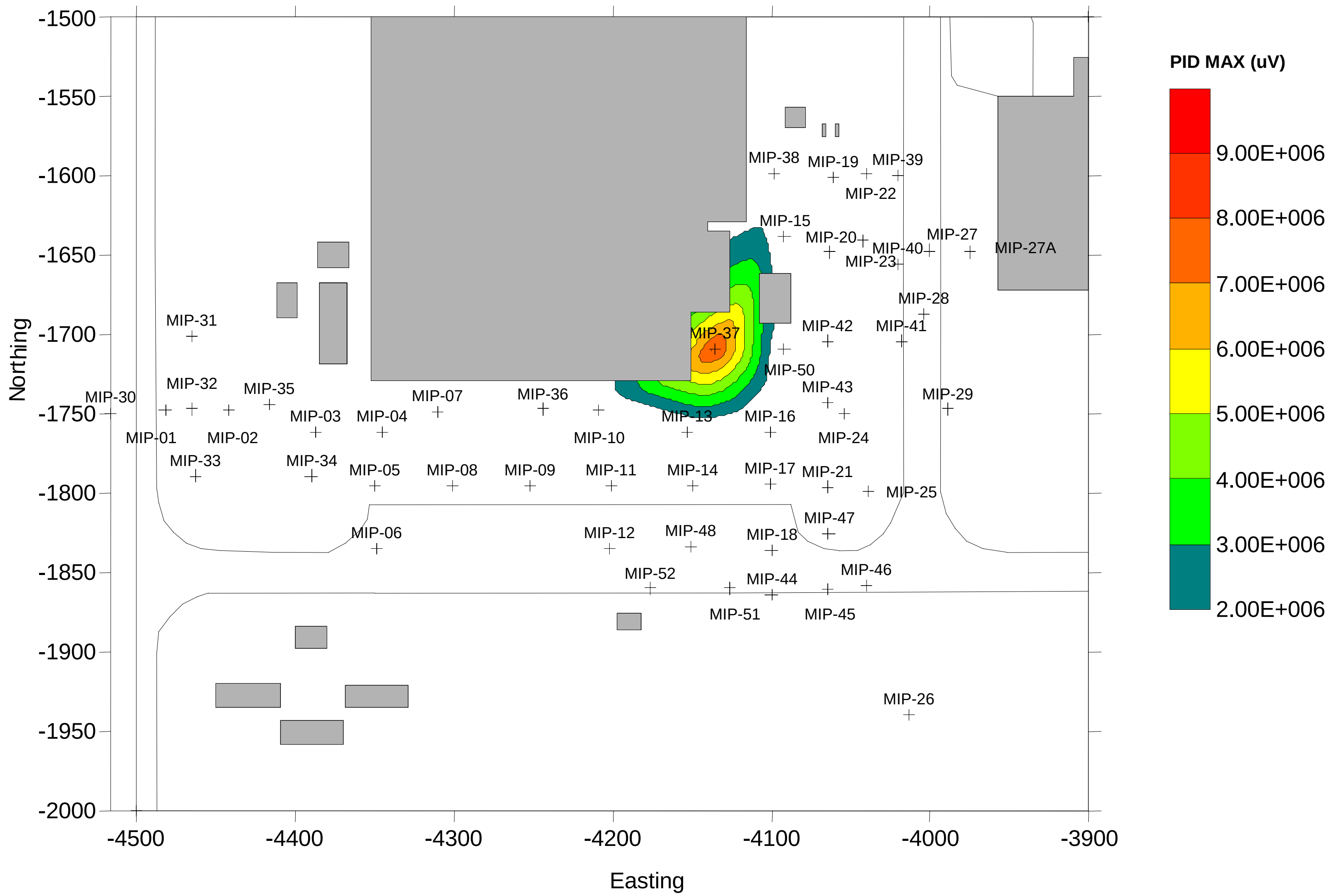
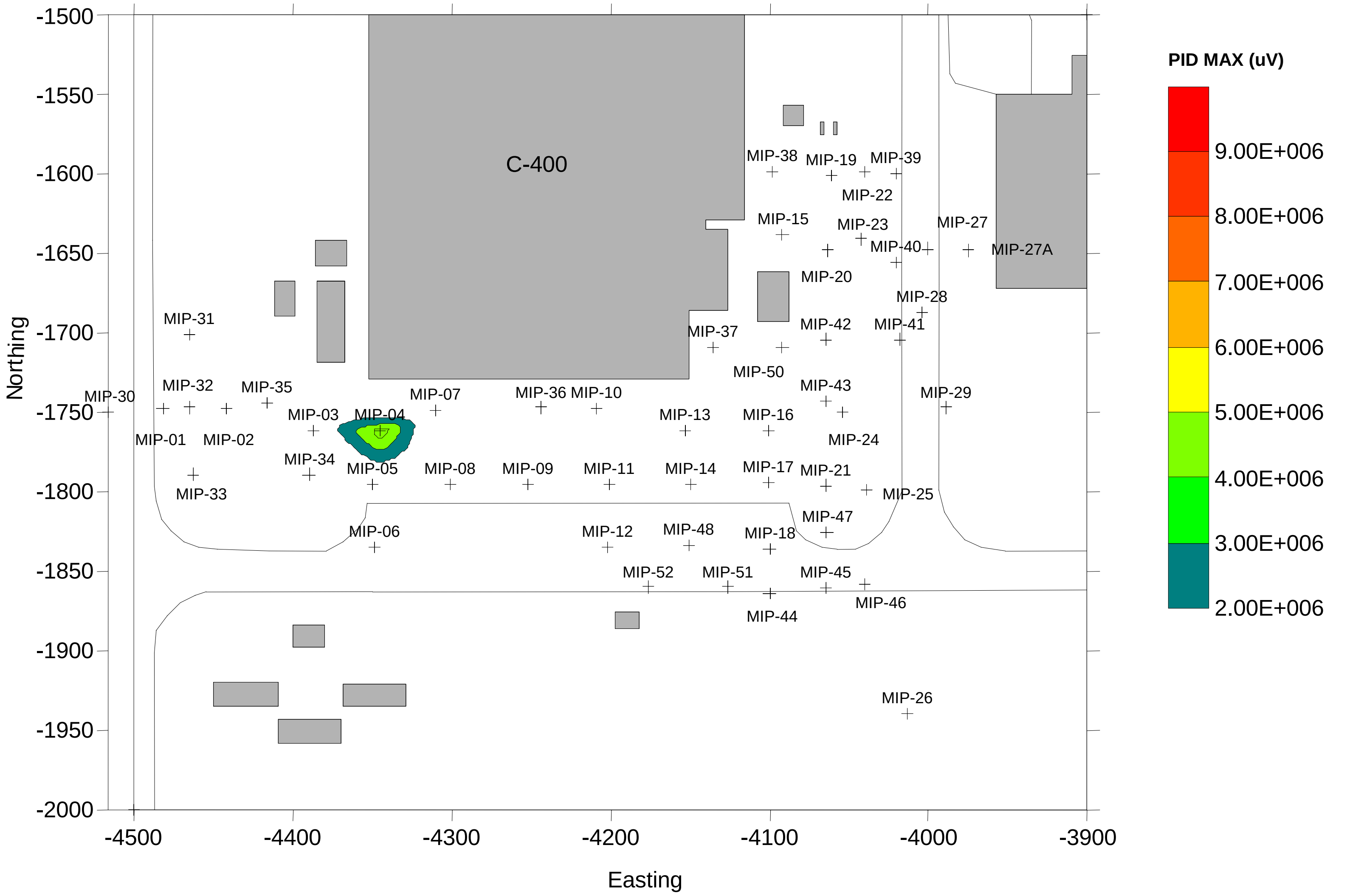
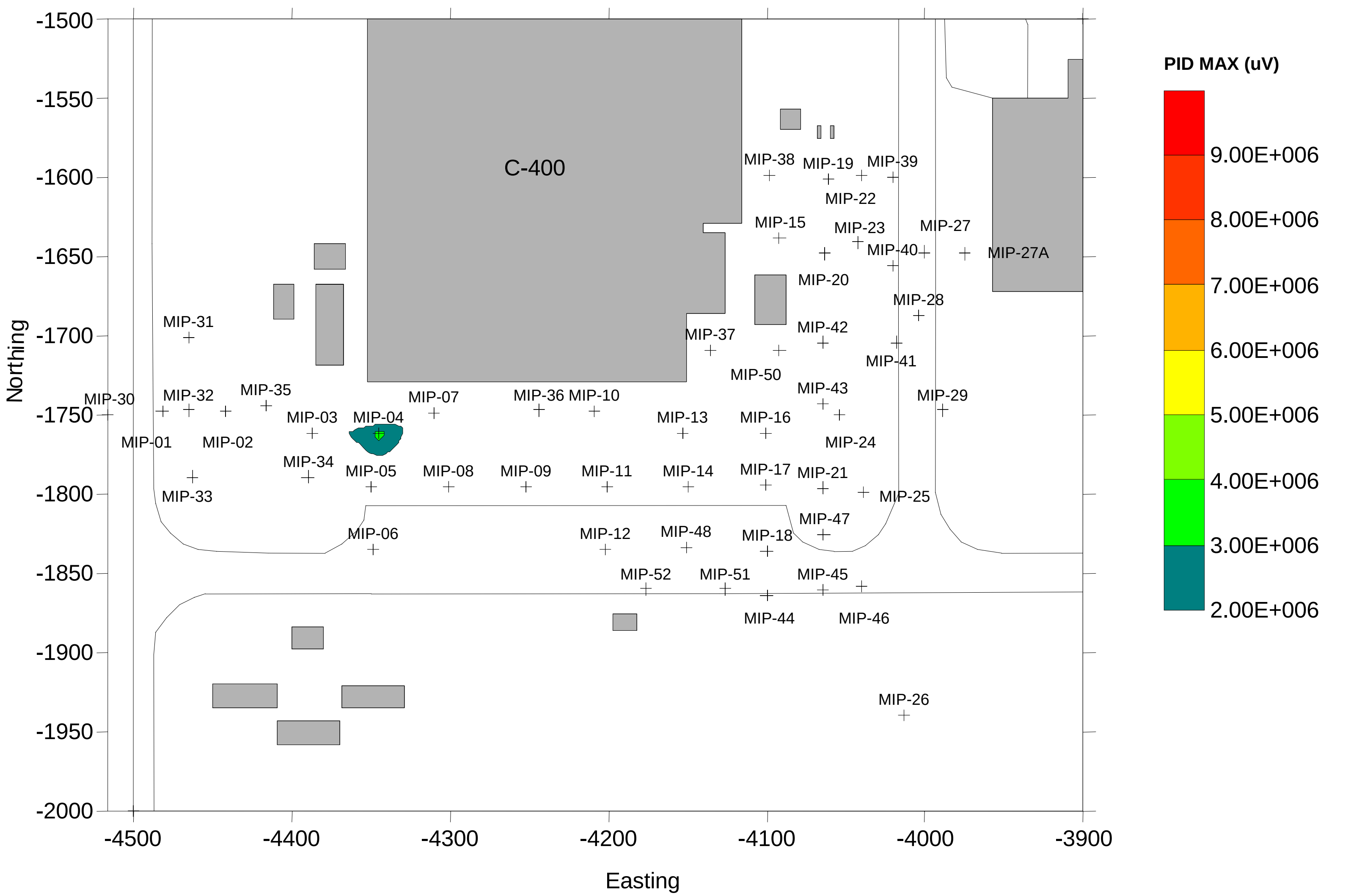
Unsaturated Zone
0-5 Foot Interval Maximum
Natural Neighbor



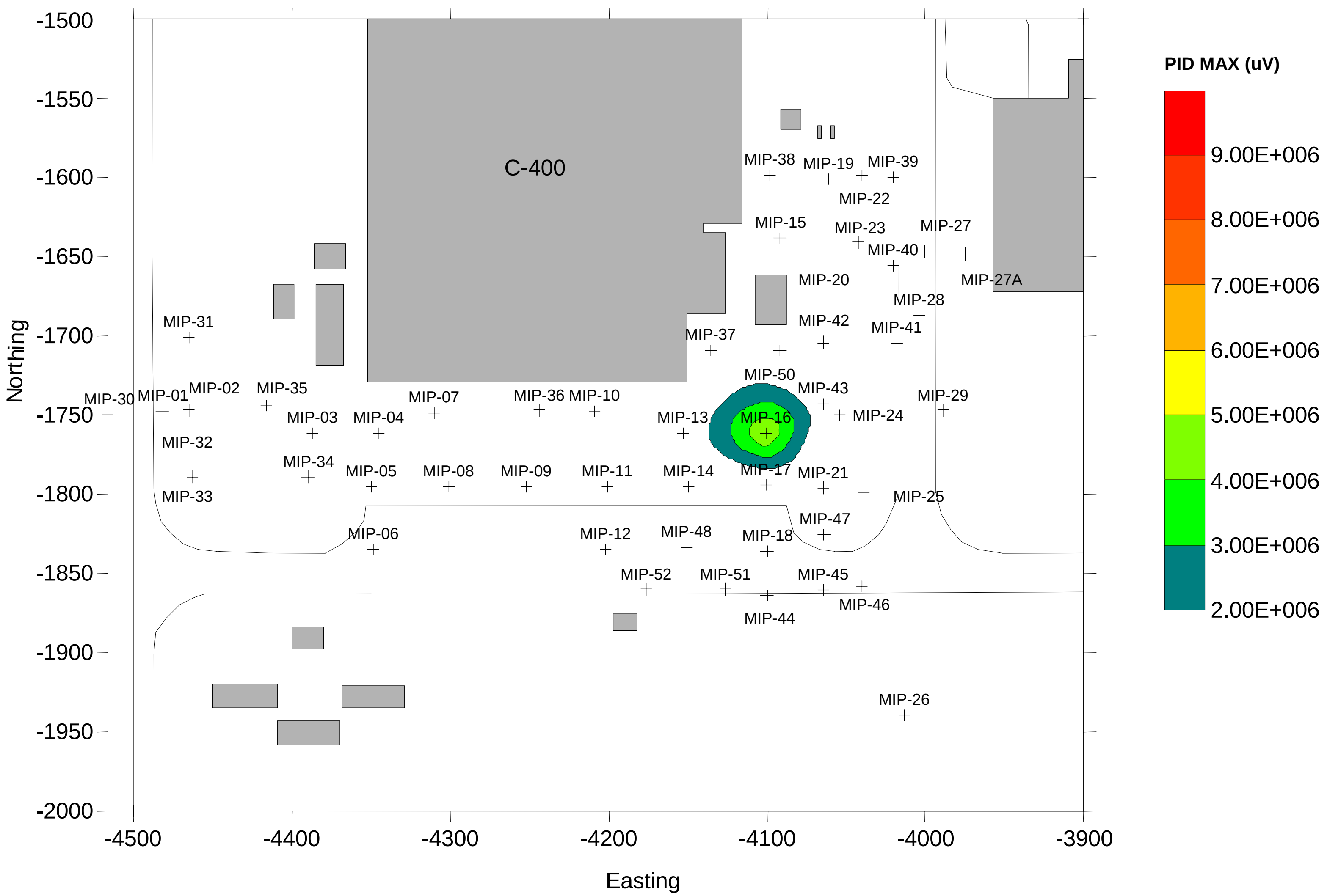
Unsaturated Zone
5-10 Foot Interval Maximum
Natural Neighbor



Unsaturated Zone
10-15 Foot Interval Maximum
Natural Neighbor



Unsaturated Zone
15-20 Foot Interval Maximum
Natural Neighbor



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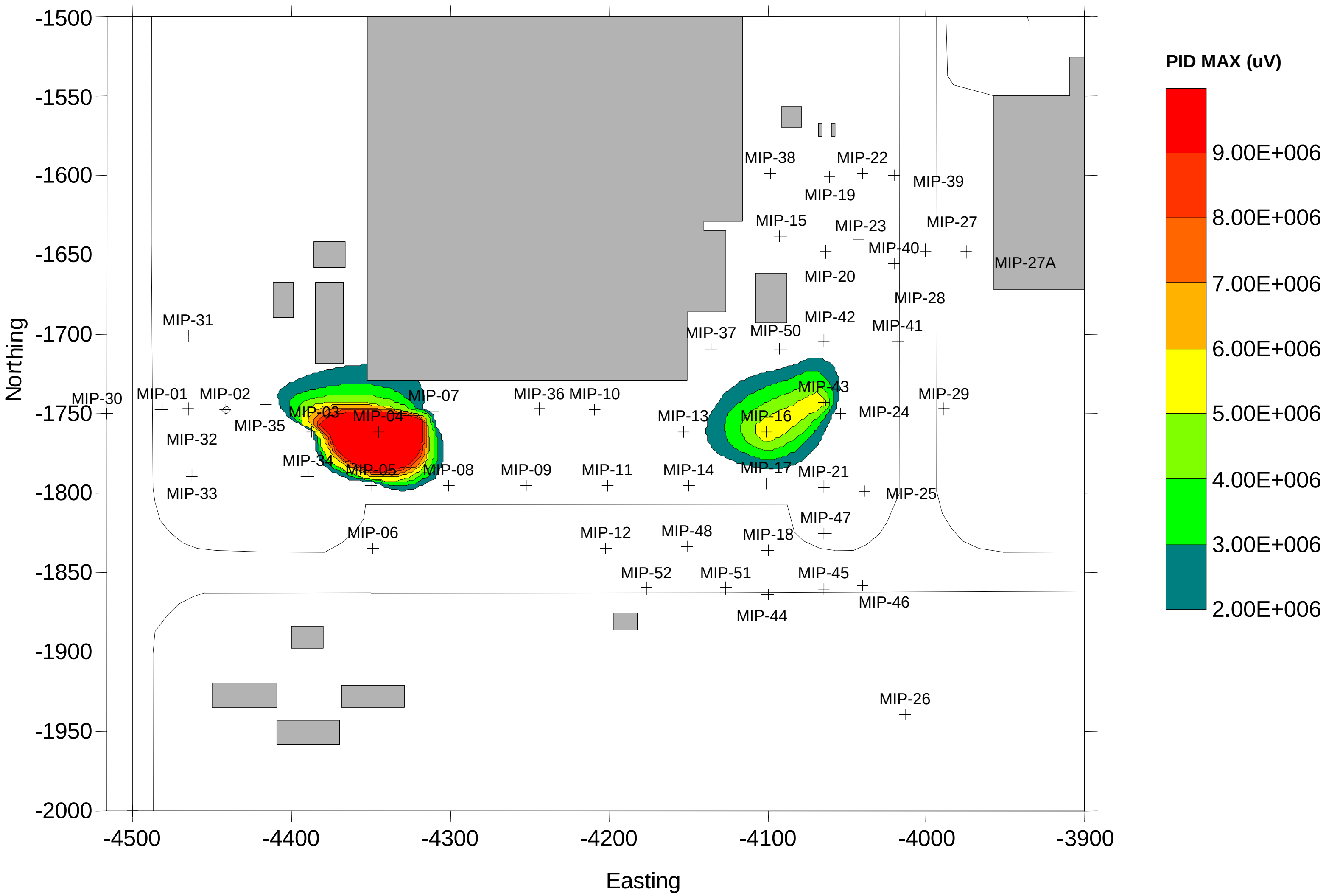
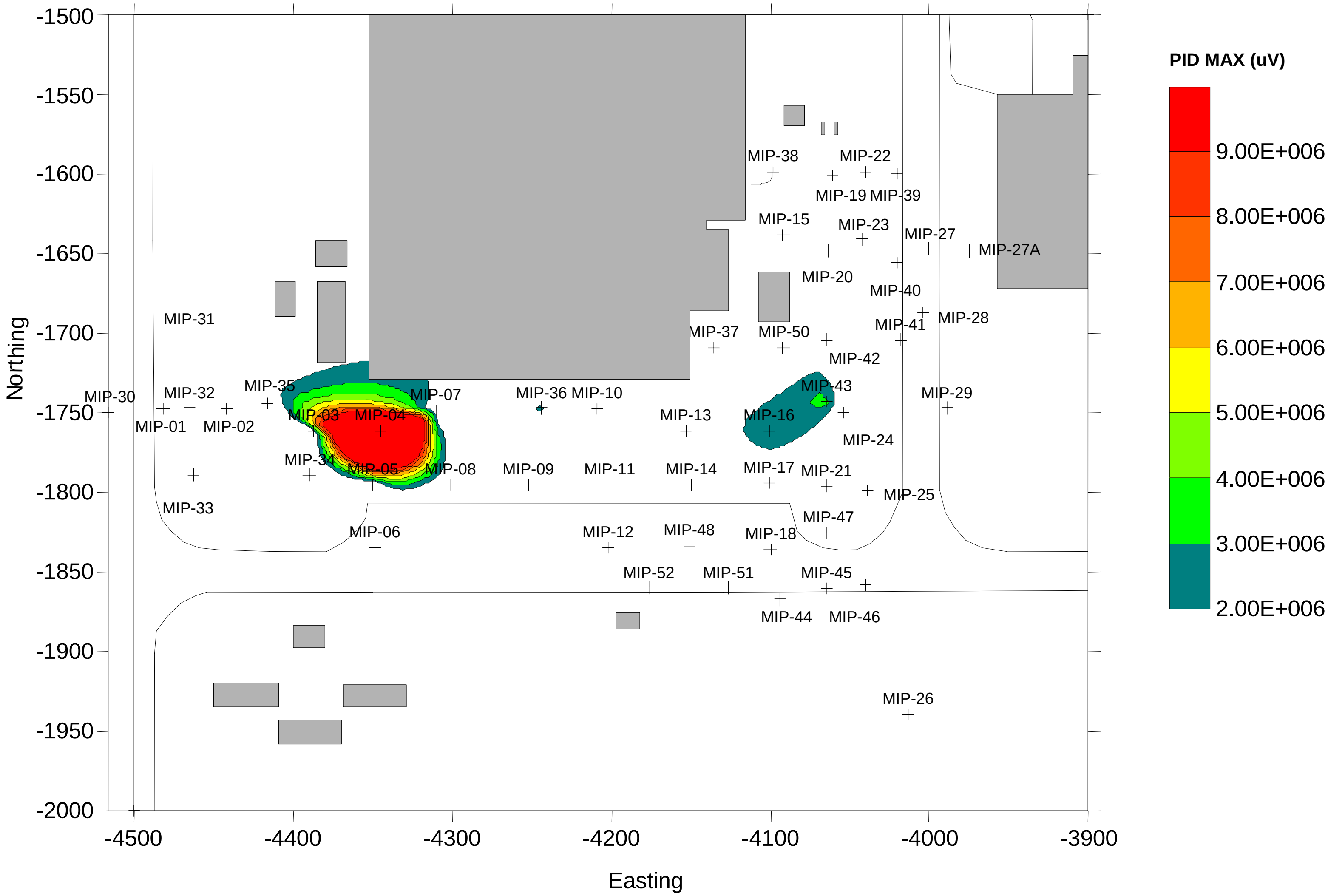
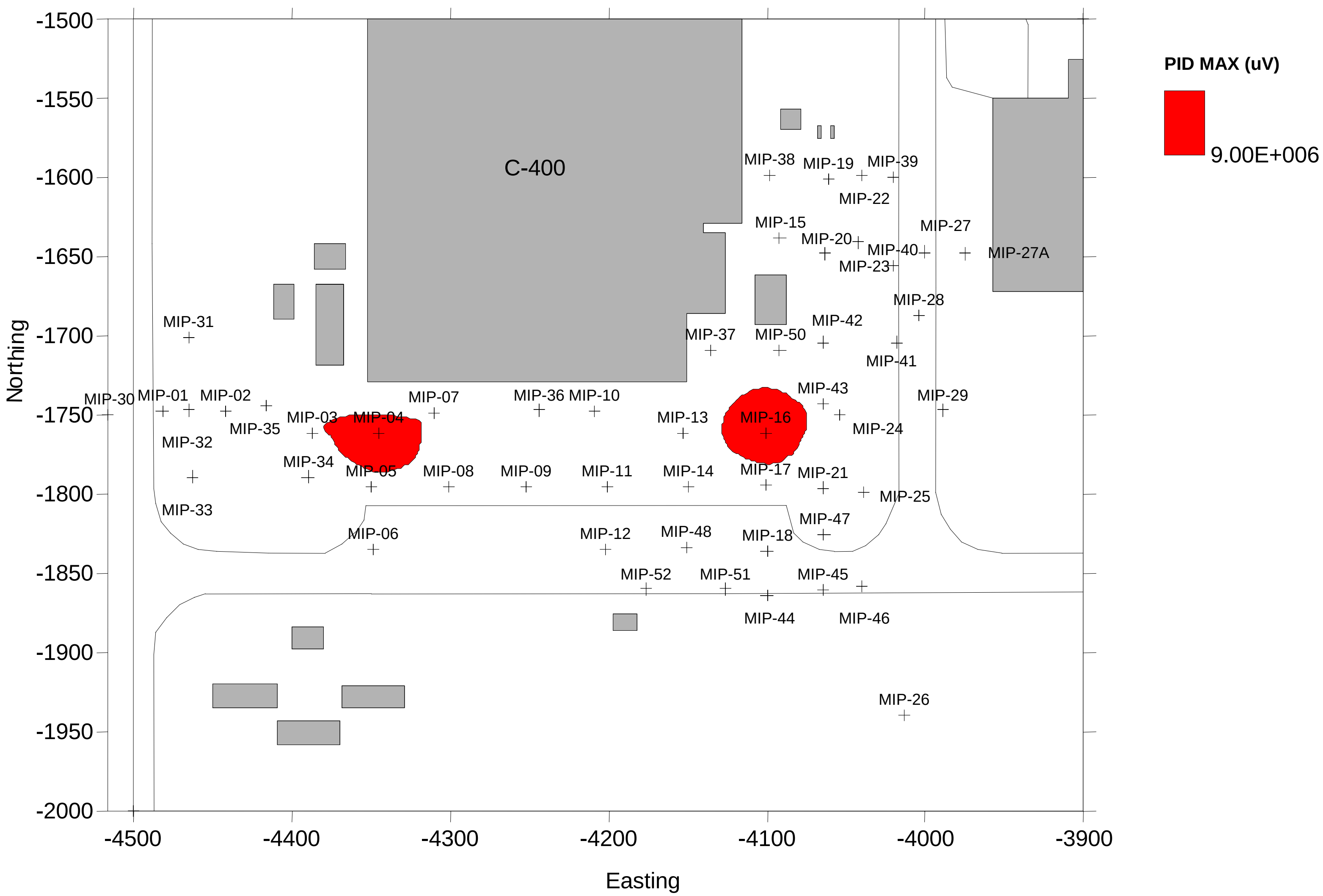
Unsaturated Zone
20-25 Foot Interval Maximum
Natural Neighbor



Unsaturated Zone
25-30 Foot Interval Maximum
Natural Neighbor



Saturated Zone
30-35 Foot Interval Maximum
Natural Neighbor



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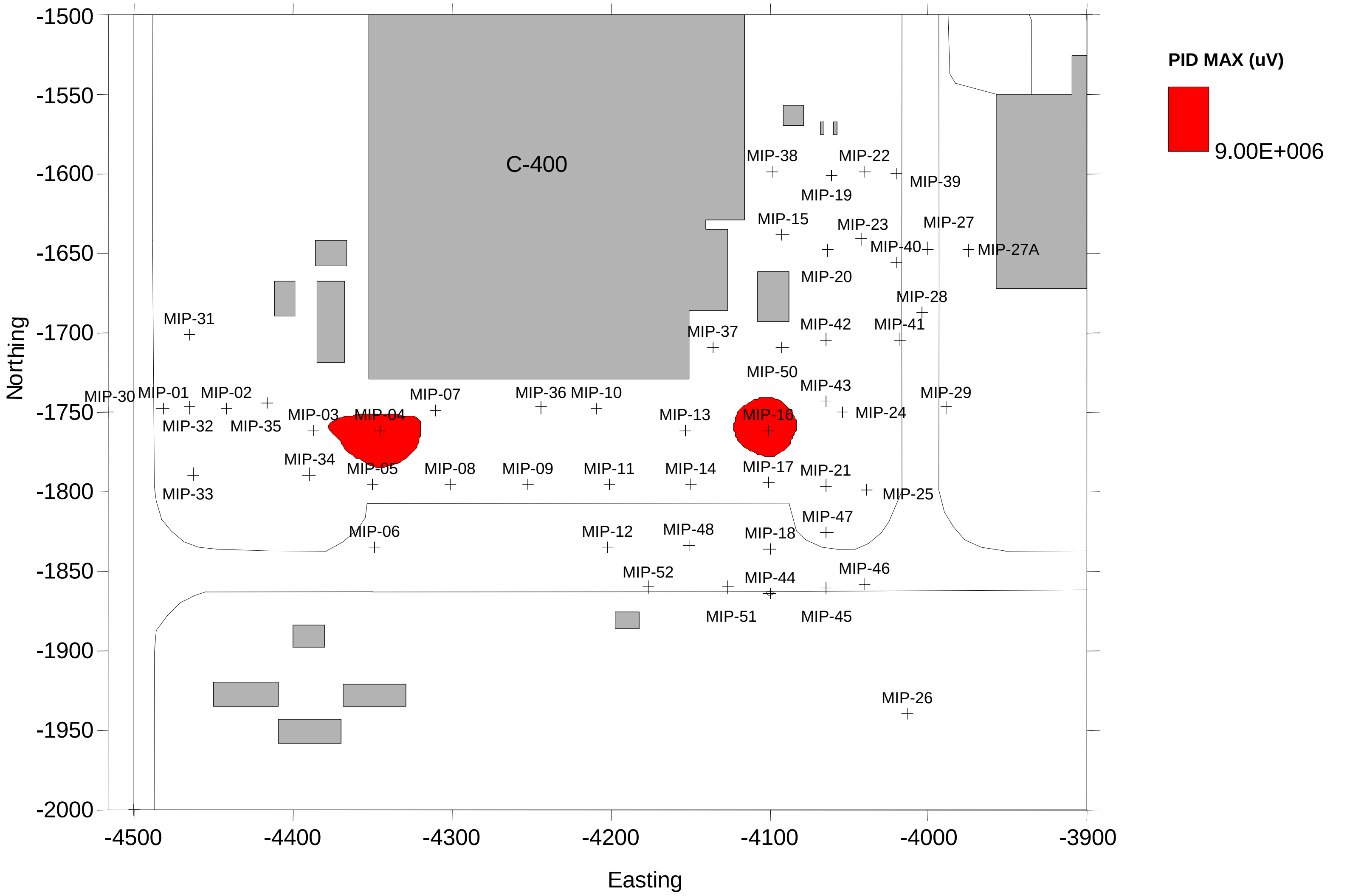
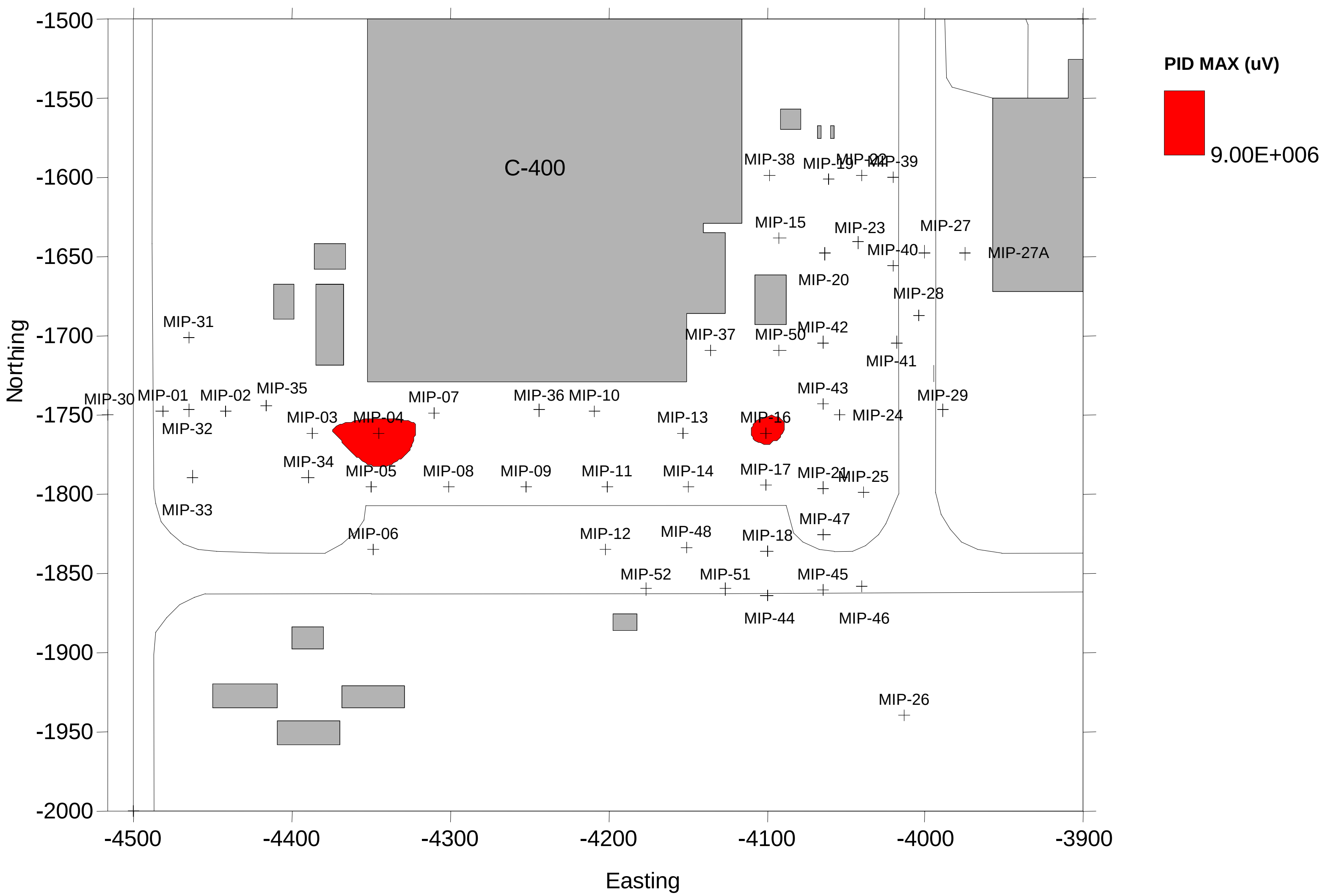
Saturated Zone
35-40 Foot Interval Maximum
Natural Neighbor



A3-10

Saturated Zone
40-45 Foot Interval Maximum
Natural Neighbor



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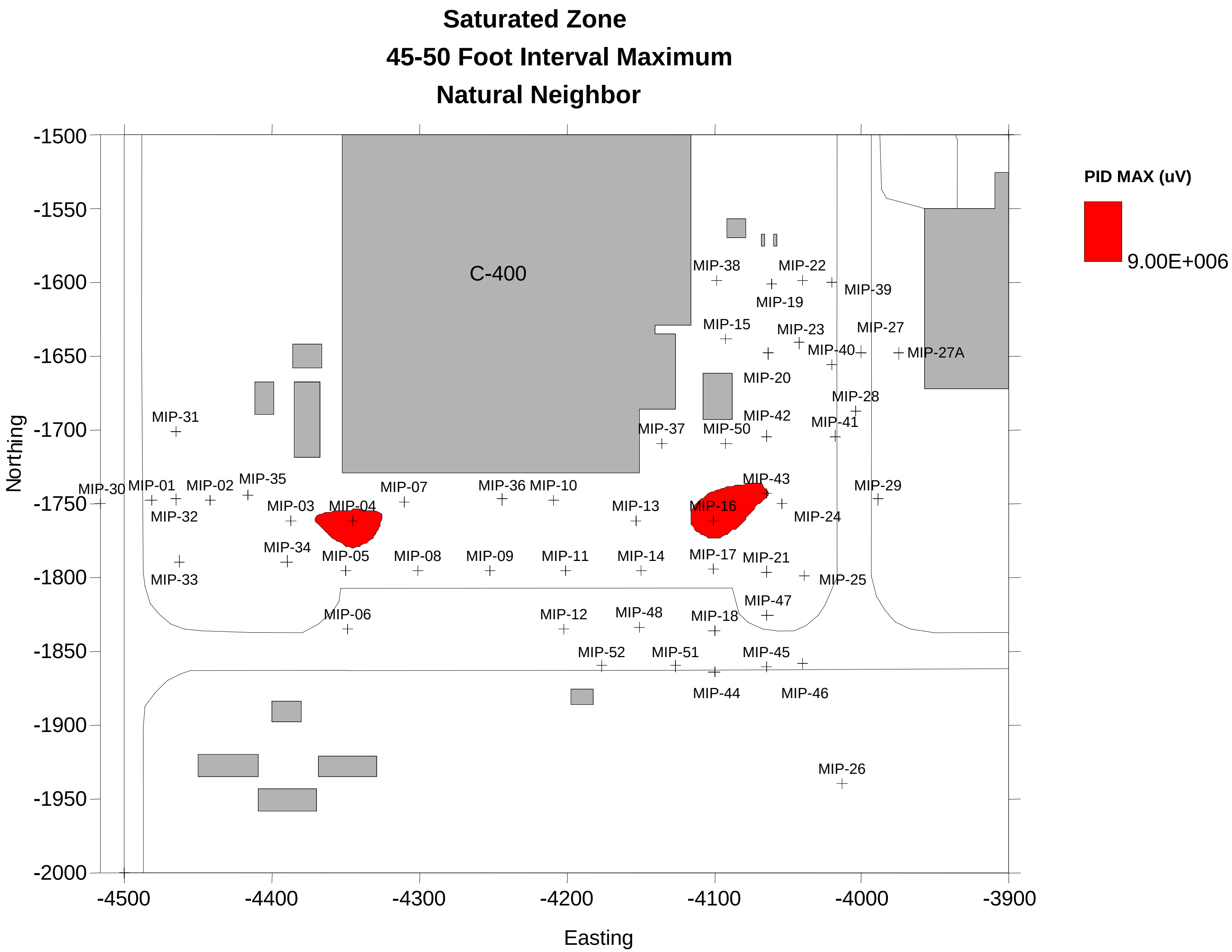
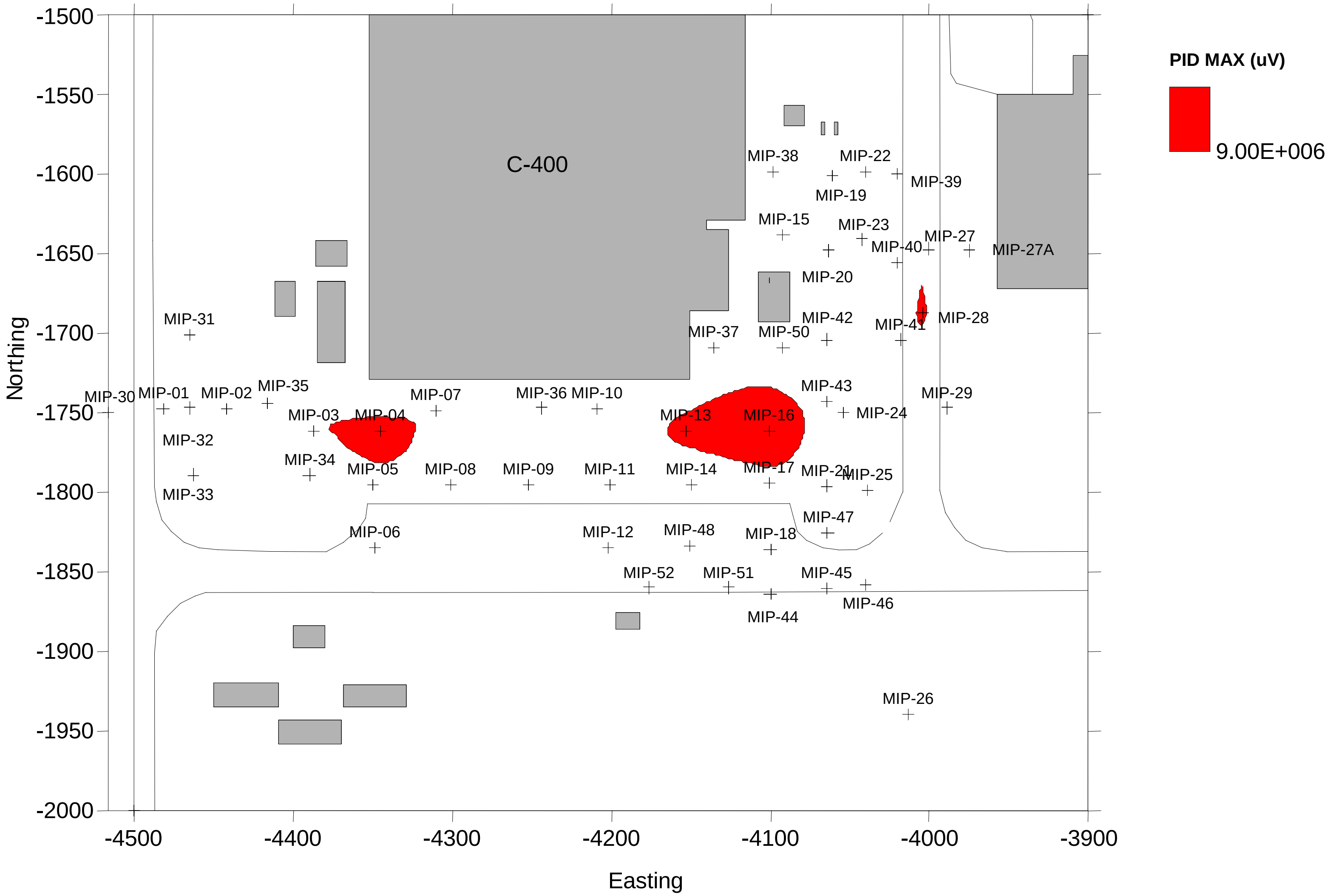


Saturated Zone
50-55 Foot Interval Maximum
Natural Neighbor



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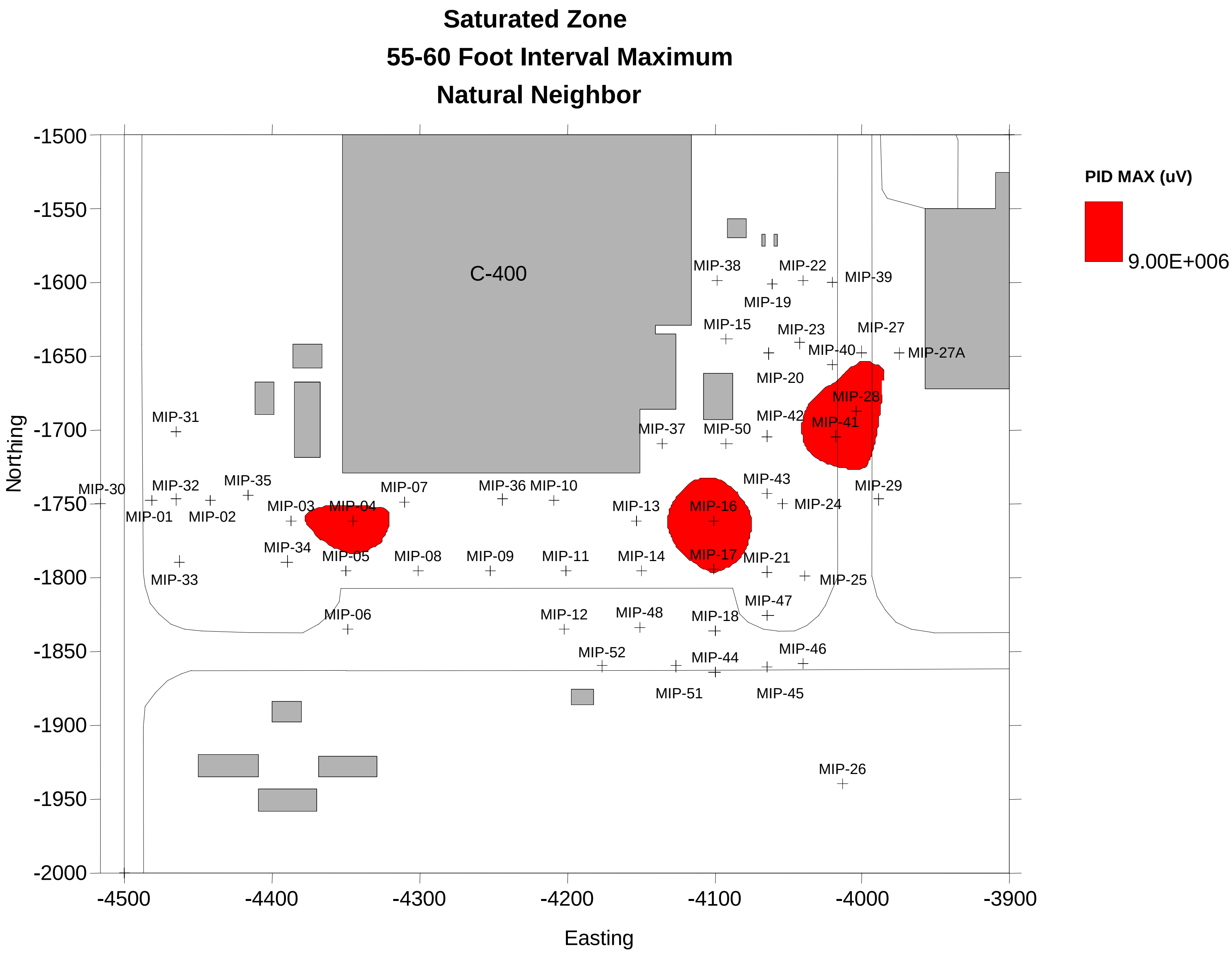
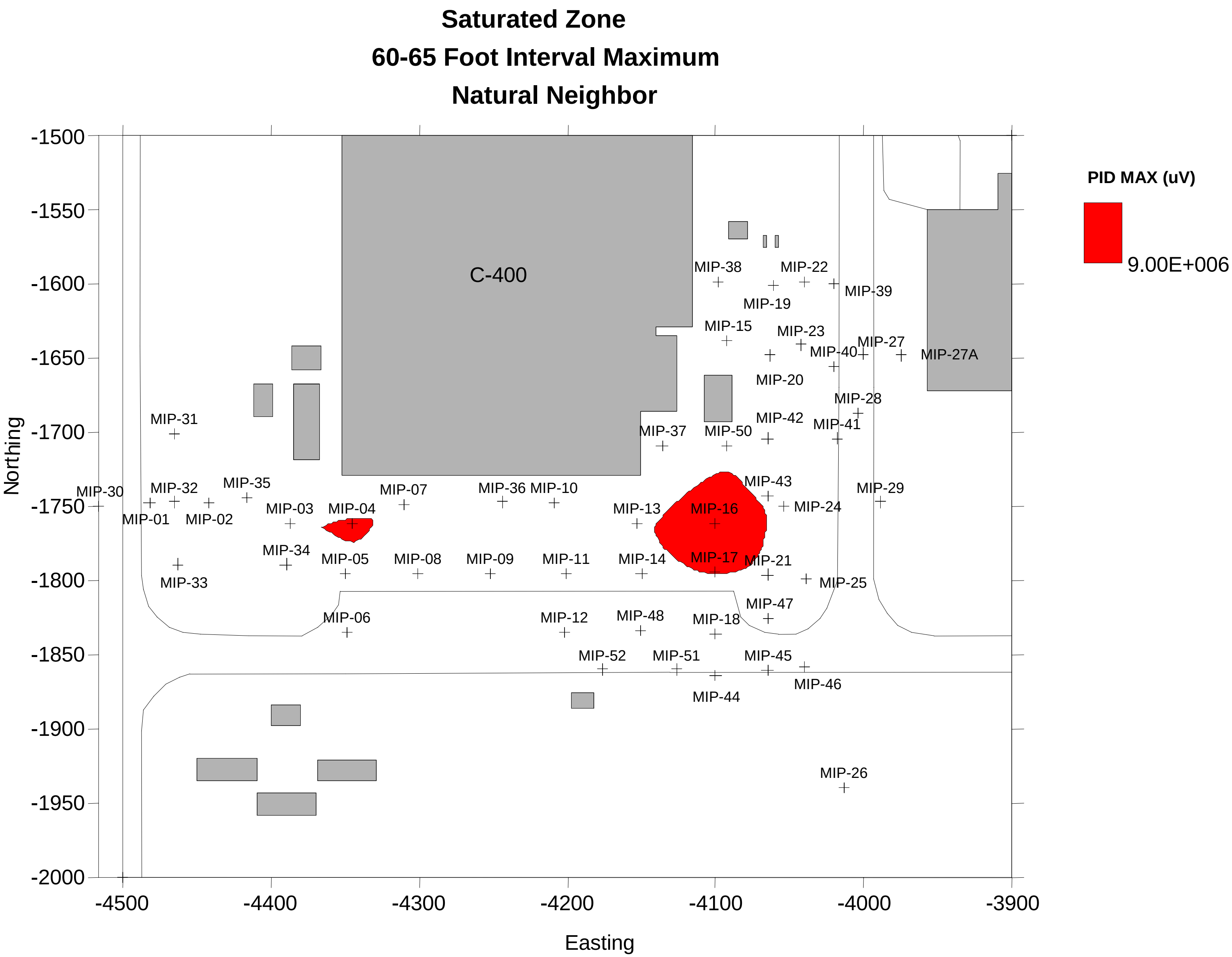
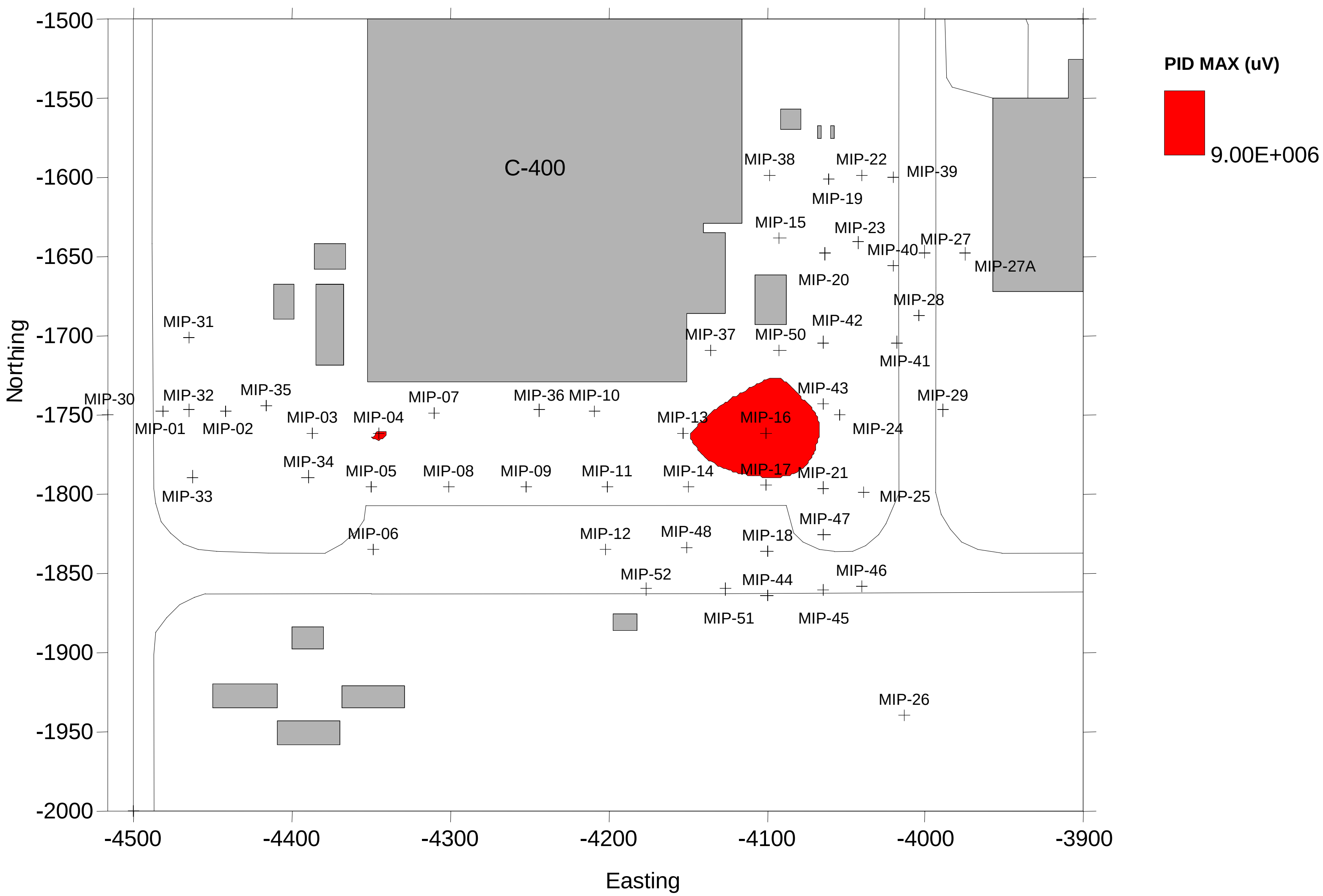
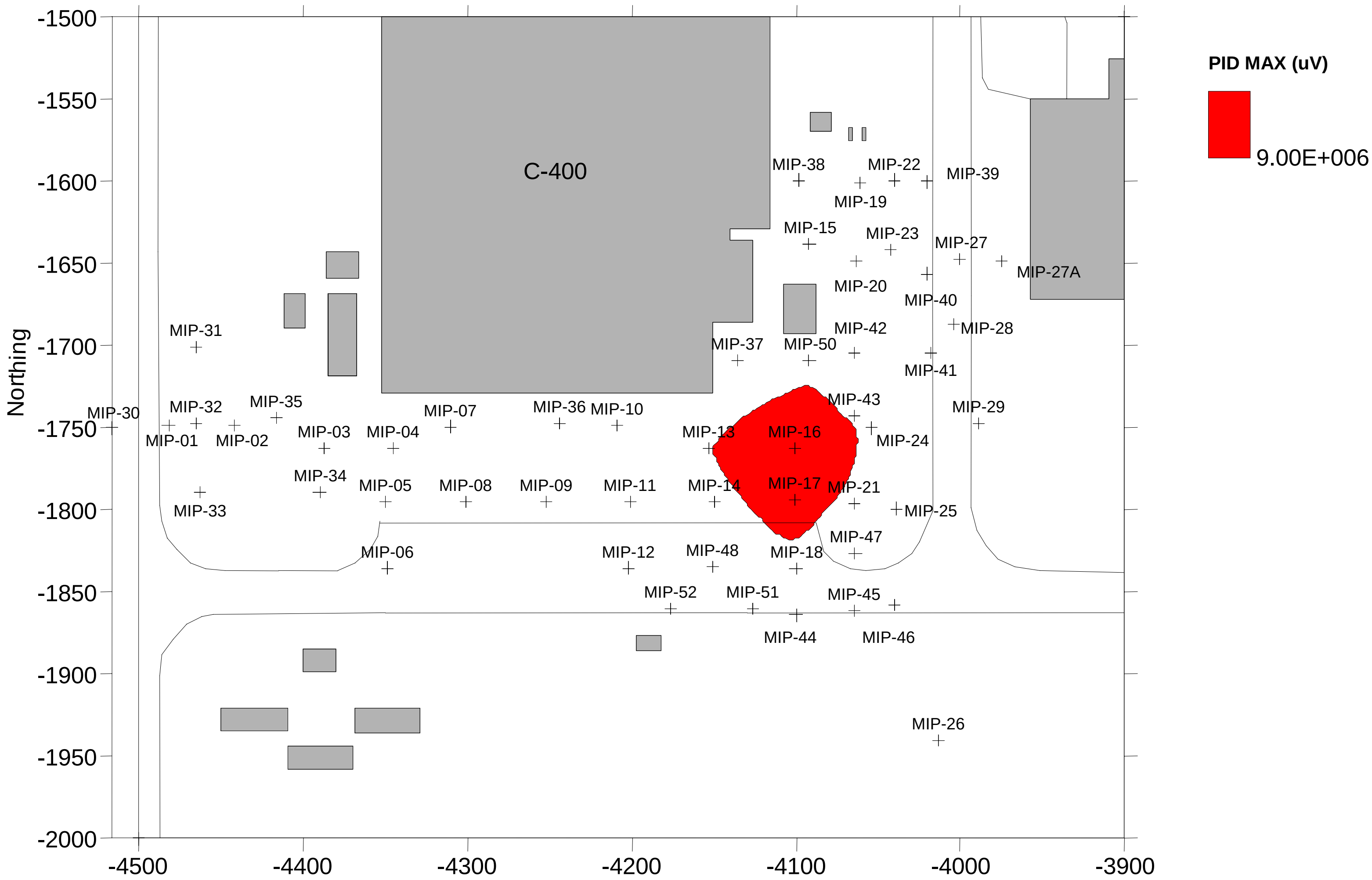



Saturated Zone
60-65 Foot Interval Maximum
Natural Neighbor
PID MAX (uV)
9.00E+006
C-400
Northing
Easting
-1500
-1550
-1600
-1650
-1700
-1750
-1800
-1850
-1900
-1950
-2000
-4500
-4400
-4300
-4200
-4100
-4000
-3900
MIP-01
MIP-02
MIP-03
MIP-04
MIP-05
MIP-06
MIP-07
MIP-08
MIP-09
MIP-10
MIP-11
MIP-12
MIP-13
MIP-14
MIP-15
MIP-16
MIP-17
MIP-18
MIP-19
MIP-20
MIP-21
MIP-22
MIP-23
MIP-24
MIP-25
MIP-26
MIP-27
MIP-27A
MIP-28
MIP-29
MIP-30
MIP-31
MIP-32
MIP-33
MIP-34
MIP-35
MIP-36
MIP-37
MIP-38
MIP-39
MIP-40
MIP-41
MIP-42
MIP-43
MIP-44
MIP-45
MIP-46
MIP-47
MIP-48
MIP-50
MIP-51
MIP-52

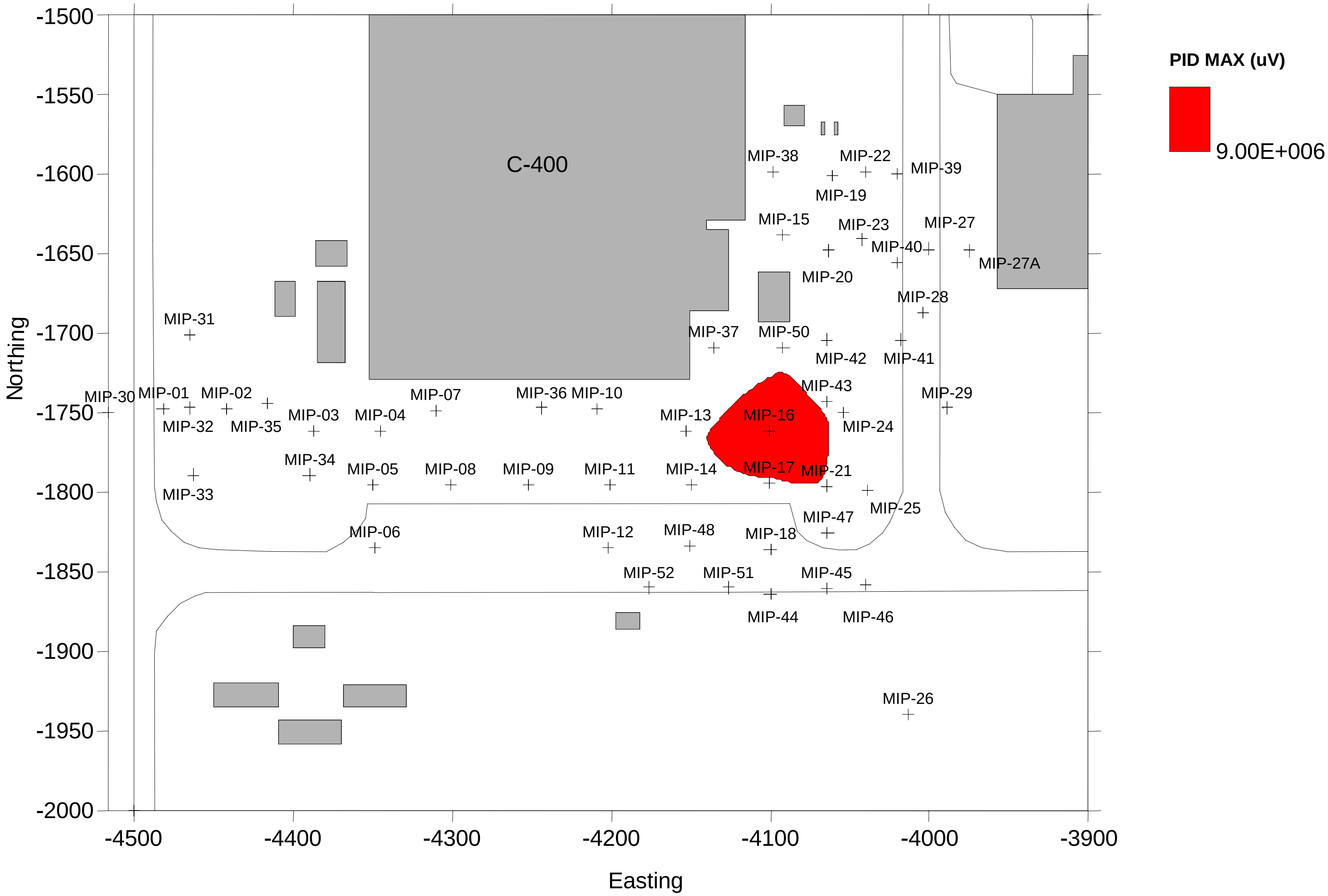
Saturated Zone
65-70 Foot Interval Maximum
Natural Neighbor



Saturated Zone
70-75 Foot Interval Maximum
Natural Neighbor



Saturated Zone
75-80 Foot Interval Maximum
Natural Neighbor



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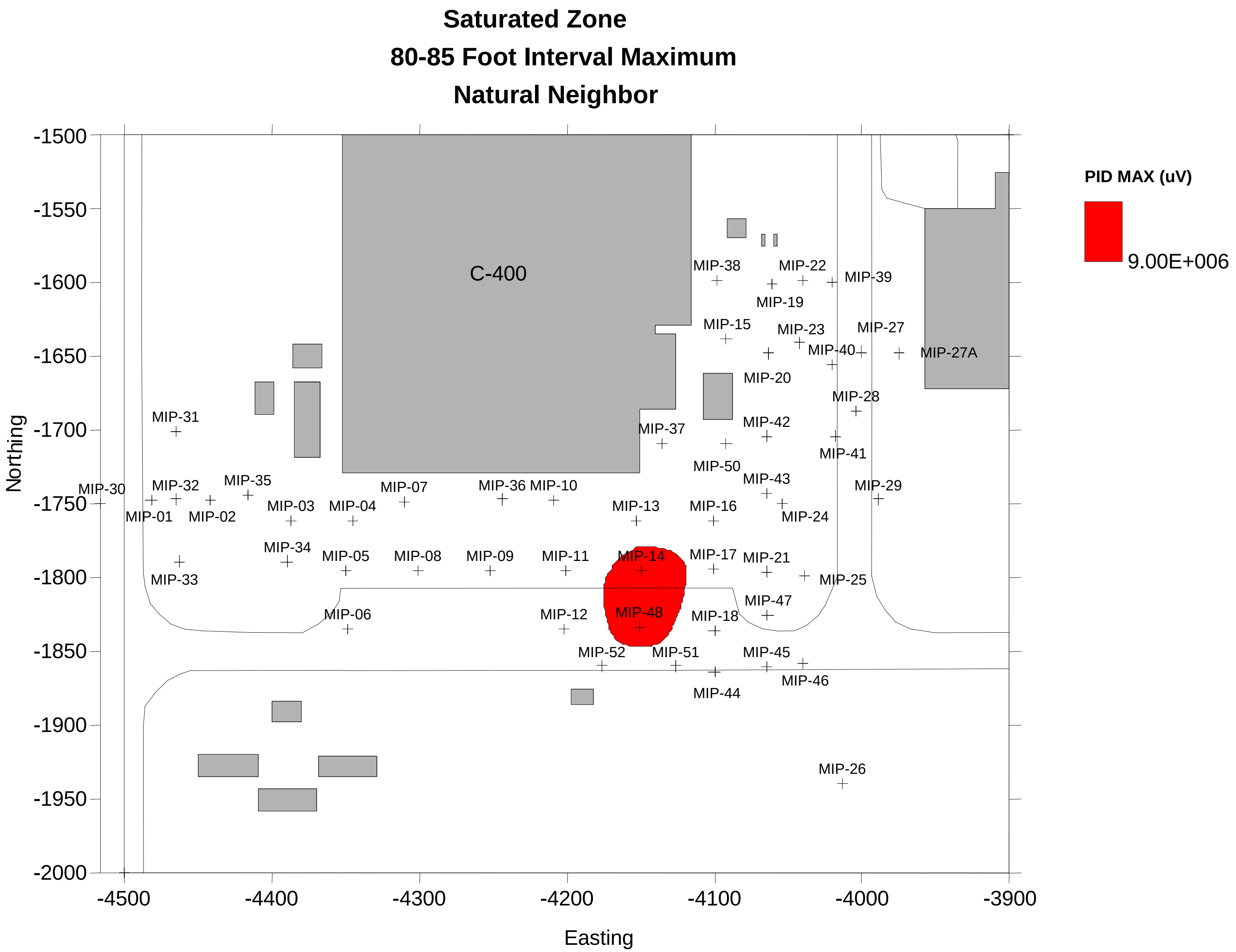
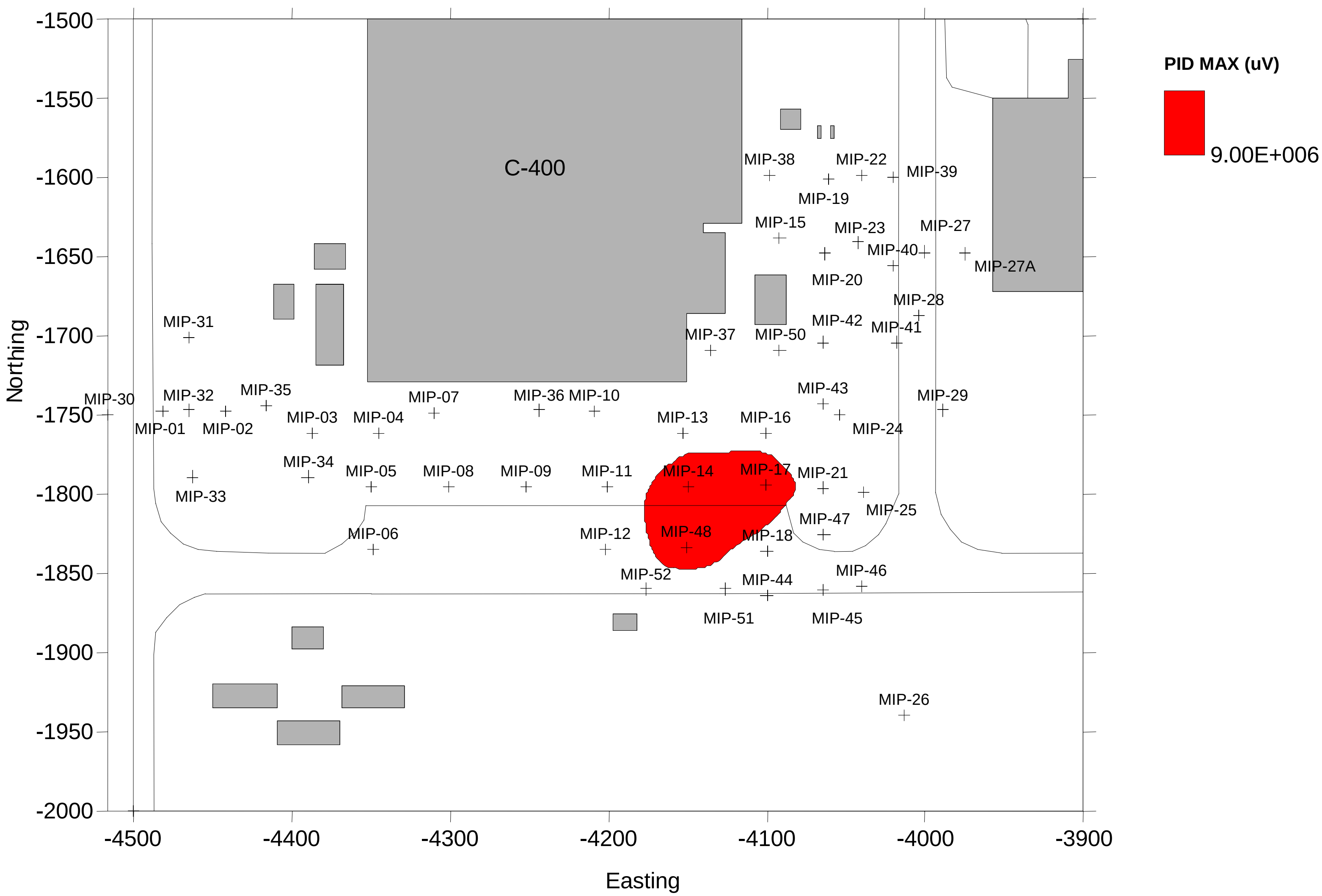
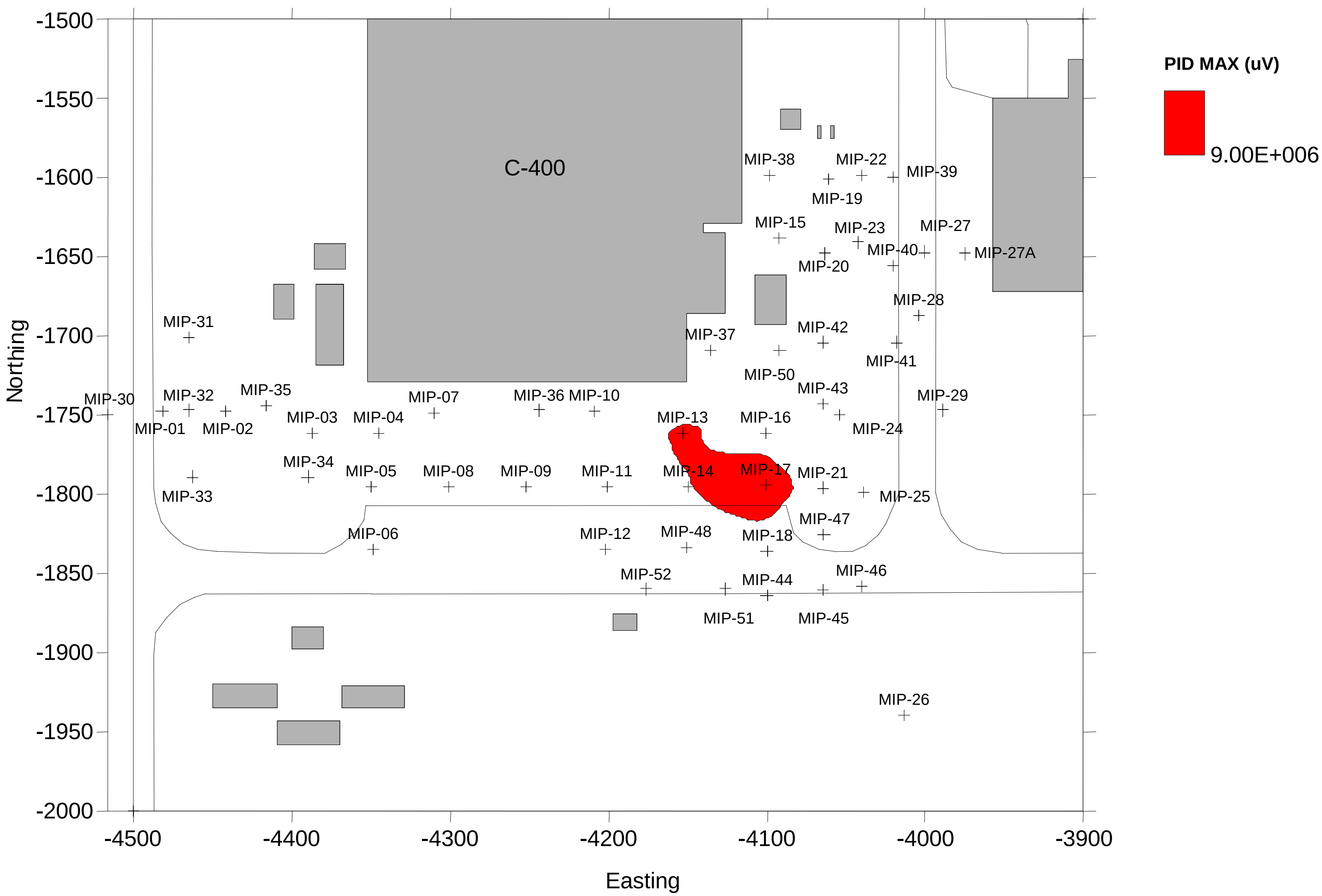


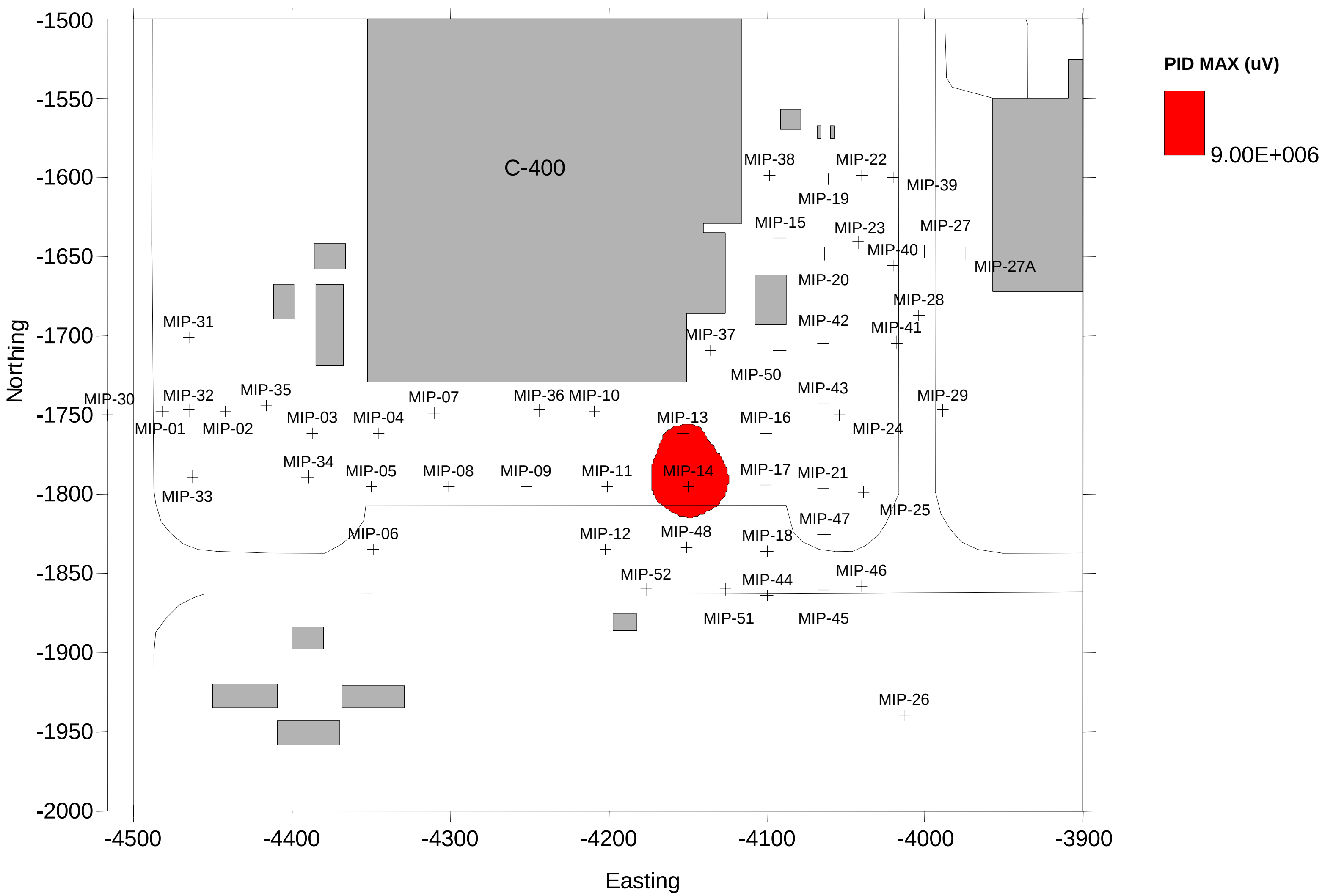
Saturated Zone
85-90 Foot Interval Maximum
Natural Neighbor



Saturated Zone
90-95 Foot Interval Maximum
Natural Neighbor



Saturated Zone
95-100 Foot Interval Maximum
Natural Neighbor



ATTACHMENT A4

COMPARISON OF EXTRAPOLATION TECHNIQUES FOR PID DATA FROM 90-TO-95 FT DEPTH INTERVAL

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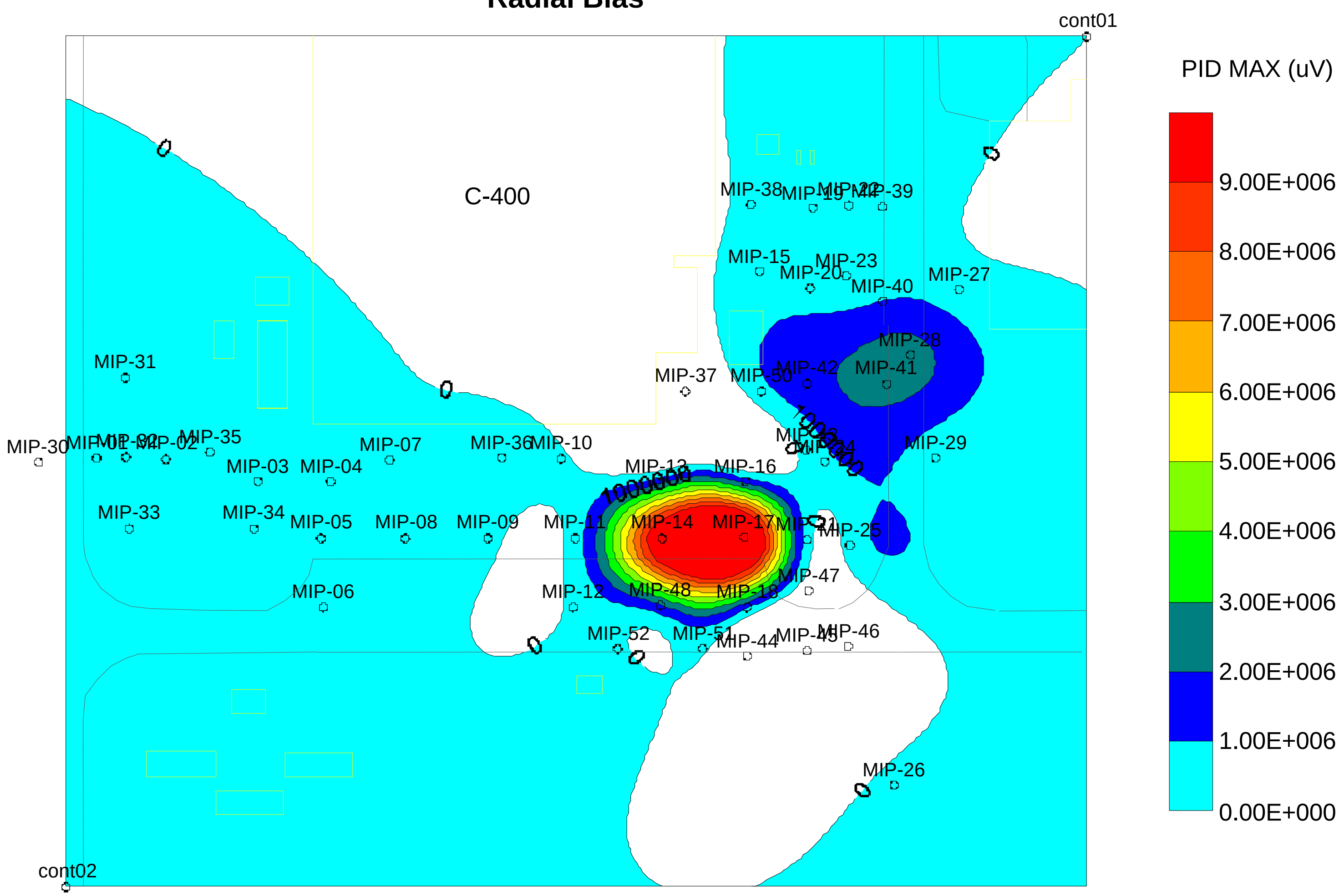
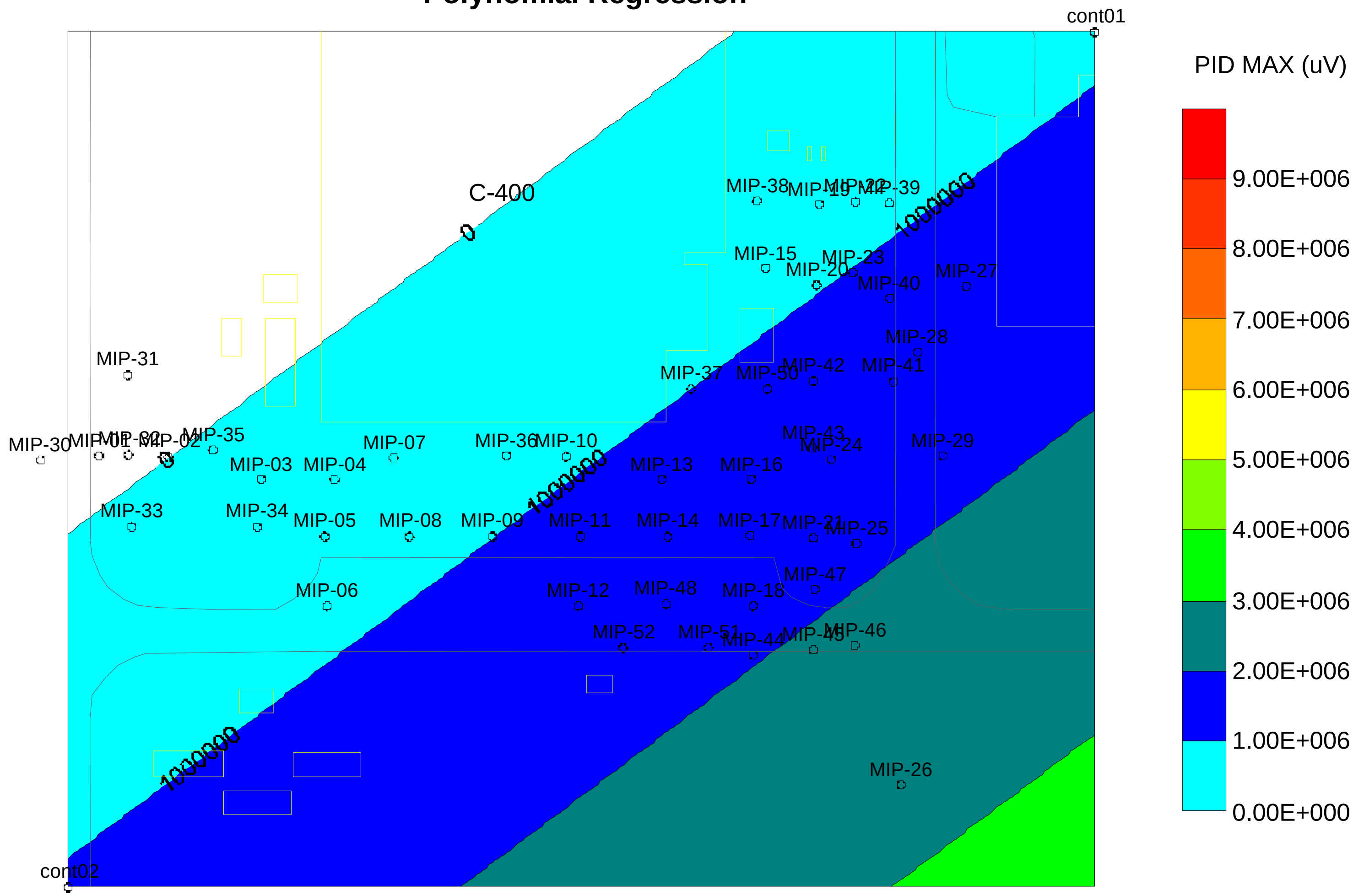
Radial Bias

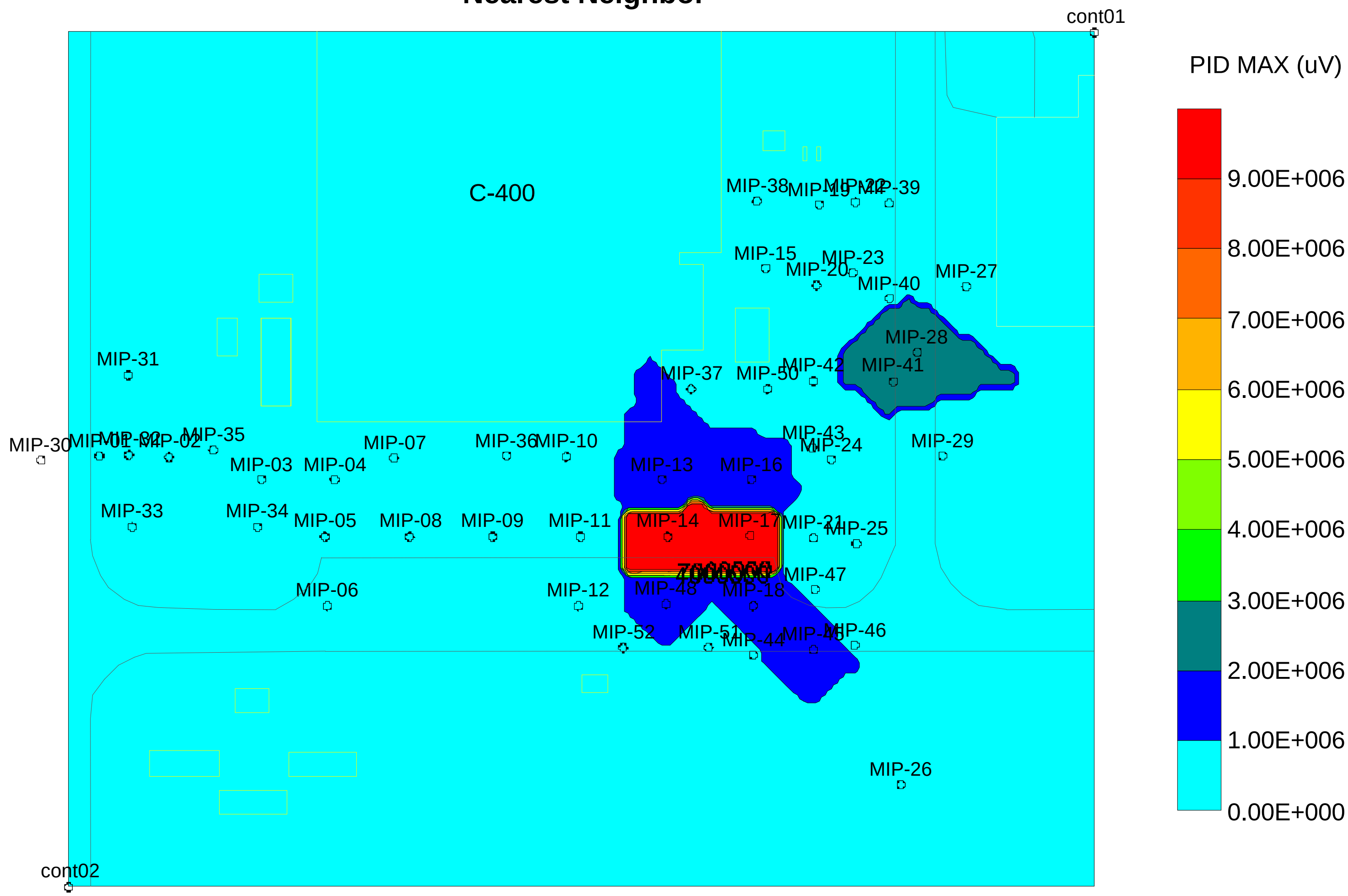

cont01
cont02
C-400
PID MAX (uV)
9.00E+006
8.00E+006
7.00E+006
6.00E+006
5.00E+006
4.00E+006
3.00E+006
2.00E+006
1.00E+006
0.00E+000
MIP-38
MIP-39
MIP-15
MIP-23
MIP-20
MIP-40
MIP-27
MIP-28
MIP-42
MIP-41
MIP-31
MIP-37
MIP-30
MIP-35
MIP-07
MIP-36
MIP-10
MIP-29
MIP-03
MIP-04
MIP-16
MIP-33
MIP-34
MIP-05
MIP-08
MIP-09
MIP-14
MIP-25
MIP-47
MIP-06
MIP-12
MIP-48
MIP-52
MIP-44
MIP-46
MIP-26

A4-4

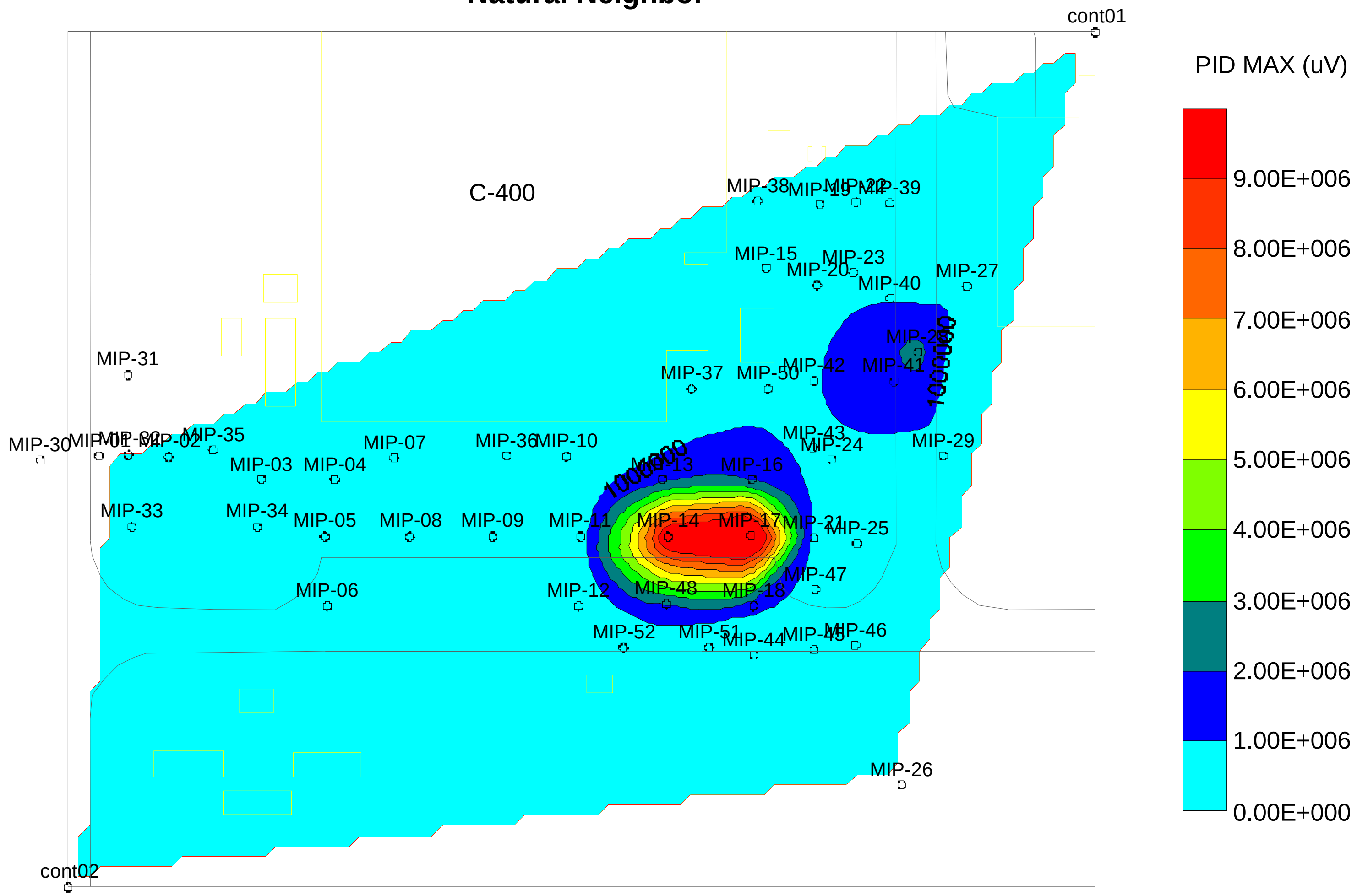
Polynomial Regression



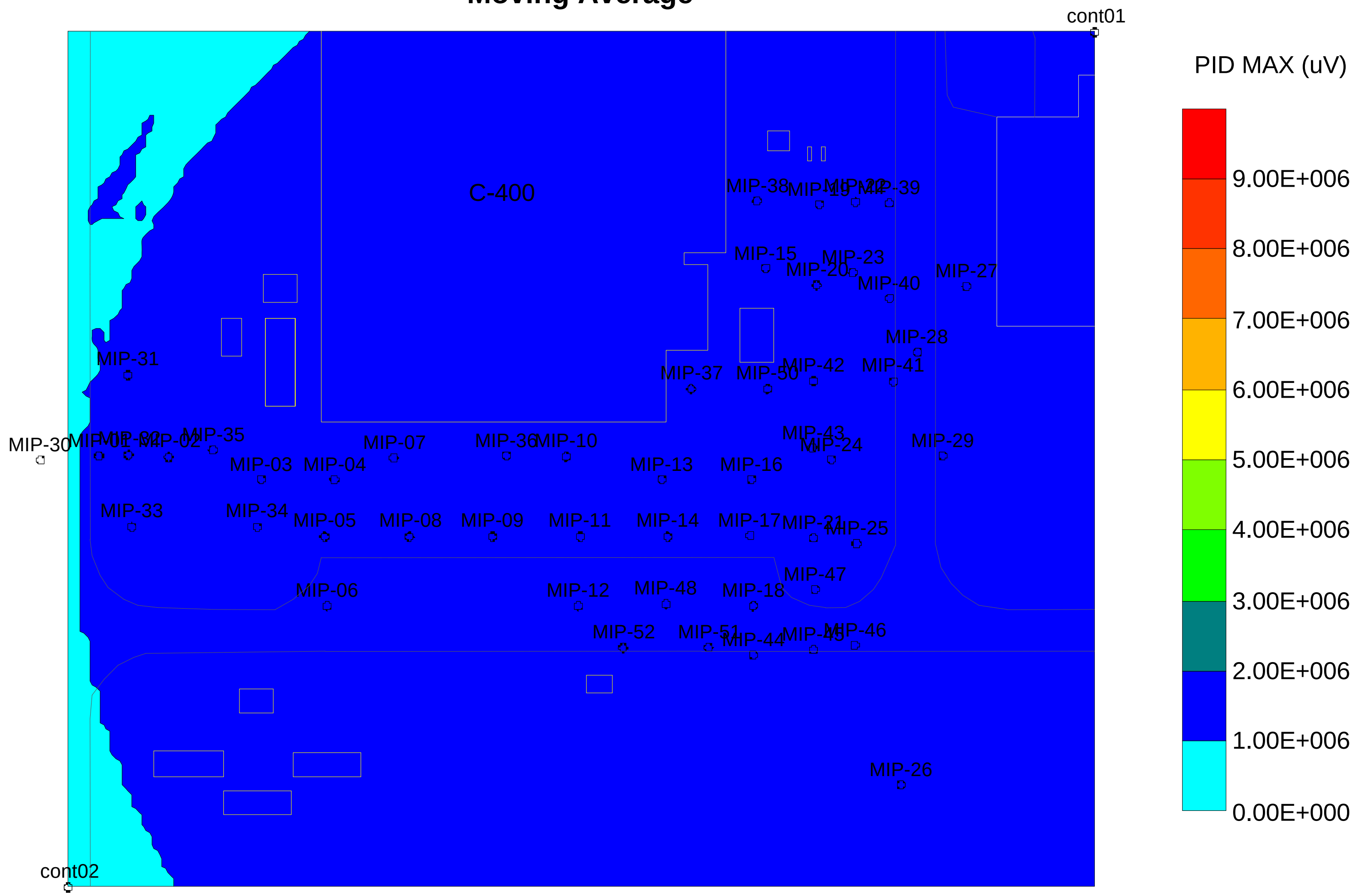
Nearest Neighbor



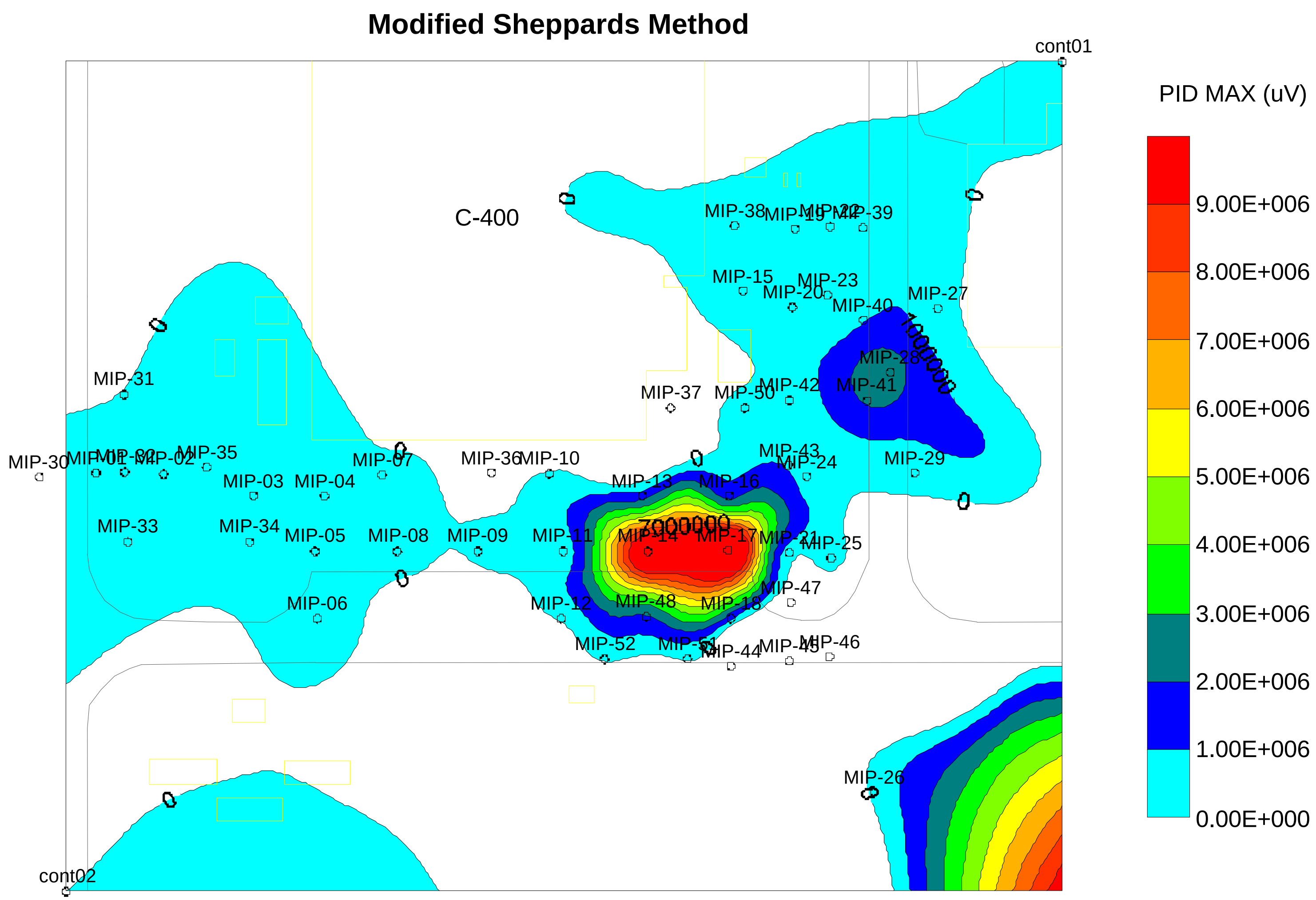
Natural Neighbor



Moving Average



A4-7


Modified Sheppards Method
PID MAX (uV)
9.00E+006
8.00E+006
7.00E+006
6.00E+006
5.00E+006
4.00E+006
3.00E+006
2.00E+006
1.00E+006
0.00E+000
cont01
cont02
C-400
MIP-30
MIP-01
MIP-02
MIP-35
MIP-31
MIP-33
MIP-34
MIP-03
MIP-04
MIP-05
MIP-06
MIP-07
MIP-08
MIP-09
MIP-36
MIP-10
MIP-11
MIP-12
MIP-13
MIP-14
MIP-16
MIP-17
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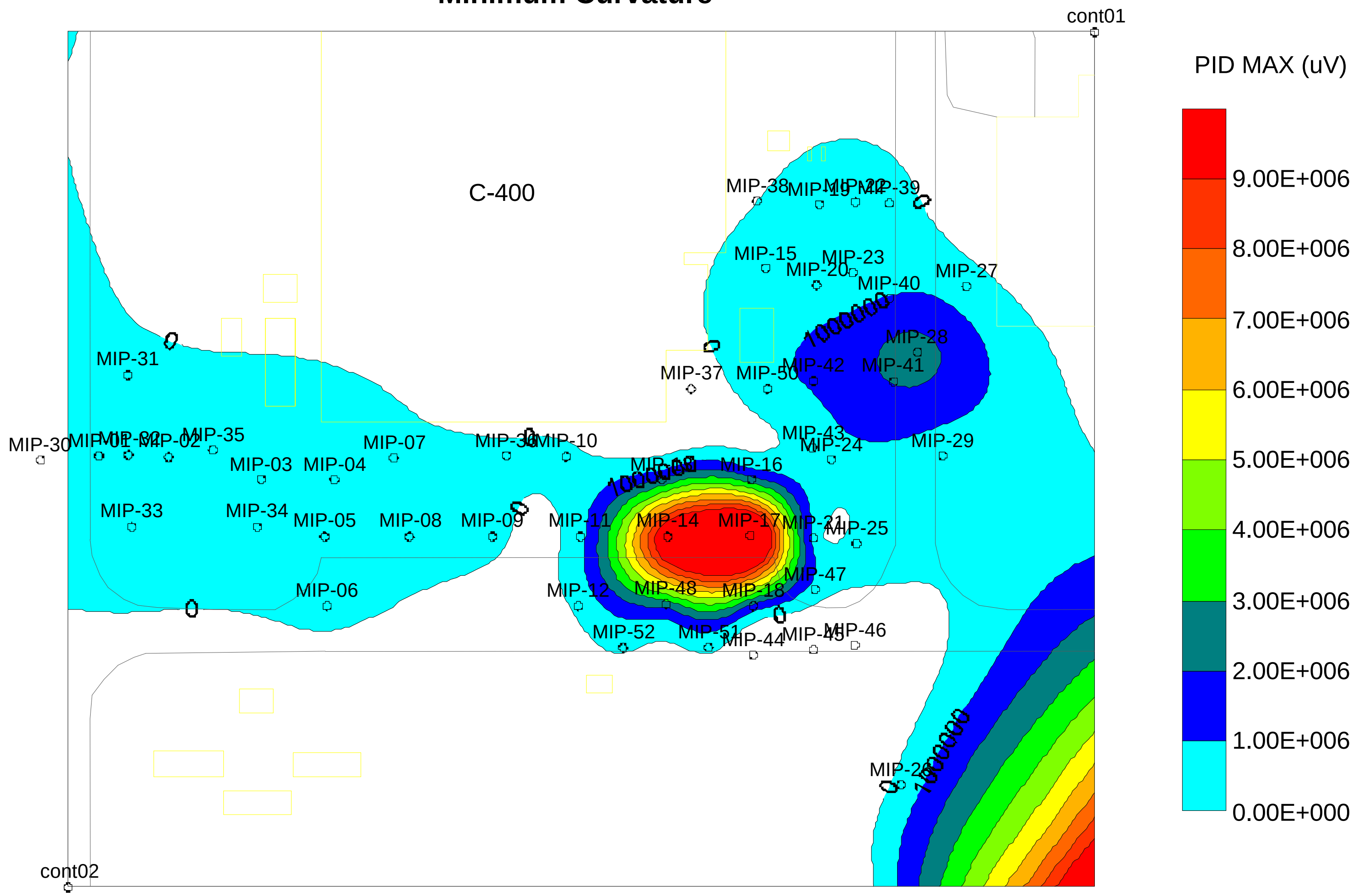
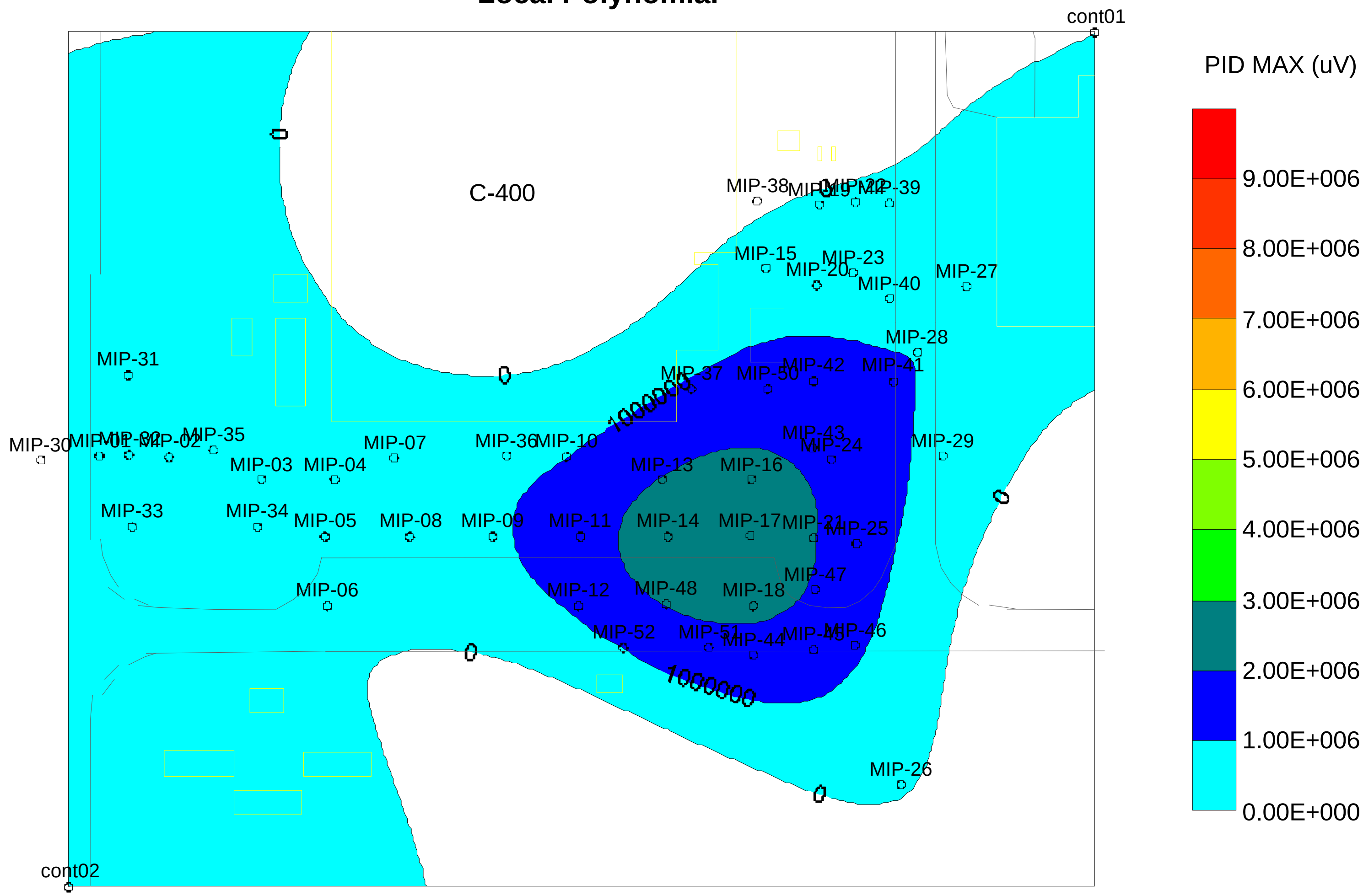
MIP-41
MIP-42
MIP-50
MIP-43
MIP-24
MIP-29
MIP-25
MIP-47
MIP-48
MIP-52
MIP-44
MIP-46
MIP-26
7000000
1000000
0

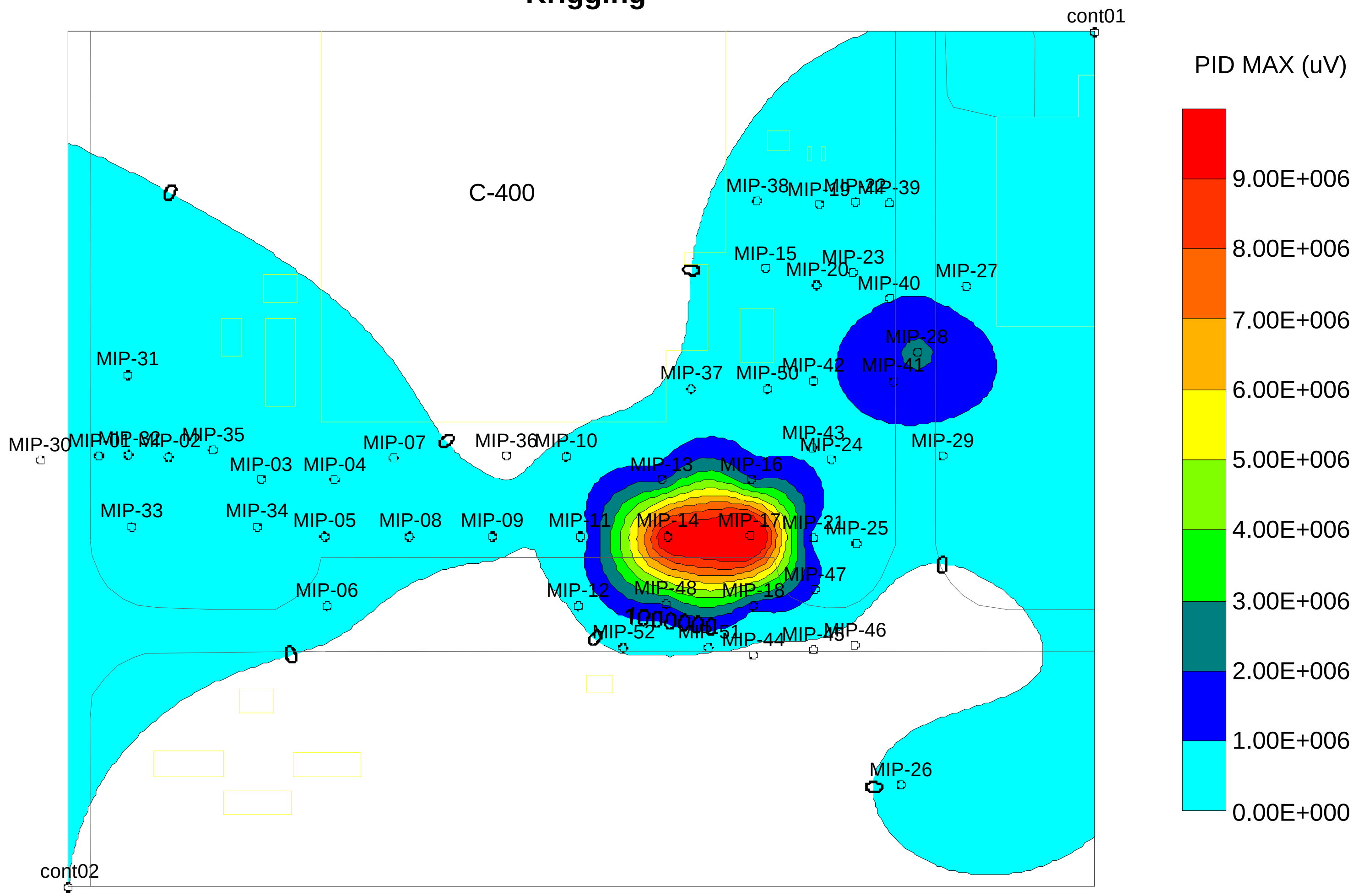
Minimum Curvature



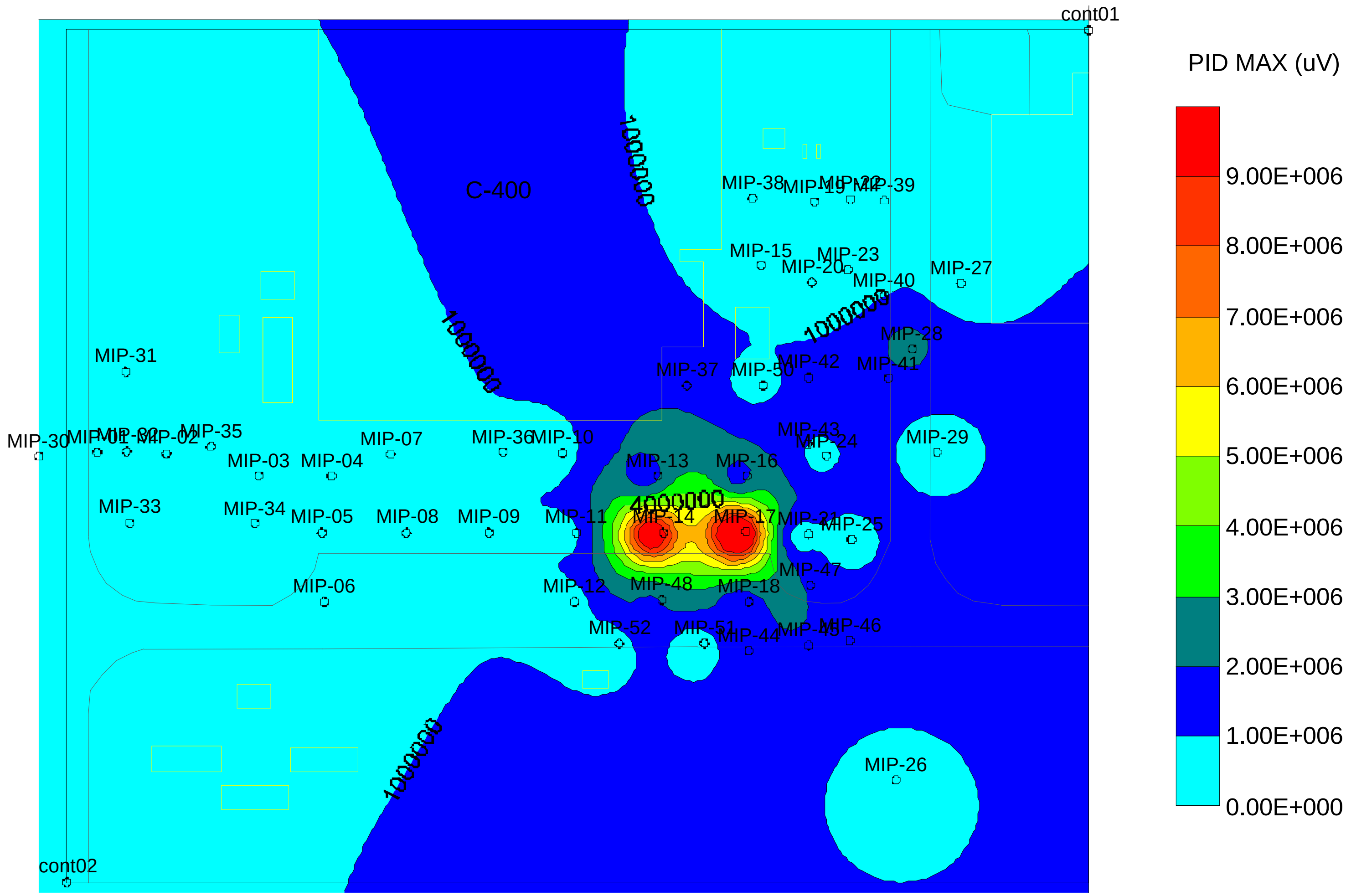
Local Polynomial



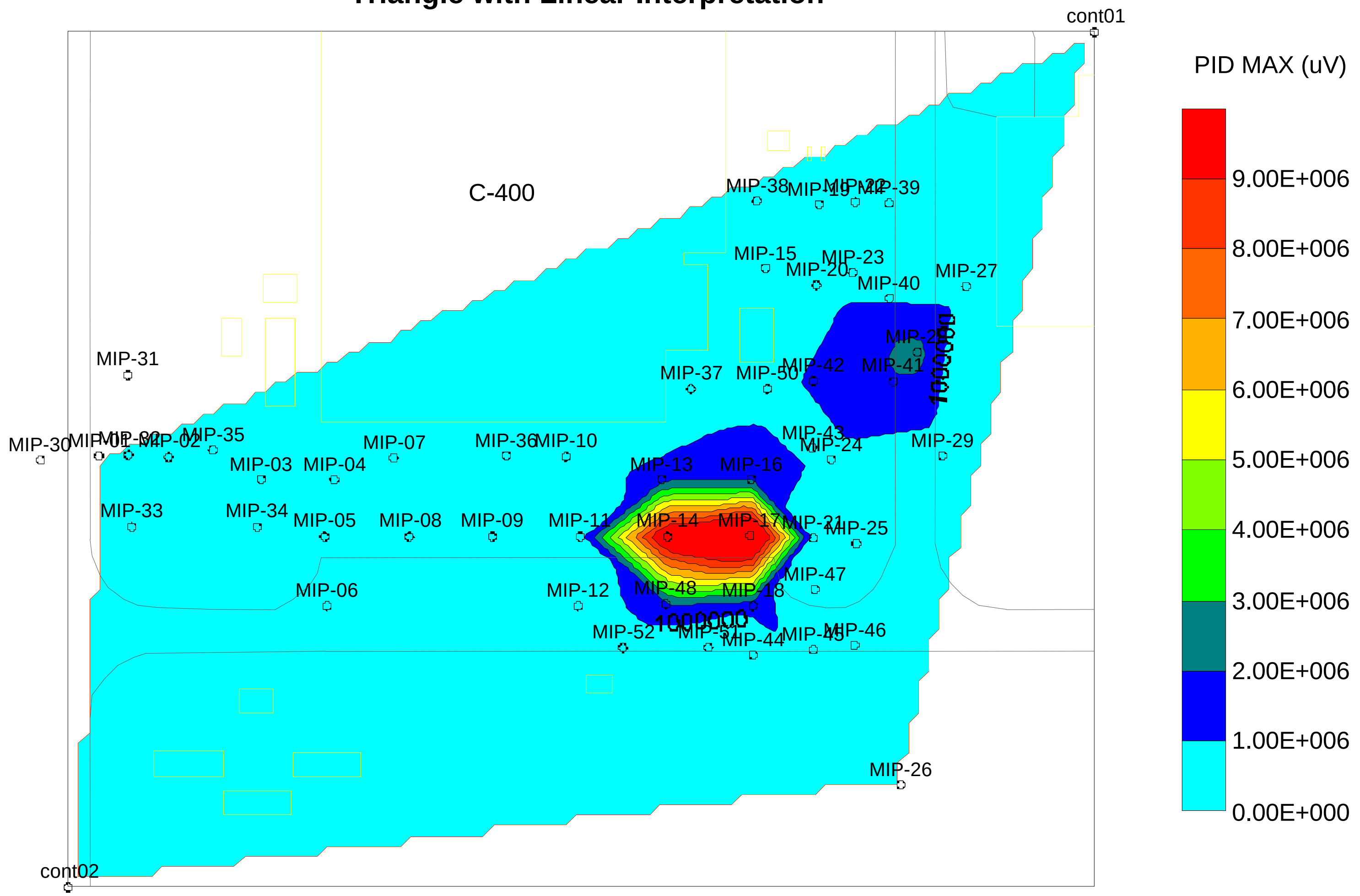
Kriging


cont01
cont02
C-400
PID MAX (uV)
9.00E+006
8.00E+006
7.00E+006
6.00E+006
5.00E+006
4.00E+006
3.00E+006
2.00E+006
1.00E+006
0.00E+000
MIP-31
MIP-30
MIP-35
MIP-03
MIP-04
MIP-07
MIP-36
MIP-10
MIP-33
MIP-34
MIP-05
MIP-08
MIP-09
MIP-11
MIP-06
MIP-12
MIP-38
MIP-39
MIP-15
MIP-23
MIP-27
MIP-40
MIP-28
MIP-37
MIP-41
MIP-43
MIP-24
MIP-29
MIP-13
MIP-16
MIP-14
MIP-25
MIP-47
MIP-48
MIP-18
MIP-52
MIP-44
MIP-46
MIP-26

Inverse Distance to a Power



Triangle with Linear Interpretation



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ATTACHMENT A5

CONVERSION OF TCE CONCENTRATION AND DNAPL SATURATION

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For soil present below the water table, the TCE concentration in contaminated soil is equal to the following:

Equation A.1

$$\frac{\text{TCE mass}}{\text{TCE mass + soil mass + water mass}}$$

where:

TCE mass = TCE density x soil porosity x DNAPL saturation,
soil mass = soil matrix density x (1 - soil porosity), and
water mass = water density x (soil porosity – soil porosity x DNAPL saturation).

The density of TCE is 1.46 g/cc. At PGDP, the soil matrix mineralogy is predominately quartz, as silt which comprises the loess and Upper Continental Deposits, and chert, as sand and gravel in the Lower Continental Deposits. Quartz and chert have a density of 2.65 g/cc. The density of pure water is 1.00 g/cc. Dissolved solids levels in the PGDP groundwater (typically less than 1,000 parts per million) do not materially impact the water density.

The WAG 6 RI provides numerous geotechnical analyses of soil samples from the Upper and Lower Continental Deposits. In both units, the representative porosity value is 0.36 (36%).

By substituting values for density and porosity, the equation for TCE concentration in soil becomes:

Equation A.2

$$\frac{\text{1.46 g/cc x 0.36 x DNAPL saturation}}{\text{1.46 g/cc x 0.36 x DNAPL saturation + 2.65 g/cc x 0.64 + 1.00 g/cc x (0.36 – 0.36 x DNAPL saturation)}}$$

which simplifies to the following:

Equation A.3

$$\frac{\text{0.5256 x DNAPL saturation}}{\text{2.056 + 0.1656 x DNAPL saturation}}$$

This relationship can also be expressed as follows:

Equation A.4

$$\text{DNAPL saturation} = \frac{\text{2.056 x TCE concentration}}{\text{0.5256 - 0.1656 x TCE concentration}}$$

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APPENDIX B

PHASE II MASS VOLUME ESTIMATE

(The following is Attachment A2 of the Revised Proposed Plan for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/LX/07-1263&D1, issued December 2011.)

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ATTACHMENT A2

PHASE II MASS VOLUME ESTIMATE

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A2.1. INTRODUCTION

The purpose of this attachment is to present a summary of the revised estimates of trichloroethene (TCE) mass volume for the C-400 Interim Remedial Action Phase II treatment area based on the analyses of soil samples obtained during the field characterization effort conducted in early 2011. The Field Sampling Plan (FSP) (DOE 2011) describes the activities associated with the 2011 field characterization effort for the Phase II treatment area. Revised mass volume estimates for the Phase II area were generated to refine the conceptual site model (CSM) and support the basis of technology identification selection. This attachment supports the Draft *Evaluation of the Technologies and Alternatives for C-400 Phase IIb, Regional Gravel Aquifer, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*.

The estimate of the total TCE mass volume of the Phase II treatment area is anticipated to range between 7,300 and 85,000 lb (600 and 7,000 gal). For the interval between 0–60 ft below ground surface (bgs),[1] which is primarily the Upper Continental Recharge System (UCRS), the estimate ranges from 290 to 30,500 lb (24 to 2,500 gal). For the interval from 60–100 ft bgs in the Regional Gravel Aquifer (RGA) the estimate ranges from 7,000 to 55,000 lb (576 to 4,500 gal). As indicated, the estimates of mass volume are provided as a range of values. For estimates of residual TCE dense nonaqueous-phase liquid (DNAPL) mass, similar to the C-400 Phase II site, the concept of a range of values is appropriate given the typically heterogeneous nature of DNAPL distribution in subsurface environments similar to that present at C-400 (ITRC 2003). Kueper et al. point out that the majority of the porous media within a DNAPL source zone will contain neither residual nor pooled DNAPL, and the probability of directly encountering residual or pooled DNAPL with a conventional drilling program is relatively small (Kueper et al. 2003). The range of estimates provided is considered to be valid to within an order of magnitude on the upper end. The lower end of the range is identified for informational purposes to indicate the estimate of mass based solely on the results of soil samples analyzed for TCE.

A2.2. GOALS AND SAMPLING METHODS OF THE 2011 INVESTIGATION

LATA Environmental Services of Kentucky, LLC, performed the field characterization investigation of the C-400 Phase II treatment area during the period February through May 2011. Two of the goals of the investigation[2] were these:

- Development of predictive relationships of previous and proposed membrane interface probe (MIP) responses to current TCE concentrations, and
- Assessment of the TCE DNAPL mass and volume within the C-400 Phase II treatment area.

The investigation included MIP logging in six locations (collocated with soil borings) to collect data for development of predictive relationships; collection of soil and groundwater samples for TCE analysis

[1] The three estimate approaches modeled the base of the UCRS at 56, 59, and 60 ft bgs. The Phase IIa remedial action will remove TCE from soils down to a depth of approximately 62 ft using electrical resistance heating (ERH).
[2] The investigation also collected soil samples for analyses of RGA grain size and natural oxidant demand and installed an upgradient well cluster.

from the UCRS, RGA, and the top of the McNairy Formation in six deep soil borings; and collection of soil samples from the UCRS for TCE analysis from an additional two shallow soil borings.

Table A2.1 summarizes the sampling requirements of the FSP. Figure A2.1 shows the location of the 2011 sampling activities, as well as other local MIP borehole locations from a 2006 Remedial Design Support Investigation.

A2.2.1 SAMPLE SUMMARY

In total, the investigation collected soil samples from 250 discrete locations and groundwater samples from 40 discrete locations for analysis of TCE and degradation products. As anticipated, TCE was the dominant contaminant. Tables A2.2 and A2.3 summarize the TCE analyses.

TCE-in-soil concentrations of approximately 200,000 µg/kg are indicative of DNAPL presence in sandy aquifers (Parker et al. 2003). Only one of the analyses of TCE-in-soil (1,700,000 µg/kg TCE from a depth of 59 ft in SB55) is indicative of the presence of DNAPL (approximately 1% DNAPL saturation). While none of the groundwater samples collected DNAPL, all TCE-in-groundwater analyses exceeded 1% of the effective solubility of TCE (11,000 µg/L), a commonly recognized indication of the presence of DNAPL (EPA 2009).

A2.2.2 PREDICTIVE RELATIONSHIPS

Visual comparison of plots of the MIP logs and TCE analyses revealed that the data were poorly related (Figure A2.2 demonstrates the overall lack of correlation of MIP data and TCE analyses.) Of the collocated soil and MIP borings, the best comparison was evident using the photoionization (PID) log of MIP-54 (paired with TCE analyses of SB55) (Figure A2.3). In general, the TCE concentrations in the investigation samples were below the sensitivity range of the MIP detectors.

The predictive relationship assessment included a linear regression analysis of PID measurements and TCE analyses for four MIP/soil boring pairs to qualify the correlation of the data sets. This analysis applied a linear trend line to plots of TCE soil concentrations versus MIP PID data and calculated the correlation coefficient (R^2) value. The assessment successively compared each soil sample with three MIP PID readings: the “non-averaged” PID reading for the sample depth and PID values averaged over 5 ft (Figure A2.4) and 10 ft (Figure A2.5) intervals centered on the sample depth.

Correlations with high correlation coefficient values would be required to predict accurately TCE concentrations from the MIP PID data. Strong correlation coefficients of 0.9 and above were not found on a consistent basis. Because a consistent correlation between MIP readings and analytical data does not exist, the two data sets could not be used in a quantitative TCE mass and volume estimate.

A2.2.3 INITIAL MASS VOLUME ESTIMATE APPROACHES

Three approaches were used to develop initial estimates of the TCE mass volume as follows:

(1) Interpolation of TCE soil analyses within the broader southeast C-400 area, using data from the 2011 investigation and other area historical analyses;

(2) Interpolation of TCE soil analyses within the anticipated treatment zone and its immediate perimeter, using only data from the 2011 investigation; and

Table A2.1. Field Sampling Plan Sampling Requirements

C-400 PHASE II (2011) SOIL BORING	C-400 PHASE II (2011) MIP BORING	SOILS								GROUNDWATER			C-400 RDSI (2006) MIP BORING
		VOCs				NOD		GRAIN SIZE/VOCs		VOCs			
		Horizons	Frequency	Depths (ft bgs)	Sample Quantity	Horizons	Depths (ft bgs)	Horizons	Depths (ft bgs)	Horizons	Depths (ft bgs)	Sample Quantity	
SB53	MIP-53	UCRS/ McN	1	20 – 65, 95	46	NS	NS	RGA	65, 70, 75, 80, 85	RGA	70, 75, 80, 85, 90, 94	6	MIP-13
SB54	MIP-55	UCRS/ McN	2	20 – 55, 97	19	NS	NS	NS	NS	RGA	60, 65, 70, 75, 80, 85, 90, 95	8	MIP-14
SB55	MIP-54	UCRS/ McN	1	0 – 62, 94	63	RGA	75 - 81	NS	NS	RGA	65, 70, 75, 80, 85, 90, 95	7	MIP-16
SB56	MIP-56	UCRS/ McN	2	20 – 65, 96	24	NS	NS	NS	NS	RGA	70, 75, 80, 85, 90, 95	6	MIP-17
SB57	MIP-57	UCRS/ McN	2	20 – 57, 95	20	NS	NS	RGA	60, 65, 70, 75, 85, 90, 94	RGA	60, 65, 70, 75, 80, 85, 90, 94	8	MIP-21
SB58	MIP-58	UCRS	2	20 - 61	21	NS	NS	NS	NS	NS	NS	NS	MIP-43
SB59	NS	UCRS/ McN	2	20 – 61, 94	22	NS	NS	RGA	62, 65, 70, 75, 80, 85, 90, 93	RGA	65, 70, 75, 80, 85, 90, 93	7	MIP-48
SB60	NS	UCRS	2	20 - 61	21	NS	NS	NS	NS	NS	NS	NS	MIP-44
MW507	NS	UCRS	1	PID ≥ 50 PPM	TBD	RGA	64 – 70 76 – 82 88 - 96	NS	NS	NS	NS	NS	MIP-26

Notes:

Frequency = vertical spacing of samples (in ft)
McN = Upper 1 ft of McNairy Formation
MIP = membrane interface probe
NOD = Natural Oxidant Demand
NS = not sampled
PID = Photoionization Detector
PPM = parts per million
RGA = Regional Gravel Aquifer
TBD = to be determined in field (no soil exceeded 50 PPM on the PID and no samples were collected)
UCRS = Upper Continental Recharge System
VOCs = Volatile Organic Compounds

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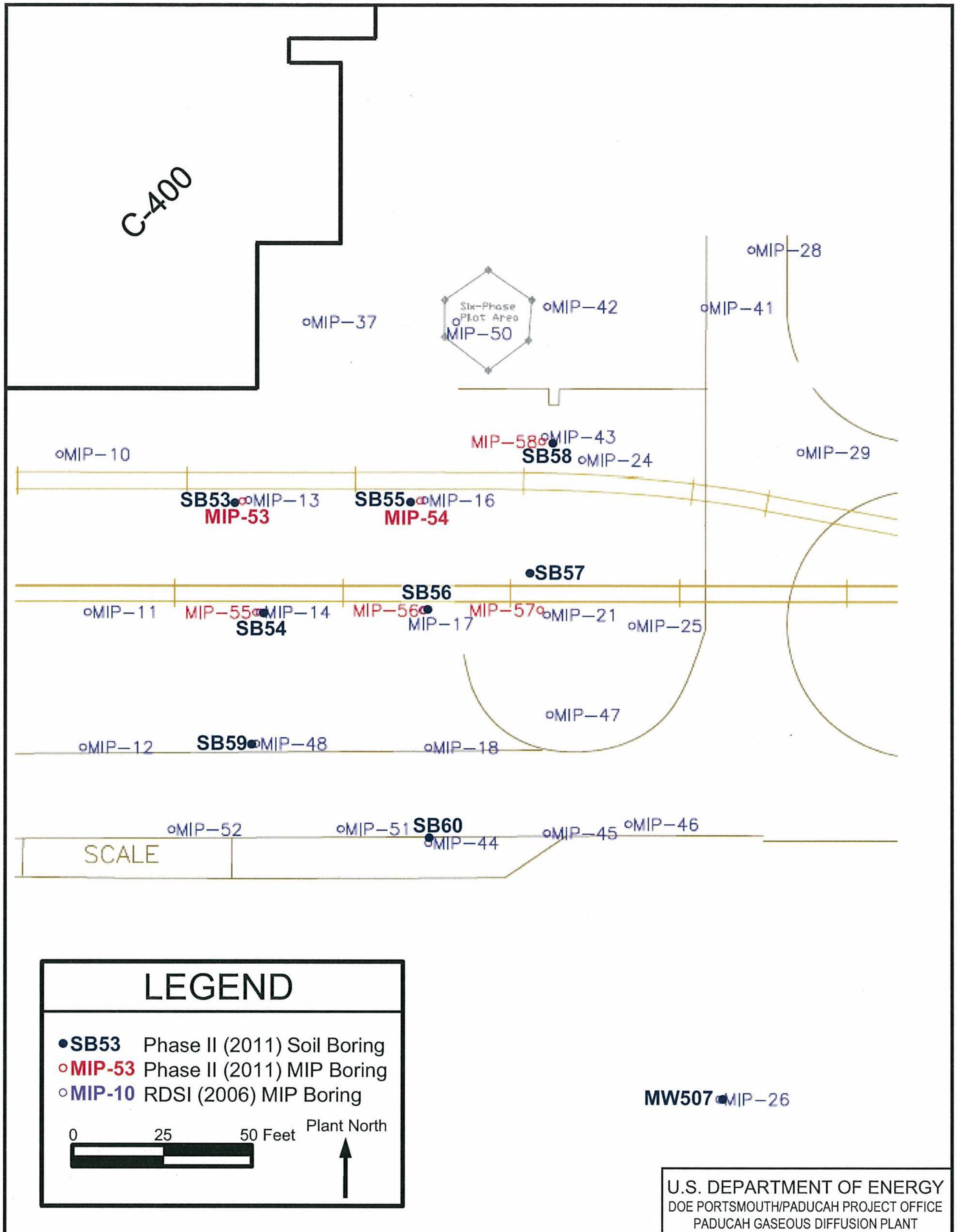

Figure A2.1. 2011 Sampling Locations

LATA Environmental Services of Kentucky, LLC

Table A2.2. Soil Trichloroethene Analytical Results for the C-400 Phase II Area Showing Maximum Value by Depth

DEPTH	Soil Boring and Trichloroethene (µg/kg)							
(ft bgs)	SB53	SB54	SB55	SB56	SB57	SB58	SB59	SB60
5	NS	NS	9	NS	NS	NS	NS	NS
6	NS	NS	4	NS	NS	NS	NS	NS
7	NS	NS	10	NS	NS	NS	NS	NS
8	NS	NS	710	NS	NS	NS	NS	NS
9	NS	NS	480	NS	NS	NS	NS	NS
10	NS	NS	640	NS	NS	NS	NS	NS
11	NS	NS	820	NS	NS	NS	NS	NS
12	NS	NS	1,200	NS	NS	NS	NS	NS
13	NS	NS	1,300	NS	NS	NS	NS	NS
14	NS	NS	2,000	NS	NS	NS	NS	NS
15	NS	NS	1,500	NS	NS	NS	NS	NS
16	NS	NS	1,500	NS	NS	NS	NS	NS
17	NS	NS	2,100	NS	NS	NS	NS	NS
18	NS	NS	1,900	NS	NS	NS	NS	NS
19	NS	NS	280	NS	NS	NS	NS	NS
20	12,000	2	1,400	49	530	1,300	NS	220
21	12,000	NS	1,600	NS	NS	NS	NS	NS
22	14,000	1	2,300	79	490	2,700	NS	400
23	18,000	NS	8,700	NS	NS	NS	NS	NS
24	14,000	5	10,000	74	5,500	8,600	NS	640
25	1,800	NS	26,000	NS	NS	NS	NS	NS
26	4,000	1	30,000	40	1,200	2,200	4	410
27	5,000	NS	14,000	NS	NS	NS	NS	NS
28	170	1	12,000	100	910	14,000	2	130
29	1,100	NS	31,000	NS	NS	NS	NS	NS
30	320	8	790	2	1,400	3,300	5	180
31	1,100	NS	1,300	NS	NS	NS	NS	NS
32	5,600	200	70,000	81	2,800	6,400	14	290
33	54	NS	99,000	NS	NS	NS	NS	NS
34	110	270	33,000	43	1,900	2,600	6	7
35	1,200	NS	55,000	NS	NS	NS	NS	NS
36	49	3	82,000	58	2,200	23,000	NS	44
36.1	NS	NS	NS	NS	NS	NS	2	NS
36.6	NS	NS	93,000	NS	NS	NS	NS	NS
37	280	NS	74,000	NS	NS	NS	NS	NS
38	730	34	30,000	71	600	12,000	9	1,100
39	860	NS	15,000	NS	NS	NS	NS	NS
39.6	NS	NS	NS	NS	NS	NS	NS	NS
40	240	64	57,000	55	750	29,000	170	110
41	1,100	NS	20,000	NS	NS	NS	NS	NS
41.9	NS	3,000	NS	NS	NS	NS	NS	NS

µg/kg = microgram/kilogram
NS = not sampled

Table A2.2. Soil Trichloroethene Analytical Results for the C-400 Phase II Area Showing Maximum Value by Depth (Continued)

DEPTH	Soil Boring and Trichloroethene (µg/kg)							
(ft bgs)	SB53	SB54	SB55	SB56	SB57	SB58	SB59	SB60
42	5,400	190	27,000	7	3,100	22,000	NS	16
42.1	NS	NS	NS	NS	NS	NS	150	NS
42.9	NS	NS	NS	NS	NS	NS	49	NS
43	4,600	NS	81,000	NS	NS	NS	NS	NS
44	6,900	2,600	8,400	98	2,800	2,100	1,100	3
45	1,700	NS	69,000	NS	NS	NS	NS	NS
46	8,700	2,500	NS	15	250	10,000	2,100	5,900
47	8,700	NS	NS	NS	NS	NS	NS	NS
48	7,500	3,400	NS	1,400	5,400	5,000	130	12,000
49	8,600	NS	NS	NS	NS	NS	NS	NS
50	9,200	3,700	NS	2,000	7,800	11,000	2,200	170
51	14,000	NS	48,000	NS	NS	NS	NS	NS
52	17,000	2,200	96,000	1,700	490	8,400	2,500	100
53	14,000	NS	60,000	NS	NS	NS	NS	NS
54	23,000	750	35,000	440	470	6,100	2,600	3,100
55	23,000	130	24,000	NS	2,000	NS	NS	NS
56	7,100	NS	15,000	5,500	NS	66,000	4,100	4,000
57	8,600	NS	8,400	NS	NS	NS	NS	NS
58	6,200	NS	14,000	850	NS	41,000	5,600	890
59	1,900	NS	1,700,000	NS	NS	NS	NS	NS
60	6,700	NS	75,000	2,600	NS	8,500	3,700	2,600
60.5	NS	NS	NS	NS	NS	NS	NS	380
61	8,000	NS	64,000	NS	NS	NS	1,900	1,500
62	6,600	NS	67,000	2,600	NS	2,300	NS	NS
63	4,000	NS	NS	NS	NS	NS	NS	NS
64	620	NS	NS	7,100	NS	NS	NS	NS
65	130	NS	NS	NS	NS	NS	NS	NS
66	16,000	NS	NS	NS	NS	NS	NS	NS
71	23,000	NS	NS	NS	NS	NS	NS	NS
76	NS	NS	NS	NS	NS	NS	2,700	NS
85	1,100	NS	NS	NS	54,000	NS	NS	NS
90	NS	NS	NS	NS	21,000	NS	NS	NS
91	NS	NS	NS	NS	NS	NS	1,300	NS
94	16,000	NS	1,900	NS	NS	NS	2,900	NS
95	NS	5,100	NS	NS	NS	NS	NS	NS
95.1	NS	NS	NS	NS	9,100	NS	NS	NS
95.2	NS	NS	NS	NS	NS	NS	1,900	NS
95.4	NS	NS	2,000	NS	NS	NS	14,000	NS
95.6	NS	NS	NS	NS	48	NS	NS	NS
95.8	NS	7,900	NS	NS	NS	NS	NS	NS
96	NS	NS	NS	150,000	NS	NS	NS	NS
96.3	NS	NS	NS	1,300	NS	NS	NS	NS

µg/kg = microgram/kilogram
NS = not sampled

Table A2.3. Groundwater Trichloroethene Analytical Results for the C-400 Phase II Area Showing Maximum Value by Depth

DEPTH (ft)	Soil Boring and Trichloroethene (µg/L)					
	SB53	SB54	SB55	SB56	SB57	SB59
60	NS	28,000	NS	NS	NS	NS
65	NS	21,000	610,000	NS	280,000	16,000
70	77,000	23,000	570,000	280,000	400,000	27,000
75	55,000	NS	430,000	430,000	270,000	20,000
79	180,000	19,000	NS	NS	NS	NS
80	NS	NS	84,000	240,000	340,000	24,000
84	100,000	NS	NS	NS	NS	NS
85	NS	580,000	57,000	240,000	590,000	70,000
89	87,000	NS	NS	NS	NS	NS
90	NS	410,000	53,000	230,000	1,200,000	52,000
93	NS	NS	NS	NS	NS	34,000
94	76,000	NS	46,000	NS	870,000	NS
95	NS	330,000	NS	200,000	NS	NS

µg/L = microgram/liter
NS = not sampled

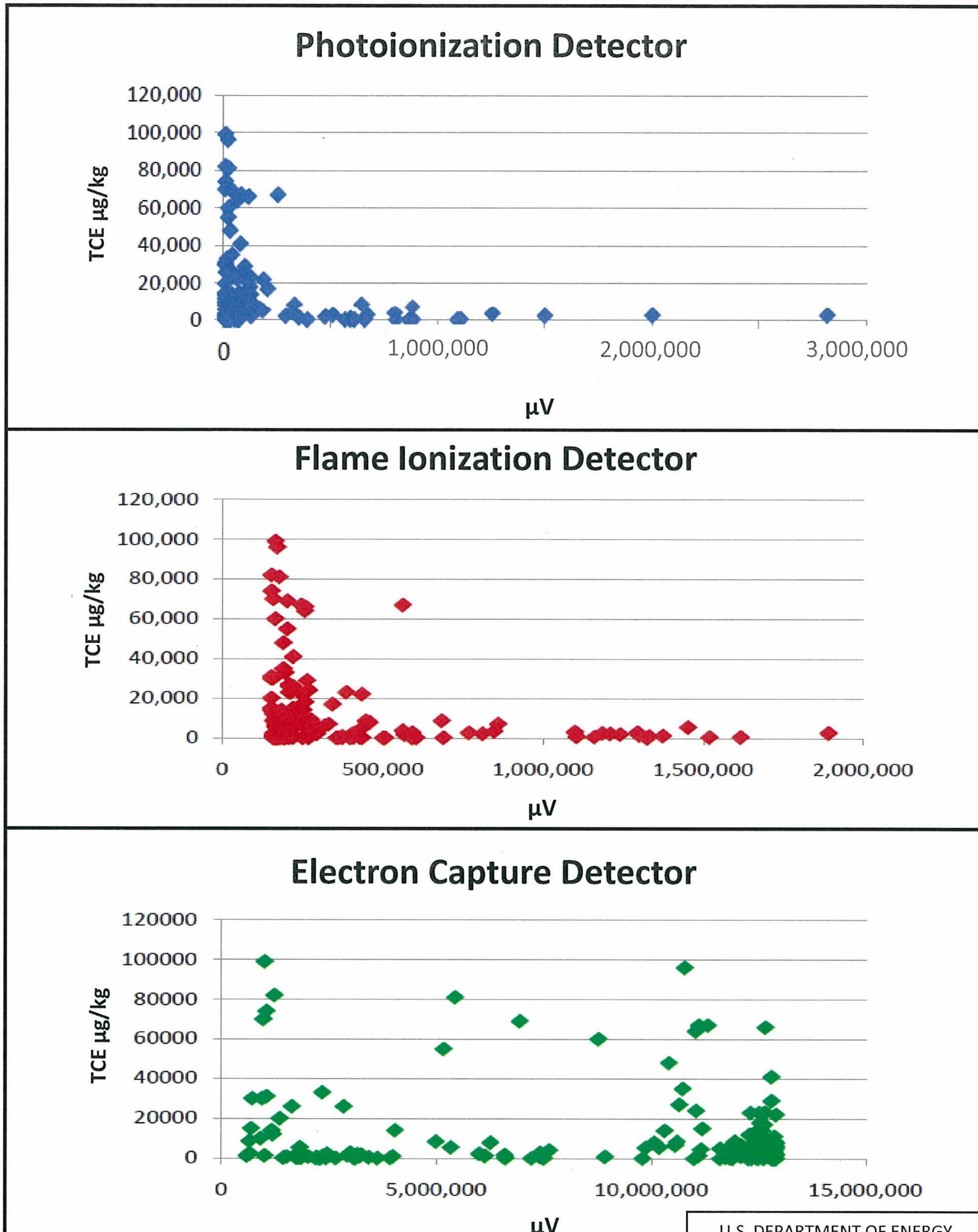

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Figure A2.2. 2011 C-400 Phase II Investigation Trichloroethene Concentrations in Soil versus MIP Detector Responses

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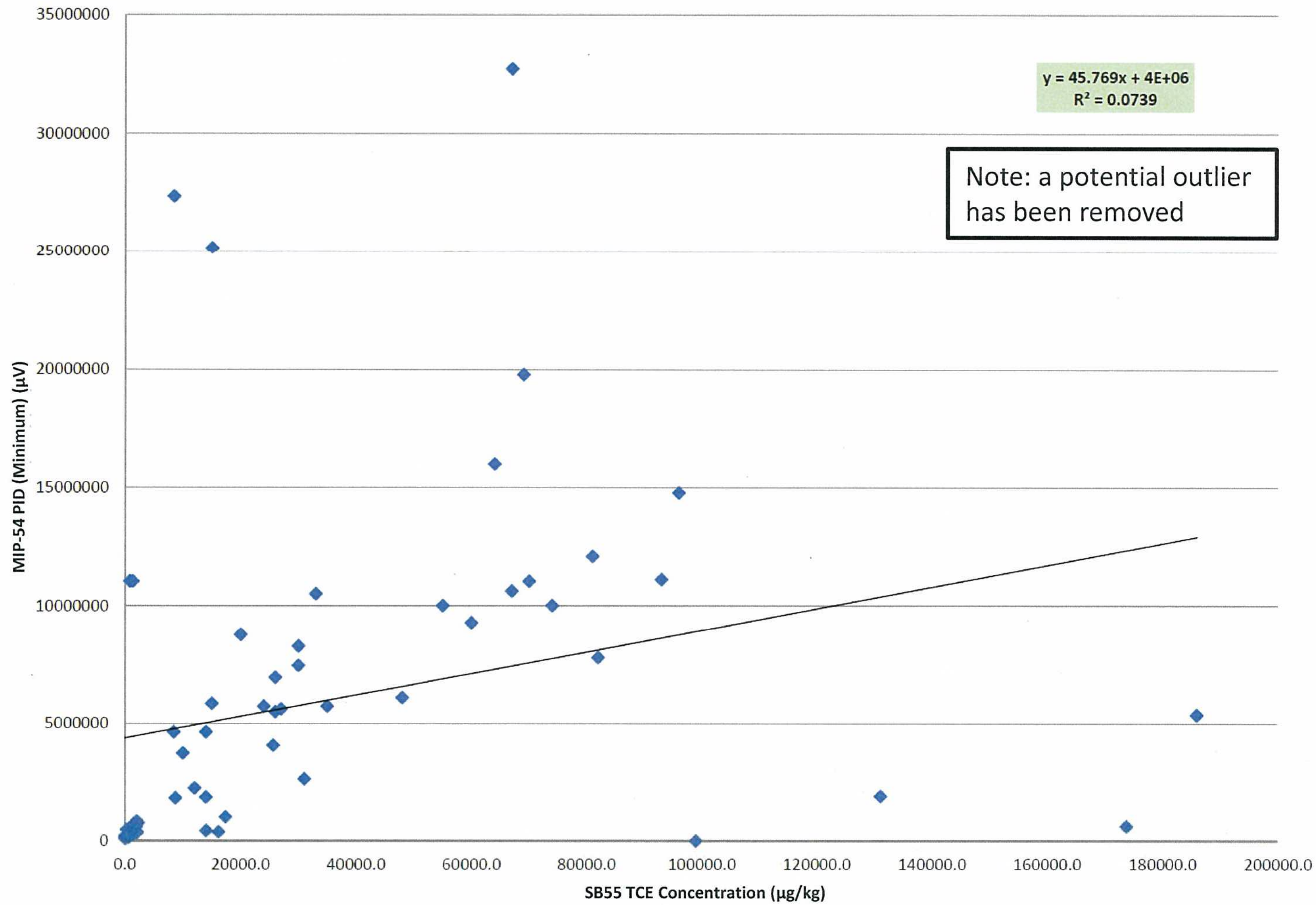

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Figure A2.3. Linear Regression of C-400 Phase II Trichloroethene Concentrations in Soil at SB55 versus Photoionization Detector Response in MIP-54

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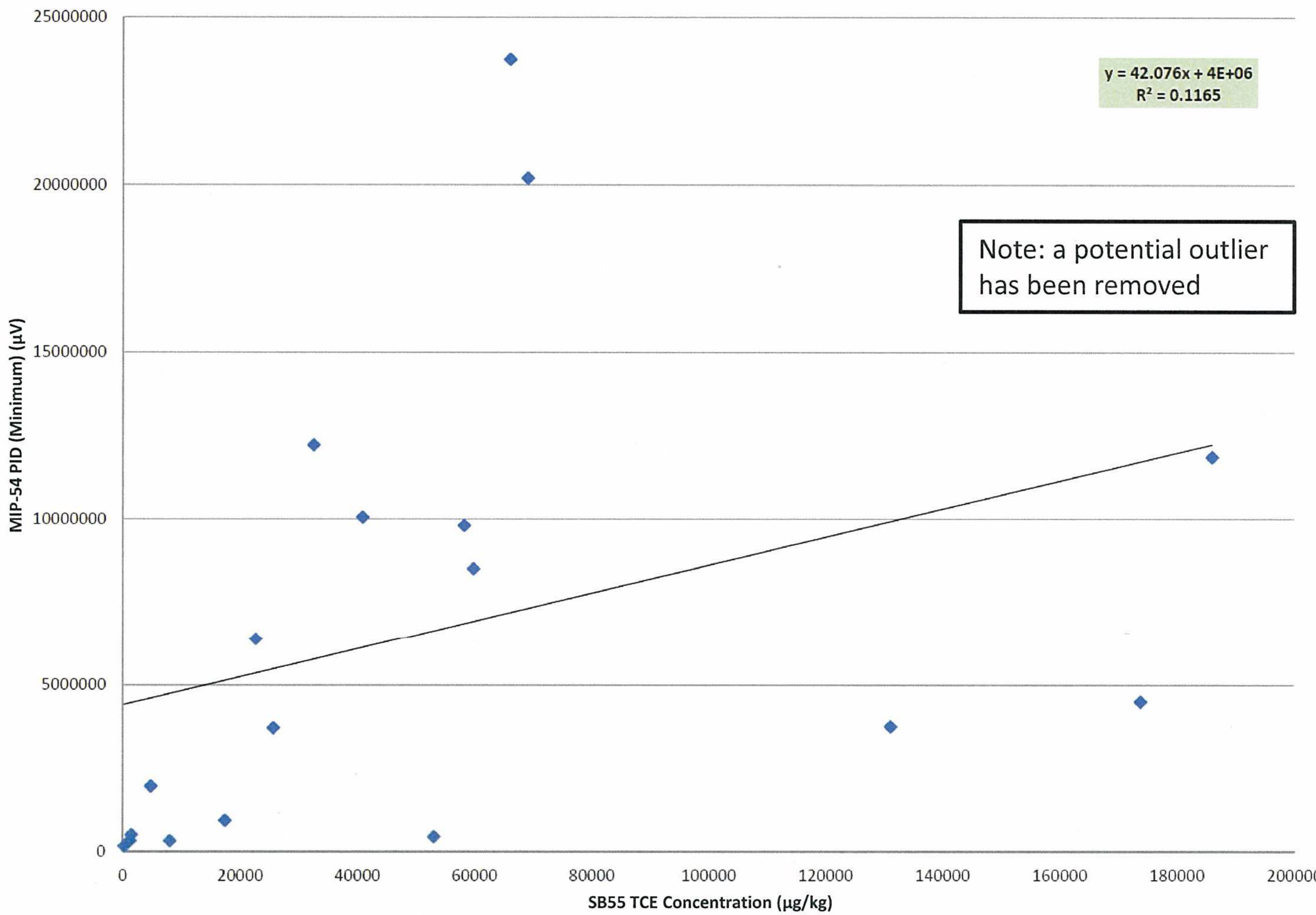

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Figure A2.4. Linear Regression of C-400 Phase II Trichloroethene Concentrations in Soil at SB55 versus 5-ft Average Photoionization Detector Response in MIP-54

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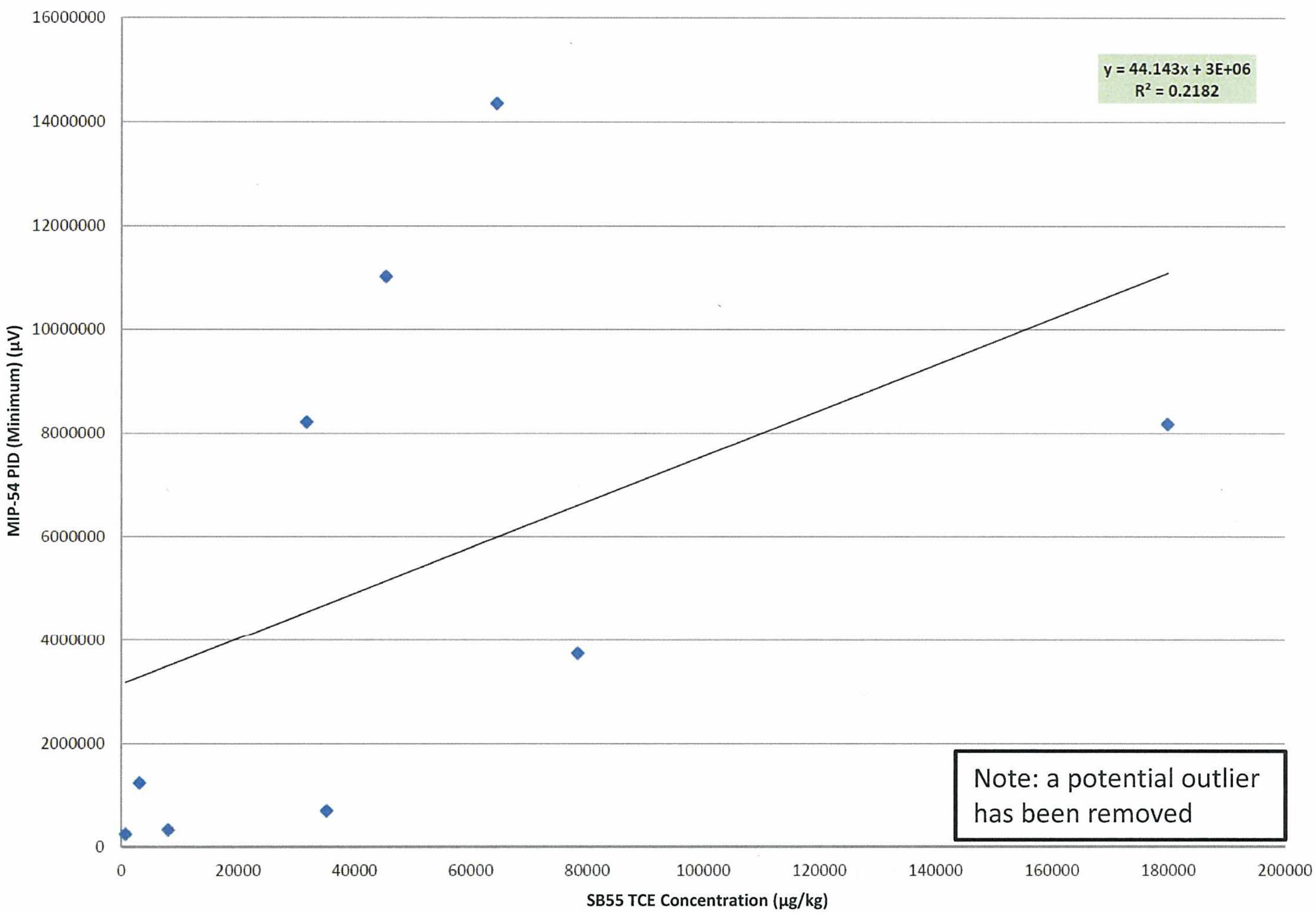

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Figure A2.5. Linear Regression of C-400 Phase II Trichloroethene Concentrations in Soil at SB55 versus 10-ft Average Photoionization Detector Response in MIP-54

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(3) Interpolation of TCE soil analyses from three soil borings of the 2011 investigation, based on a CSM incorporating a point of DNAPL release.

Approach 1

The assessment of the broader southeast C-400 area used Esri ArcGIS to discretize the model volume into 5-ft depth intervals down to the base of the RGA and to interpolate (contour) soil analyses across each of the 5-ft intervals (Figure A2.6). Inverse distance weighted interpolation was used, with MIP borings providing outer boundary points for the area of interpolation. For each 5-ft depth interval, the assessment calculated the TCE mass within soil volumes of equal concentration as follows:

> TCE Mass (lb) = Area of Equal Concentration [ft^2] × Interval Depth [ft] × Soil Weight [kg/ft^3] × Average Concentration [µg/kg] × Micrograms to Pounds Conversion Factor [lb/µg]
>
> (Soil weight was specific to the UCRS and RGA)

and summed the TCE mass calculations. Table A2.4 summarizes the results of the mass calculation. Because few soil analyses are available for the RGA, the assessment included calculated soil concentrations, derived from the available groundwater analyses by use of a partitioning coefficient.

The Esri ArcGIS-based assessment estimated 780 lb (64 gal) of TCE are present in the UCRS down to a depth of 56 ft and 7,000 lb (570 gal) of TCE are present in the RGA below 56 ft.

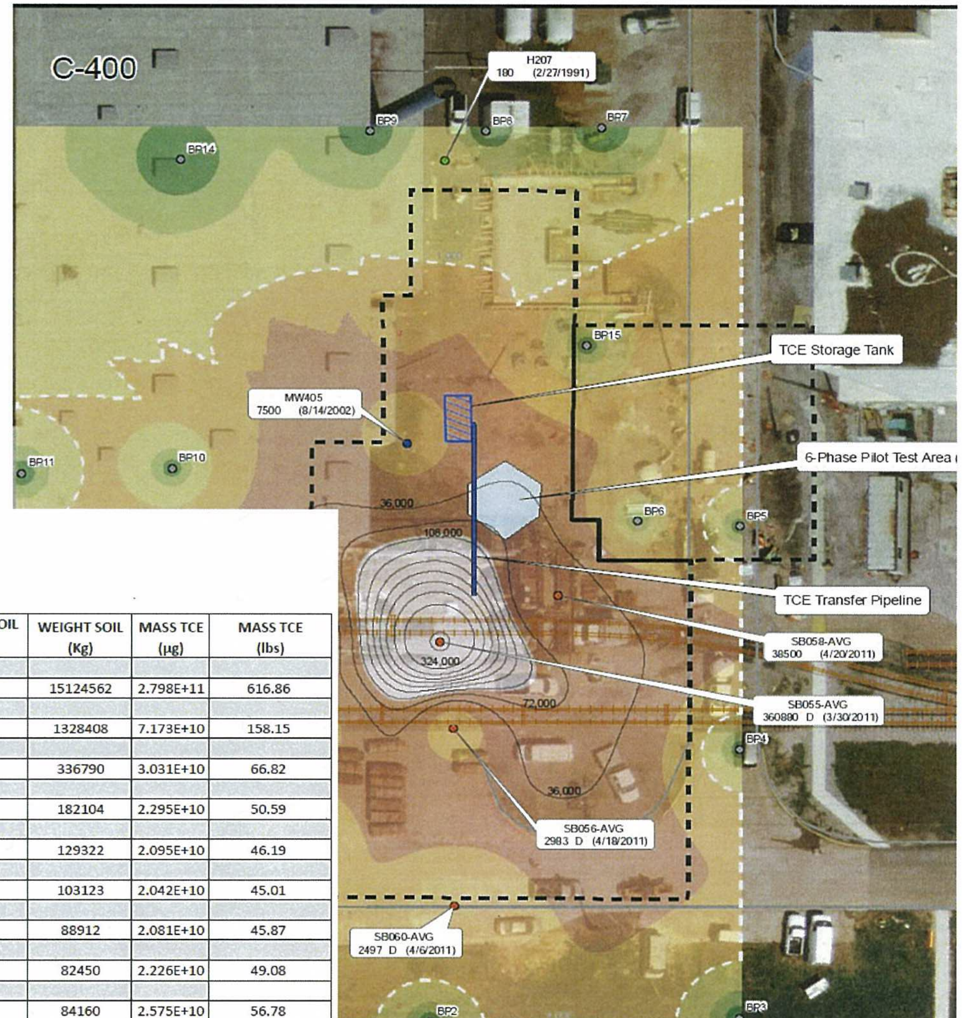
Approach 2

The assessment limited to the anticipated treatment zone (and perimeter) used the U.S. Geological Survey's Modular Three-Dimensional Groundwater Flow Model (MODFLOW) to discretize the Phase II treatment area volume into 1-ft x 1-ft x 1-ft model cells down to the base of the RGA and to linearly interpolate the 2011 investigation soil TCE analyses within each 1-ft depth interval throughout all of the treatment area's model cells (Figure A2.7). (This model assumed that the TCE-in-soil concentration of each of the perimeter model cells was 0.1 µg/kg.) Where the 2011 investigation did not provide a soil analysis within a 1-ft depth interval for a soil boring, the assessment created a synthetic soil analysis by (vertical) linear interpolation between analyses for the closest soil samples. MODFLOW converted the interpolated TCE-in-soil concentrations into TCE mass for each of the area's model cells using the following equation:

> TCE Mass (lb)/Model Cell = Model Cell TCE Concentration [µg/kg] × Soil Weight [kg/ ft^3] × Volume of Model Cell [ft^3] × Micrograms to Pounds Conversion Factor [lb/µg]
>
> (Soil weight is specific to the UCRS and RGA.)

Figure A2.8 shows the vertical distribution of the model-derived TCE mass.

The MODFLOW-based assessment estimated 290 lb (24 gal) of TCE are present in the UCRS down to a depth of 59 ft and 75 lb (6 gal) of TCE are present in the RGA below 59 ft.



VERTICAL INTERVAL ELEVATION:	319-324	ft AMSL
VERTICAL INTERVAL DEPTH:	5	ft
ESTIMATED SOIL DENSITY:	54.9	Kg/ft³
CONVERSION µg per lb:	453,592,370	
CONTOUR INTERVAL:	36,000	

CONCENTRATION (µg/Kg)	AVERAGE CONCENTRATION (µg/Kg)	AREA OF EQUAL CONCENTRATION (FT²)	Δ AREA (ft²)	VOLUME SOIL (ft³)	WEIGHT SOIL (Kg)	MASS TCE (µg)	MASS TCE (lbs)
1000		64106					
	18500		55123	275617	15124562	2.798E+11	616.86
36000		8982					
	54000		4842	24208	1328408	7.173E+10	158.15
72000		4141					
	90000		1227	6137	336790	3.031E+10	66.82
108000		2913					
	126000		664	3319	182104	2.295E+10	50.59
144000		2250					
	162000		471	2357	129322	2.095E+10	46.19
180000		1778					
	198000		376	1879	103123	2.042E+10	45.01
216000		1402					
	234000		324	1620	88912	2.081E+10	45.87
252000		1078					
	270000		301	1503	82450	2.226E+10	49.08
288000		778					
	306000		307	1534	84160	2.575E+10	56.78
324000		471					
	342000		435	2173	119241	4.078E+10	89.91
360000		36					

INTERVAL MASS TOTAL = 1,225 lbs
100 gallons

ft AMSL = feet above mean sea level

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Figure A2.6. Southeast C-400 Model Example Calculation Worksheet and Contour Interpolation for the 319-324 ft AMSL Layer

Table A2.4. Southeast C-400 Model TCE Mass and Volume Summary

Vertical Interval		TCE Mass (lbs)	TCE Mass (gallons)	Cumulative TCE Mass (gallons)	Cumulative TCE Mass (%)	Formation
(ft amsl)	(ft bgs)					
274 – 284	96 – 106	321	26	634	100%	RGA
284 – 289	91 – 96	915	75	608	96%	RGA
289 – 294	86 – 91	1,034	85	533	84%	RGA
294 – 299	81 – 86	667	55	448	71%	RGA
299 – 304	76 – 81	717	59	393	62%	RGA
304 – 309	71 – 76	833	68	334	53%	RGA
309 – 314	66 – 71	905	74	266	42%	RGA
314 – 319	61 – 66	337	28	192	30%	RGA
319 – 324	56 – 61	1,225	100	164	26%	RGA (HU4)
324 – 329	51 – 56	196	16	64	10%	UCRS
329 – 334	46 – 51	84	6.9	48	8%	UCRS
334 – 339	41 – 46	109	8.9	41	6%	UCRS
339 – 344	36 – 41	91	7.5	32	5%	UCRS
344 – 349	31 – 36	75	6.1	25	4%	UCRS
349 – 354	26 – 31	32	2.6	18	3%	UCRS
354 – 359	21 – 26	46	3.7	16	2%	UCRS
359 – 364	16 – 21	27	2.2	12	2%	UCRS
364 – 369	11 – 16	27	2.3	10	2%	UCRS
369 – 374	6 – 11	75	6.2	8	1%	UCRS
374 – 380	0 - 6	17	1.4	1	0%	UCRS

TOTAL MASS =	**7,735**	**634**
RGA Mass =	5,730	570
UCRS Mass =	2,005	64

ft amsl = feet above mean sea level
ft bgs = feet below ground surface
% = percent

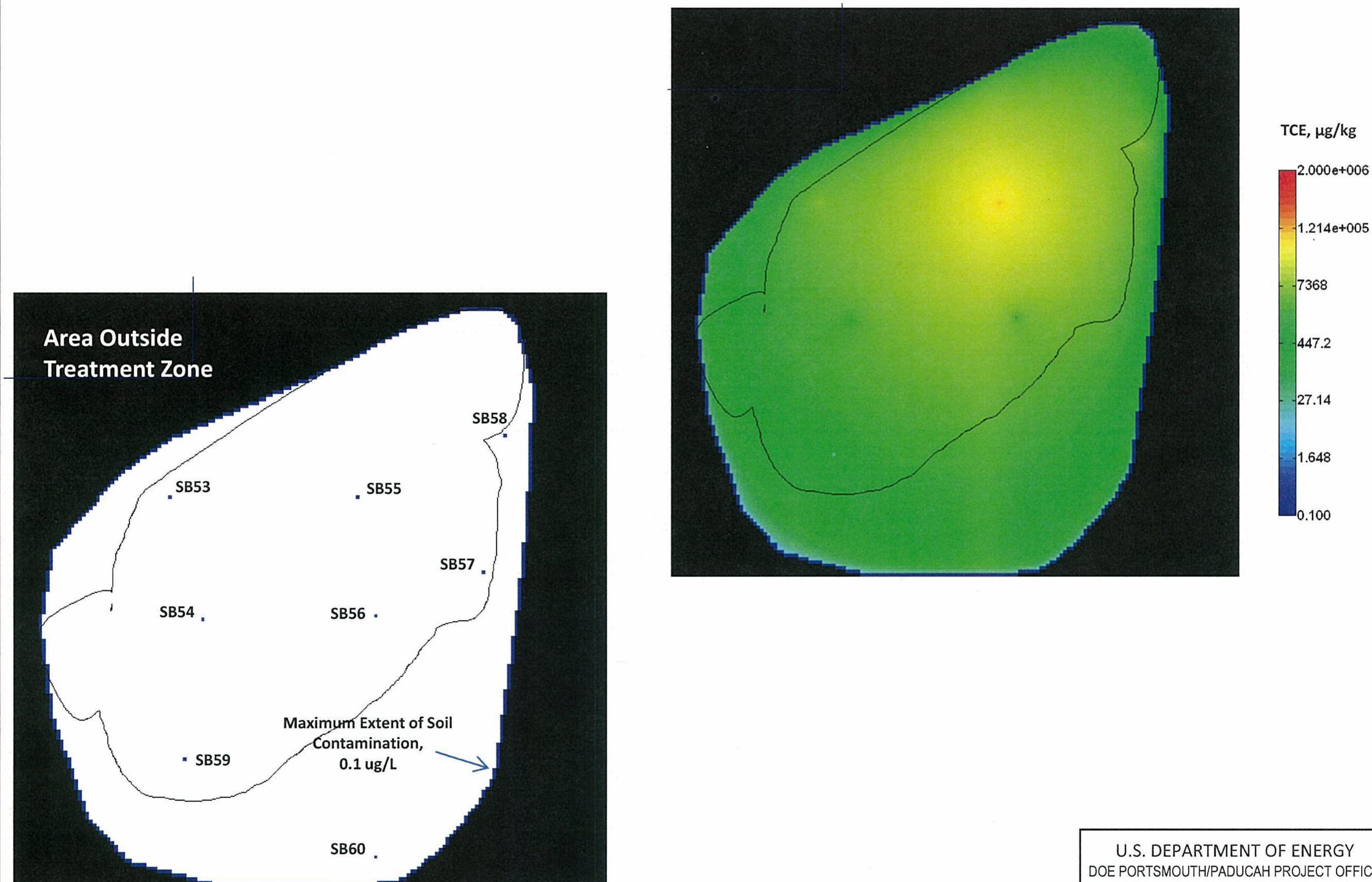

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Figure A2.7. Treatment Zone Model Domain and Example TCE Interpolation

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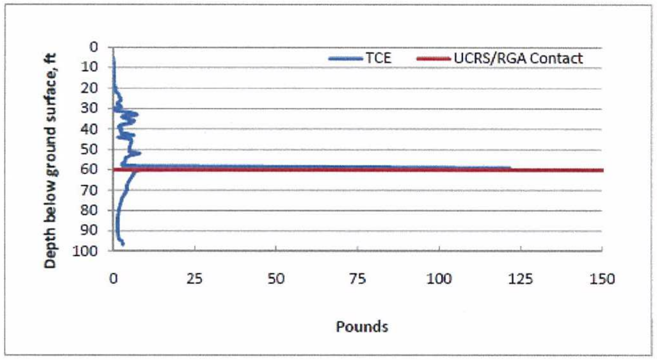
CALCULATION OF TCE MASS AND VOLUME FOR 5 FT DEPTH (MODEL LAYER 1) TO 97 FT DEPTH (MODEL LAYER 93)

Layer	Depth (ft bgs)	POUNDS OF TCE IN SOIL* (LBS-SOIL)	GALLONS OF TCE IN SOIL (GAL-SOIL)	CUMMULATIVE POUNDS OF TCE IN SOIL (CUM LBS-SOIL)	Layer	Depth (ft bgs)	POUNDS OF TCE IN SOIL* (LBS-SOIL)	GALLONS OF TCE IN SOIL (GAL-SOIL)	CUMMULATIVE POUNDS OF TCE IN SOIL (CUM LBS-SOIL)
1	5	0	0	0	48	52	8	1	112
2	6	0	0	0	49	53	5	0	117
3	7	0	0	0	50	54	4	0	121
4	8	0	0	0	51	55	4	0	124
5	9	0	0	0	52	56	4	0	128
6	10	0	0	0	53	57	3	0	131
7	11	0	0	0	54	58	3	0	133
8	12	0	0	0	55	59	122	10	255
9	13	0	0	0	56	60	8	1	264
10	14	0	0	1	57	61	6	1	270
11	15	0	0	1	58	62	6	1	276
12	16	0	0	1	59	63	6	0	282
13	17	0	0	1	60	64	5	0	287
14	18	0	0	1	61	65	5	0	292
15	19	0	0	1	62	66	5	0	297
16	20	1	0	2	63	67	4	0	301
17	21	1	0	3	64	68	4	0	306
18	22	1	0	4	65	69	4	0	310
19	23	2	0	5	66	70	4	0	314
20	24	2	0	7	67	71	4	0	318
21	25	2	0	9	68	72	3	0	321
22	26	2	0	11	69	73	3	0	324
23	27	1	0	13	70	74	3	0	327
24	28	1	0	14	71	75	3	0	329
25	29	2	0	16	72	76	2	0	332
26	30	0	0	17	73	77	2	0	334
27	31	0	0	17	74	78	2	0	336
28	32	6	0	22	75	79	2	0	337
29	33	7	1	30	76	80	2	0	339
30	34	2	0	32	77	81	2	0	341
31	35	4	0	36	78	82	1	0	342
32	36	6	1	43	79	83	1	0	344
33	37	6	0	48	80	84	1	0	345
34	38	2	0	51	81	85	1	0	346
35	39	2	0	52	82	86	1	0	347
36	40	3	0	55	83	87	1	0	349
37	41	2	0	57	84	88	1	0	350
38	42	3	0	60	85	89	1	0	351
39	43	6	1	66	86	90	1	0	353
40	44	1	0	67	87	91	1	0	354
41	45	5	0	73	88	92	1	0	355
42	46	6	0	78	89	93	2	0	357
43	47	5	0	84	90	94	2	0	359
44	48	5	0	89	91	95	3	0	361
45	49	5	0	94	92	96	3	0	364
46	50	5	0	99	93	97	3	0	367
47	51	5	0	104					

*POUNDS OF TCE IN SOIL (LBS-SOIL) is derived from MODFLOW-2000 *MODular three-dimensional finite-difference ground-water FLOW model --2000 updated version*

UCRS	RGA	TOTAL
255	112	367 LBS
21	9	30 GAL



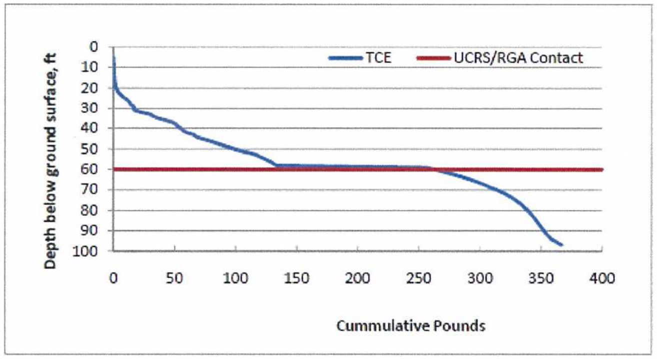


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Figure A2.8. Treatment Zone TCE Mass and Volume Summary

Distance (ft)	TCE (µgkg)	
	0.79	(Multiplication Factor)
	10,000,000	(Assumed TCE Concentration at DNAPL Core)
1	7,943,280	
2	6,309,570	
3	5,011,868	
4	3,981,067	
5	3,162,273	
6	2,511,882	
7	1,995,258	
8	1,584,889	
9	1,258,922	
10	999,997	
11	794,326	
12	630,955	
13	501,185	
14	398,106	
15	316,226	
16	251,187	
17	199,525	
18	158,488	
19	125,892	
20	99,999	Compare to 93,000 µg/kg in SB55
21	79,432	
22	63,095	
23	50,118	
24	39,810	
25	31,623	
26	25,119	Compare to 23,000 µg/kg in SB58
27	19,952	
28	15,849	
29	12,589	
30	10,000	
31	7,943	
32	6,310	
33	5,012	
34	3,981	
35	3,162	
36	2,512	
37	1,995	Compare to 2,000 µg/kg in SB58
38	1,585	
38	1,259	
40	1,000	

Values at 36 ft depth

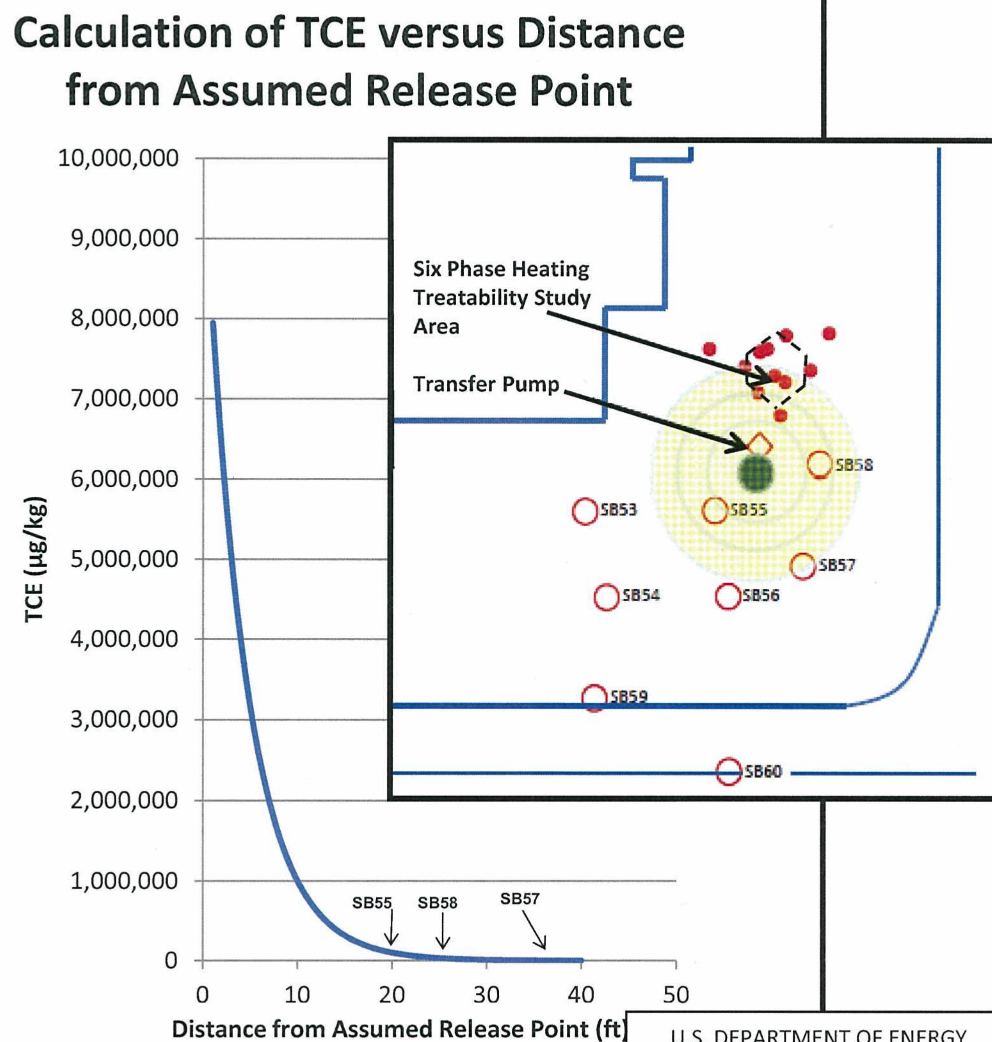

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Figure A2.9. DNAPL Release-Based Trichloroethene Mass and Volume Example

LATA Environmental Services of Kentucky, LLC

Approach 3

The DNAPL release-based model used Microsoft® Excel to interpolate soil TCE analyses in a transect between a modeled DNAPL zone near the location of the former TCE transfer pump (assigned soil TCE concentration of 10,000,000 µg/kg) and the three closest soil borings of the 2011 investigation (Figure A2.9). This model assessed TCE mass down to a depth of 60 ft, which was discretized into 13 horizons of varied thickness. Soil TCE trends and geology defined the thickness of each of the 13 model horizons.

Table A2.5 presents the depth, soil, and TCE characteristics of each model horizon. The model assumed the TCE contamination was symmetrically distributed around the DNAPL zone to extrapolate the soil TCE transect to a volume of contaminated soil. Each horizon was discretized into 1-ft wide rings/model cells. Because the most distal of the three soil borings was located 40 ft from the modeled DNAPL zone, each horizon was discretized into 40 model cells/rings per each of the 13 model horizons for calculation of soil mass and TCE mass volume.

Three interpolation techniques (exponential trend line, power function trend line, and constant percent reduction) were used to assess different TCE mass distributions away from the DNAPL zone. Each of the three interpolation techniques assumed a central TCE-in-soil concentration of 10,000,000 µg/kg [the highest observed TCE-in-soil concentration in the Southeast C-400 area (~ 4% DNAPL saturation)] and used the TCE-in-soil values derived from the three closest soil borings.

This model calculated the TCE mass for each model cell using the following equation:

> TCE Mass (g)/Model Cell = Model Cell Volume (ft^3) × Volume Conversion (cc/ft^3) × Soil Weight (g/cc) × Model Cell TCE Concentration (µg/kg) × Mass Conversion ($1\ kg/10^9\ \mu g$)

Each of the model cell masses in a model horizon were summed for a total mass/horizon value and converted to lb of TCE and volume of TCE (liters and gallons). Table A2.6 summarizes the calculated TCE mass per model horizon. The model estimated 3,200 to 31,000 lb (260 to 2,500 gal) of TCE is present in the UCRS down to a depth of 60 ft.

A separate Excel model of three zones of vertical DNAPL migration was created to assess TCE mass below 60 ft, consistent with TCE-in-groundwater trends observed in samples of the 2011 investigation (Table A2.7). The model assumed each vertical migration pathway had a radius of 5 ft, with 4% DNAPL saturation at the core, declining (using constant percent reduction) to 0.67% DNAPL saturation [equal to the maximum observed TCE-in-soil concentration (1,700,000 µg/kg) from the 2011 investigation] at the perimeter. Each model cell consisted of a 1-ft wide ring centered on the vertical migration pathway (as in the UCRS model) but only 1-ft high. There were five concentric rings of model cells for each 1-ft depth interval for each vertical migration pathway.

The calculation of TCE volume for each model cell was as follows:

> TCE Volume (ft^3) = Model Cell Volume (ft^3) × RGA Porosity (fraction percentage) × DNAPL Saturation (fraction percentage)

Each modeled 1-ft depth interval of each migration pathway contained 0.3 ft^3 (2.4 gal) of TCE. The total TCE for each migration pathway was the height of the pathway multiplied by 0.3 ft^3 (2.4 gal). In addition, the model included a basal RGA DNAPL pool with a DNAPL saturation of 10% measuring 10 ft x 80 ft and 1-ft thick. This model estimated 3,900 lb (320 gal) are present in the RGA between 60 and 96 ft depth.

Table A2.5. Dense Nonaqueous-Phase Liquid Release-Based Model Horizons

Model Horizon	Depth Range (ft)	PGDP Hydrogeologic Unit	Soil Type	Representative TCE Concentration (µg/kg) in SB55*
1	0–7.50	1	Silt	9
2	7.50–11.50	1	Silt	675
3	11.50–23.00	1	Silt	1,500
4	23.00–24.60	1	Clayey Silt	9,350
5	24.60–29.05	2	Fine Sand and Silt	26,000
6	29.05–33.00	2	Sand	24,030
7	33.00–44.85	2	Sand with Gravel	55,000
8	44.85–46.05	3	Silty Sand	69,000
9	46.05–47.40	3	Silty Sand	4,294,068
10	47.40–53.30	3	Silty Clay to Fine Sand	60,000
11	53.30–58.50	3	Fine Sand	15,000
12	58.50–59.50	3	Fine Sand	1,700,000
13	59.50–60.00	3	Fine Sand	71,000

TCE = trichloroethene

*SB55 is the closest soil boring to the modeled DNAPL release site.

Table A2.6. TCE Mass Volume Summary for Dense Nonaqueous-Phase Liquid Release-Based Model

Model Horizon	Depth Range (ft)	Trichloroethene Mass Volume	
		Pounds	Gallons
1	0–7.50	0.3	0.0
2	7.50–11.50	12.5	1.0
3	11.50–23.00	79.9	6.6
4	23.00–24.60	59.4–278.8	4.9–22.9
5	24.60–29.05	127.2–902.3	10.4–74.1
6	29.05–33.00	238.6–1,338.8	19.6–109.9
7	33.00–44.85	675.0–3,462.8	55.4–284.2
8	44.85–46.05	29.3–352.2	2.4–28.9
9	46.05–47.40	116.3–18,504.0	9.5–1,518.7
10	47.40–53.30	361.1–1,628.0	29.6–133.6
11	53.30–58.50	222.1–1,243.5	18.2–102.1
12	58.50–59.50	1,030.0–4,254.8	84.5–349.2
13	59.50–60.00	46.5–228.1	3.8–18.7

Table A2.7. Modeled RGA Migration Pathways, DNAPL Release-Based Model

Soil Borings	SB53	SB54	SB55	SB56	SB57	SB59
Depth (ft)	TCE (µg/L)					
60	NS	28,000	NS	NS	NS	NS
61	NS	NS	NS	NS	NS	NS
62	NS	NS	NS	NS	NS	NS
63	NS	NS	NS	NS	NS	NS
64	NS	NS	NS	NS	NS	NS
65	NS	21,000	**610,000**	NS	280,000	16,000
66	NS	NS	NS	NS	NS	NS
67	NS	NS	NS	NS	NS	NS
68	NS	NS	NS	NS	NS	NS
69	NS	NS	NS	NS	400,000	NS
70	77,000	23,000	**570,000**	280,000	NS	27,000
71	NS	NS	NS	NS	NS	NS
72	NS	NS	NS	NS	NS	NS
73	NS	NS	NS	NS	NS	NS
74	NS	NS	NS	NS	270,000	NS
75	55,000	NS	**430,000**	430,000	NS	20,000
76	NS	NS	NS	NS	NS	NS
77	NS	NS	NS	NS	NS	NS
78	NS	NS	NS	NS	NS	NS
79	NS	NS	NS	NS	NS	NS
80	180,000	19,000	84,000	240,000	340,000	24,000
81	NS	NS	NS	NS	NS	NS
82	NS	NS	NS	NS	NS	NS
83	NS	NS	NS	NS	NS	NS
84	NS	NS	NS	NS	**590,000**	NS
85	100,000	**580,000**	57,000	240,000	NS	70,000
86	NS	NS	NS	NS	NS	NS
87	NS	NS	NS	NS	NS	NS
88	NS	NS	NS	NS	NS	NS
89	NS	NS	NS	NS	**1,200,000**	NS
90	87,000	**410,000**	53,000	230,000	NS	52,000
91	NS	NS	NS	NS	NS	NS
92	NS	NS	46,000	NS	NS	NS
93	NS	NS	NS	NS	NS	34,000
94	76,000	NS	NS	NS	**870,000**	NS
95	NS	NS	NS	NS	NS	NS
96	NS	NS	NS	200,000	NS	NS

Modeled interval of vertical migration DNAPL zone (based on TCE analyses and MIP PID logs)

Modeled location of basal RGA DNAPL pool (based on TCE analyses and MIP PID logs)

NS = not sampled

A2.3. EVALUATION OF ESTIMATES

The range of TCE mass volume for the RGA in the initial estimates (summarized above) was determined to be inconsistent with the CSM based on characteristics of the Northwest Plume, the primary dissolved-phase contamination derived from the C-400 area, as follows:

(1) The Northwest Plume contains approximately 13,000 lb of dissolved TCE mass (based on the 2009 TCE plume footprint); and

(2) The dissolution rate for the C-400 TCE source has been approximately 4,000 lb/year (330 gal/year) (based on the annual flux of dissolved phase mass) for 50 years.

These observations suggest that the TCE mass volume spill associated with the C-400 site was at least 200,000 lb (16,500 gal). The persistence of the dissolved-phase plumes associated with the Phase II treatment area indicates the presence of a continuing large TCE source, significantly greater that the TCE mass volume estimates for the RGA (above).

These observations led to a critical review of the sources of uncertainty in the initial TCE mass volume estimates and prompted additional calculations to assess the upper bound of TCE mass volume that may be present under several DNAPL scenarios.

A2.4. UNCERTAINTY ANALYSIS

The heterogeneous nature of subsurface geologic environments, combined with the selective and tortuous nature of DNAPL migration, creates uncertainty with regard to the distribution of residual and pooled DNAPL in the subsurface and the representativeness of the corresponding data set. In the RGA, DNAPL may be retained as dispersed droplets (ganglia) reflecting prior migration pathways or as pools where migration is impeded, depending on mass volume and aquifer characteristics (i.e., interfacial tension of aquifer materials). In the RGA, the presence of pooled DNAPL is considered to be limited to a few vertical inches in the absence of potential irregularities associated with the topography of the top of the McNairy Formation and based on the generally coarse-grained nature of the unit and associated low interstitial tension of the gravel. Where DNAPL is present, industry experience strongly indicates that conventional sampling strategies may be ineffective for obtaining information that is representative of DNAPL occurrence. In general, the water-saturated gravel matrix of the RGA is a difficult medium to sample for volatile organic contamination. During RGA sample extraction, escaping pore water may “wash” sorbed contamination and influence the detection of DNAPL that may have been present in the sample. Both the heterogeneity of the TCE contamination and the difficulty of sampling (especially in the RGA) contribute to appreciable uncertainty in regard to characterizing DNAPL distribution.

To understand the potential impacts of uncertainty and further test the assessment of mass potentially present in the Phase II area based on plume extent and duration, the mass volume estimates generated from the results of soil analysis for TCE can be compared to TCE mass/volume recovered from the Phase I remedial action and the Six-Phase Heating Treatability Study. Current CSMs for the areas of the Phase I and II remedial actions suggest that significantly greater mass volume should be present in the Phase II treatment area. The 2010 Phase I remedial action extracted approximately 7,040 lb of TCE (approximately 580 gal) from the subsurface (primarily UCRS) in the southwest and east treatment areas. CSMs for the area of the Six-Phase Heating Treatability Study and the Phase II treatment area are similar. The 2003 Six-Phase Heating Treatability Study removed approximately 23,000 lb (1,900 gal) of TCE from the subsurface (both UCRS and RGA) in a 43-ft diameter treatment area near the southeast corner of the C-400 Building. With this in mind, it seems plausible that the larger Phase II treatment area may yield significantly more mass.

Additionally, a variety of approaches was used to explore the basis for an upper bound for the mass volume at the Phase II area. The approaches are as follows:

(1) Modeling of a single vertical pathway of DNAPL migration through the UCRS and RGA with assumed ranges of cross-sectional thicknesses (0.5 to 12 inches) and DNAPL saturation (5 to 20%).

> Potential impact of DNAPL ganglia on the TCE mass estimate = Volume of Soil Column [ft^3] × Soil Weight [kg/ft^3] × Threshold DNAPL Saturation Concentration [µg/kg] × Micrograms to Pounds Conversion Factor [lb/µg]

This approach estimates a possible range of 100 to 250,000 lb (10 to 20,000 gal) of TCE mass volume. Table A2.8 presents the results of the migration pathway calculations. The approach assumes that all the dispersed residual or pooled DNAPL in the UCRS and RGA could be represented as a single continuous vertical body of DNAPL with saturations that are consistent with published ranges. Because this approach is not based on any Phase II sampling results, the significance of this analysis remains uncertain.

Table A2.8. Residual DNAPL Ganglia Mass Sensitivity Analysis Summary

Radius (inches)	Formation/ Thickness	TCE Mass (Gallons)		
		5% Saturation	10% Saturation	20% Saturation
0.5	UCRS—56 ft	4.4	8.6	17
	RGA—50 ft	4.3	8.5	17
1	UCRS—56 ft	17	34	67
	RGA—50 ft	17	33	66
12	UCRS—56 ft	2,475	4,875	9,680
	RGA—50 ft	2,445	4,820	9,571

(2) Extrapolation of the frequency of detection of DNAPL in TCE soil analyses in the UCRS for the 2011 C-400 Phase II investigation (1 detection at a concentration indicative of DNAPL in 480 actual and projected analyses) to a model of the soil/aquifer volume potentially impacted by DNAPL migration (approximated by a cone shaped zone of impact emanating from the point of release) and calculation of the resulting mass volume potentially present within the DNAPL zone. This model assumed that the potential DNAPL-impacted area was 60 ft deep (depth of the UCRS) and 120 ft wide (the approximate width of the Phase II treatment area). The model calculated the TCE mass as follows:

> Total TCE Mass = Volume of Potential DNAPL-Impacted Area (ft^3) × Probability of Encountering DNAPL (1/480) × TCE Mass/Encounter (lb)

Based on the model of the anticipated treatment zone (and perimeter), each DNAPL encounter represented approximately 120 lb of TCE. This approach yielded an estimate of potential TCE mass volume of 56,000 lb (4,600 gal) for the UCRS only.

(3) Modeling of a DNAPL pool, 2-inches high, with a diameter equal to the width of the Phase II treatment area (120 ft). The model calculated the volume as follows:

Volume of DNAPL Pool (gal) = Volume of DNAPL Zone (ft^3) × RGA porosity (fraction percentage) × DNAPL saturation (fraction percentage)

This approach estimates up to an additional 51,000 lb (4,200 gal) of TCE mass volume may be present in the RGA.

A2.5. CONCLUSION

Calculations based on interpolation of the available TCE analyses, alone, determine that a minimum of 290 to 780 lb (24 to 64 gal) of TCE mass volume is present in the UCRS and 75 to 7,000 lb (6 to 570 gal) of TCE mass volume is present in the RGA. The estimate of potential TCE mass volume of the Phase II treatment area is anticipated to range between 7,300 and 85,000 lb (600 and 7,000 gal). Approximately 30,500 lb (2,500 gal) may be present in the UCRS, and approximately 55,000 lb (4,500 gal) may be present in the RGA. The estimate addresses the potential presence of TCE source-related mass that may be present as residual and/or pooled DNAPL in the UCRS and RGA. The range of values exceeds an order of magnitude and is indicative of the difficulty in characterizing DNAPL distribution in subsurface environments. A calculation record that provides a detailed accounting of inputs, assumptions, and results for the summary presented above is currently in preparation.

A2.6. REFERENCES

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APPENDIX C

ELECTRICAL RESISTANCE HEATING DESIGN FOR PHASE IIa OF THE C-400 INTERIM REMEDIAL ACTION AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY

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ET-DSP™
Electro-Thermal Dynamic Stripping Process

PREPARED FOR:

LATA Environmental Services of Kentucky, LLC

Electrical Resistance Heating Design for Phase IIa of the C-400 Interim Remedial Action at the Paducah Gaseous Diffusion Plant

Paducah, Kentucky

McMILLAN-McGEE CORP.

CREATORS OF ET-DSP™

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Electrical Resistance Heating Design for Phase IIa of the C-400 Interim Remedial Action at the Paducah Gaseous Diffusion Plant

Paducah, Kentucky

PREPARED FOR:

LATA Environmental Services of Kentucky, LLC

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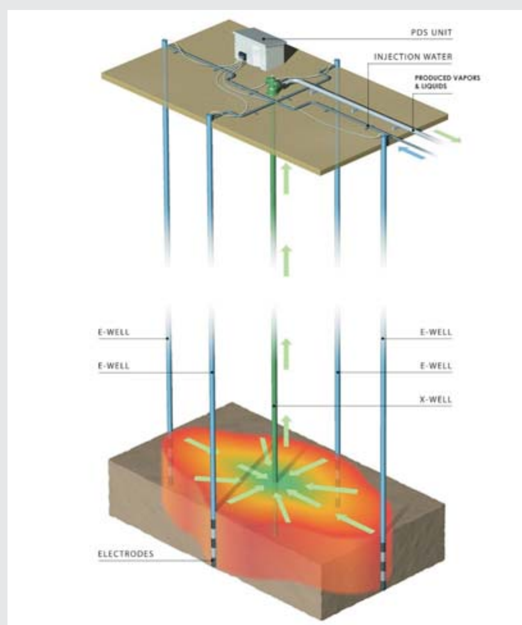

Computer simulation showing current distribution between multiple layers of ET-DSP™ electrodes.

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Acronyms & Abbreviations

A	Amperes
AC	Alternating Current
AHA	Activity Hazard Assessment
BGS	Below Ground Surface
BOE	Bottom Of Electrode
COC	Contaminant of Concern
DC	Direct Current
digiCT™	Digital Current Transformer
digiPAM™	Digital Pressure Acquisition Module
digiTAM™	Digital Temperature Acquisition Module
DNAPL	Dense Non-Aqueous Phase Liquids
ERH	Electrical Resistive Heating
ESD	Emergency Shutdown Device
ET-DSP™	Electro-Thermal Dynamic Stripping Process
ft	Feet
gpm	Gallons Per Minute
H&S	Health and Safety
I	Current
I_{eff}	Effective current
I_{rms}	Root-mean squared current
kVA	Kilo-Volt-Ampere
kW	Kilowatt
kWh/m^3	Kilowatt Hour Per Cubic Meter
LATA Kentucky	LATA Environmental Services of Kentucky LLC
lbs	Pounds
LED	Light Emitting Diode
m	Meters
m^3	Cubic Meters
mA	Milliamp
Mc^2	McMillan-McGee Corporation
MCL	Maximum Contaminant Level
MPE	Multiphase Extraction
NEC	National Electrical Code
NFPA	National Fire Protection Association
O&M	Operations and Maintenance
PDS	Power Delivery System
PDP	Power Distribution Panel
PGDP	Paducah Gaseous Diffusion Plant
PPE	Personal Protective Equipment
psi	Pounds Per Square Inch
RGA	Regional Gravel Aquifer
scfm	Standard cubic feet per minute
SE	Southeast
SW	Southwest
TCE	Trichloroethene
TOE	Top Of Electrode
TDC	Time-Distributed Control
TDCM	Time-Distributed Control Module

UCRS	Upper Continental Recharge System
V	Volts or Voltage
VOC	Volatile Organic Compound
WCS	Water Circulation System

1. Introduction

This Electrical Resistive Heating (ERH) Report has been prepared by McMillan-McGee Corporation (Mc^2) to install the Electro-Thermal Dynamic Stripping Process (ET-DSP™) at the Paducah Gaseous Diffusion Plant (PGDP) C-400 Cleaning Building in Paducah, Kentucky. ET-DSP™ is an enhanced in-situ ERH technology that is applicable for the site cleanup activities. The activities defined within this Remediation Plan will be performed under contract to LATA Environmental Services of Kentucky, LLC (LATA Kentucky).

The proposed PGDP C-400 Phase IIa treatment area is the southeast (SE) corner of the C-400 Cleaning Building. The treatment depth interval is the Upper Continental Recharge System (UCRS) from 20 to 60 feet (ft) below ground surface (BGS). The contaminant of concern (COC) for this area is trichloroethene (TCE) and its breakdown products.

1.1. Remedial Objectives

The operational strategy is to meet the remediation goals by operating the ET-DSP™ and multiphase extraction (MPE) systems until monitoring indicates that heating has stabilized in the subsurface and that TCE concentration in the recovered vapor has diminished to a point where there is minimal mass removal.

The detailed remedial objectives can be referenced in Section 3.3 of LATA Kentucky's RDR revision.

1.2. Remediation Plan

ET-DSP™ will be used in combination with an MPE system for remediation of the site. The approach is based upon the success of other ET-DSP™ remediation projects, including completion of the Phase I project at the PGDP C-400 Site, in conjunction with the numerical simulation completed using site specific data. The remediation will be performed using ET-DSP™ and a multiphase extraction and treatment process. As part of the remedial approach a numerical simulation of the system utilizing site specific and laboratory measured data has been used to determine a strategy to achieve the temperature requirement in the treatment area and operate the system to achieve the remediation goals.

The goals of the remediation system will be to efficiently heat up the 40 ft thickness of the treatment volume, achieve and maintain a temperature shown in section 3.3 of LATA Kentucky's RDR revision throughout the volume, create sufficient steam for thorough dynamic stripping and extraction of contaminants, and extract liquids and vapors to maintain hydraulic and pneumatic control during contaminant recovery without removing excessive energy from the subsurface. Conservation of energy while extracting vapor and liquids has the greatest impact on the efficiency and economics of the process.

This ERH Report includes the following:

1. ET-DSP™ technical summary and modeling results;
2. A narrative description of the proposed system, drawings showing well field layout and equipment, and technical specifications for system components;
3. Lessons learned from the Phase I project;

4. Well development requirements;
5. Extraction system header specifications;
6. Vapor cap specifications;
7. Proposed solution for operational monitoring of ERH components installed below grade in front of the roll up door on the SE corner of C-400;
8. Specification of instruments for operational monitoring of the remediation process;
9. Utility interfaces for ET-DSP™ equipment; and
10. System design calculations.

2. System Technical Requirements

2.1. Modeling Results

The ET-DSP™ design for PGDP C-400 Phase IIa remediation is based on the simulation report (Remedial Design Report: C-400 Cleaning Building Phase I, Appendix B) completed prior to the original Phase I design, along with the demonstrated success of the Phase I design in effectively treating the UCRS. In particular the temperature goals for Phase I were exceeded throughout the UCRS and reached 115ºC (240ºF) at some sensor well locations.

Because the groundwater is relatively stagnant in the UCRS and treatment depth for Phase IIa only extends approximately 5 ft below the water table, it is not necessary to consider groundwater flow conditions as in the original simulation report. Although the electrode spacing for the simulation report was set at 20 ft due to higher resistivities and groundwater flow in the Regional Gravel Aquifer (RGA), this spacing proved effective for operation of the UCRS electrodes in the southwest (SW) and east areas during Phase I. Maintaining 20 ft electrode spacing for Phase IIa allows flexibility both for operating the electrodes in varying electrical and hydraulic soil properties across the SE area and for placement of electrodes with respect to subsurface utilities and no-drill zones.

The original Phase I design for the SE treatment area included electrodes placed within the RGA for remediation of the contaminant plume below 60 ft BGS. Because the Phase IIa design will remediate the UCRS portion of the SE area only, the number of electrodes has been reduced from 227 to 156. Thus the operating parameters have been recalculated as presented in Appendix A.

2.2. Technical Specifications

Table 1 presents a synopsis of the remediation plan for the C-400 Cleaning Building SE treatment area.

Table 1 Project Technical Summary

Item	Description	Comments
Site Characteristics		
Treatment Area [ft²]	13,224	Based on supplied information
Volume Treated [yd³]	25,291[1]	Based on 40 ft treatment depth
Deep Extent of Treatment [ft. BGS]	60	Based on supplied information
Shallow Extent of Treatment [ft. BGS]	20	Based on supplied information
Depth to Groundwater [ft. BGS]	~55	Based on supplied information
Contaminants of Concern	TCE	DNAPL suspected
Contaminant Mass in Place [lbs]	193,760	Estimated
Soil Resistivity [Ω·m]	12-200	Measured range of resistivity
Remedial Approach		
ET-DSP™ Electrode (E) Wells	52	10" O.D. x 10' long electrodes
Total Electrodes	156	Triple stack electrode wells
Power Delivery Systems [kVA]	7 x 660 kVA or 2 x 1330 kVA and 2 x 660 kVA	Two options are being explored. Depends on unit availability at time of construction.
digiTAM™ Temperature Sensors	740	37 digiTAM™ wells each with 20 sensors
Vacuum Monitoring Wells	15	V (5), and DV (10)
Total Sensor Boreholes	42	D (27), DV(10), and V(5) wells
Electrode Spacing [ft]	20	Horizontal spacing between wells
Bottom of Deep Electrode [ft BGS]	63.2	Heat transfer 3-4 ft below electrode
Top of Shallow Electrode [ft BGS]	17.9	Heat transfer 3-4 ft above electrode
Target Temperature [°C]	-	See §3.3 of LATA Kentucky's RDR revision
Multiphase Extraction (X) Wells	22	Each MPE well has a pneumatic pump
Upper Vapor Extraction (XE) Wells	39	Vapor extraction at electrode wells
Vapor Extraction (VX) Wells	11	Vapor extraction only
Vapor Recovery Air Flow [scfm]	660-972	Based on Lessons Learned
Vapor Recovery Vacuum Level [inHg]	-15.0	Based on Lessons Learned
Liquid/Condensate Recovery [gpm]	30.6	Average based on simulation
Electrical Power Input [kW]	1,522	Based on simulated formation input power
Summary Information		
Cumulative Energy Input [MWh]	6,576	Based on simulated formation input energy
Average Water Demand [gpm]	25.0	Re-circulation strategy
Time to Target Temp. [days]	50-60	Approximately
Thermal Operations [days]	180	Approximately

[1] The calculation for the volume treated incorporates the thermal influence at the ends of the electrodes. This calculation is shown in Appendix A.

3. ERH System Description

ERH via ET-DSP™ involves heating soil in the saturated and unsaturated zones by passing current between electrodes buried in the soil, with simultaneous injection of water through the electrodes in order to transfer heat by convection. The coupling of electrical heating with heat transfer by convection greatly enhances the efficiency and uniformity of ERH technology. Complete volatilization of each contaminant is achieved as temperature in the soil approaches the boiling point of the contaminant, and simultaneous vapor and liquid extraction removes the contaminants from the subsurface.

Electrical heating increases the temperature of the soil and groundwater by conducting current through the resistive connate water that fills the porosity of the soil. Water injection through the ET-DSP™ electrode—a patented feature of the technology—results in the conductive pathway remaining fully functional. Consequently, there are no resistive or 'cold' zones created within the treatment area. The makeup water supplied to the electrode is continually vaporized and replaced, creating a guided steam front that strips contaminants away and carries them to extraction wells.

In a typical application of ET-DSP™, electrodes are strategically placed into and around the contaminated zone. The pattern of electrodes is designed so conventional three-phase power can be used to heat the soil. The distance between electrodes and their location is determined from the heat transfer mechanisms associated with vapor extraction, electrical heating and fluid movement in the contaminated zone. Vapor recovery and liquid extraction wells are located within the contaminated soil. The position of the extraction wells relative to the electrodes is determined so that heat transfer by convection within the porous soil is maximized, thus minimizing heat loss and increasing the uniformity of the temperature distribution. Consideration of all the heat transfer mechanisms results in the most effective heating process and, hence, a more successful remediation project.

The preliminary design for the thermal remediation of the Phase IIa C-400 Cleaning Building SE treatment area includes:

1. 52 ET-DSP™ electrode wells (E wells)
2. 39 extraction / electrode wells (XE wells);
3. 22 MPE wells (X wells);
4. 11 vapor extraction wells (VX wells);
5. 5 vacuum monitoring wells (V wells);
6. 27 digiTAM™ sensor wells (D wells);
7. 10 digiTAM™ / vacuum monitoring wells (DV wells).

Well field layout for the site is defined in drawings #E7DC40000C014 and #E7DC40000C015 for the two PDS availability scenarios. For all wells shown within the railway buffer zone, surface completions are to be no greater than six inches high. Wellheads in this zone are to be constructed as detailed in drawing #C7DC40000C009 for extraction wells and drawing #C7DC40000C008 for electrode wells. All design drawings are included in Appendix B.

3.1. Electrode Wells

The electrodes are designed to conduct high current to the targeted volume of soil. A minor volume of water injection through each electrode maintains electrical conductivity of the soil, achieves convective heat transfer, and enhances displacement of the chemicals towards the extraction wells. The top electrode in the borehole has a water return line to prevent the subsurface pressure from exceeding the local fracture pressure.

Electrodes are fabricated of high temperature and chemically resistive materials. They are connected to the PDS with appropriately sized electrical cables. As well, each electrode is connected to a water circulation system (WCS) using a high temperature and pressure rated hose. To enhance electrical contact with the soil, each electrode is coated with granular graphite paste over its surface. During well installation, granular graphite will be placed around the electrodes to improve electrical continuity. Automated monitoring and control of the current and water flow to each electrode ensures the system is operating within its design parameters, while preset breakers prevent the electrodes from exceeding the designed amperage.

The electrodes will be spaced laterally with 20 ft centers to prevent the formation of any cold spots and ensure optimal heating within the treatment area. The tops of the uppermost electrodes will be located at 17.9 ft BGS and the soil will be heated approximately 3 ft above this. This will allow any volatized contaminants to be captured in the vapor extraction system before they condense.

Water will be added at each electrode to promote convective heat transfer throughout the treatment volume. Each shallow electrode is equipped with a water return line - which has a spring check valve to prevent back flow - to purge water from the electrode well as needed to prevent overpressure conditions below surface.

Each of the 52 electrode wells is a triple stacked electrode well utilizing a 10 inch diameter by 10 ft long electrode and will be installed inside a 12 inch drill casing. Each electrode well will have at surface: 3 electrode wires, 3 top water injection hoses, 3 bottom water injection hoses, 1 liquid return hose and 3 electrode ropes. See Appendix B for the electrode well completion drawing #E7DC40000C016 and the electrode wellhead construction drawing #C7DC40000C008.

For the Phase IIa C-400 treatment area, 156 electrodes will be installed to heat the UCRS treatment depth from 20 to 60 ft BGS. The number of electrodes has been reduced from the 227 electrodes specified in the original Phase I C-400 SE area design, which was developed to heat a treatment depth from 20 to 100 ft BGS.

Triple stacked electrodes will be installed at all electrode wells, including at west perimeter locations where the treatment depth extends only to 40 ft BGS. This is intended to improve the phase balance of the system, resulting in more efficient ET-DSP™ operation and decreased voltage potentials at surface. This will also ensure uniform heating of the treatment volume when target temperature is achieved on the west edge of the 40 to 60 ft BGS contaminant plume.

3.2. Extraction Wells

MPE wells (X wells) extract groundwater with submersible pumps and extract vapor through the vadose zone well screen and into the vacuum lines. Each MPE well has a pneumatic pump with a 4-inch diameter bottom inlet placed 6 inches above a 3 ft long sump for liquid extraction. The vapor screen interval is from 15 to 65 ft BGS. Unlike Phase I, submersible sample pumps will not be installed in the MPE wells as these would need to be placed above the extraction pumps, and too shallow relative to the water table to sample liquid during operations. The sum totals of the designed liquid and vapor extraction flow rates for all extraction wells will average 30.6 gallons per minute (gpm) and 440 standard cubic feet per minute (scfm), respectively.

Vapor extraction wells (VX wells) will be used during operations for vapor extraction only. The vapor screen interval is from 15 to 50 ft BGS. The sum total of the designed vapor extraction flow rates for all VX wells will average 220 scfm at -15 inHg vacuum.

During Phase I operations, the maximum vapor flow rate achieved at -10 inHg of vacuum was 12 scfm. The vapor flow calculation presented in Appendix A indicates a vapor flow rate of 20 scfm per well will be achieved at -15 inHg of vacuum and an effective ROC of 15 ft. Based on the 15 ft ROC, the Phase IIa design has 30 ft maximum distance between extraction well centers to ensure sufficient vacuum over the entire treatment volume.

X wells and VX wells are to be installed as shown in drawing #C7DC40000C006 and extraction wellheads are to be completed as shown in drawing #C7DC40000C009. Drawings are included in Appendix B.

The extraction component of the extraction/electrode well (XE well) will be used to cool the vadose zone between surface and 15 ft BGS to prevent temperature increases above the allowable limits at these depths. The XE wells can also be used to extract vapors that are not captured by the X and VX wells. The vapor screen interval is from 6.6 to 13.1 ft BGS. The sum total of the designed vapor extraction flow rates for all extraction/electrode wells will average 312 scfm at -15 inHg vacuum. Refer to electrode well completion drawings #E7DC40000C016 and #C7DC40000C008 in Appendix B.

3.3. Sensor Wells

Subsurface temperature is the most important operational parameter monitored during an ERH remediation project. Temperature data needs to be current and comprehensive. In order to meet this data need, a uniform distribution of digital Temperature Acquisition Module (digiTAM™) sensors will be deployed in the subsurface at the C-400 SE treatment area. Each temperature sensor responds to the ET-DSP™ site computer as frequently as every five minutes with a current temperature reading. The computer and site operators utilize this temperature feedback to optimize system settings.

To monitor subsurface temperatures, 740 digiTAM™ sensors will be used in 37 digiTAM™ wells (27 D wells and 10 DV wells) uniformly distributed throughout the treatment area.

On the project website, temperature data will be summarized for each sensor point and each well location, with hourly updates. Strategic placement of digiTAMs™ provides an accurate representation of actual temperatures in the subsurface; visualization of temperatures in the treatment volume is accomplished using temperature contour maps. These maps are generated using current digiTAM™ data at the actual sensor location and interpolation of nearby digiTAM™ data for other locations between electrode wells. In addition, temperatures at the electrode wells are calculated using current power levels and cumulative energy inputs at each electrode. These data are input to "kriging" software to create an image file. The contour maps are usually generated on a daily basis to monitor heating progress.

The remediation process will be operated such that water levels within the treatment area are drawn down relative to levels outside this area. This approach will ensure that groundwater flow is always directed into the treatment volume.

The hydraulic balance within the treatment area is calculated based off of an extraction to injection ratio for the site and is further broken down into the extraction rate at a given well using its pneumatic cycle counter and the injection rate of the electrodes surrounding that well. The injection rates to individual electrodes are logged into Mc2 server via the flow meter located within the WCS units. The site totalizers for extraction and overall injection are standalone units along with the cycle counters which are recorded by the on-site operator. Field data shall be forwarded to McMillan-McGee Corp. in Calgary within a timely manner of being obtained. The hydraulic data obtained from the field will be evaluated by McMillan-McGee staff to confirm that the extraction/injection ratio is being achieved as per the RDR.

Vacuum monitoring wells are designed to monitor vacuum conditions at the edge of the contaminant plume. These wells will be placed within the ROC of extraction wells such that vacuum should be detected (i.e. vacuum level below -0.1 inHg) at each vacuum monitoring well when the extraction system is operating. If vacuum conditions are not as designed, these wells could be connected to the vapor extraction system but are not designed for high flow.

To monitor the subsurface vacuum, a total of 15 vacuum gages will be used on 5 vacuum monitoring wells and 10 digiTAM™/vacuum monitoring wells.

Sensor wells are to be installed as shown in drawing #C7DC40000C005, with sensor wellheads completed as shown in drawing #C7DC40000C007. Both drawings are included in Appendix B.

3.4. Drilling Summary

Table 2 Drilling Program Details

Item	Qty	Depth (ft BGS)	Boring Diameter (inch)	Total Depth to Drill (ft)	Notes
Electrode Boreholes	52	63.65	12	3,310	Min. 12-inch diam. boring to accommodate 10-inch electrode and graphite backfill.
Multiphase Extraction Boreholes	22	68.5	8	1,507	8-inch diameter boring to accommodate 4 inch SS well screen.
Vapor Extraction Boreholes	11	50.5	8	555.5	8-inch diameter boring to accommodate 4 inch SS well screen.
Vacuum Monitoring Boreholes	5	50.5	4	252.5	4 inch diam. boring to accommodate 2-inch fiberglass (or equivalent) well casing.
DigiTAM™ Boreholes	27	68.5	6	1849.5	6 inch diam. boring to accommodate 2-inch fiberglass (or equivalent) well casing.
DigiTAM™ / Vacuum Monitoring Boreholes	10	68.5	8	685.0	8-inch diam. boring to accommodate 2 – 2-inch fiberglass (or equivalent) well casings.[2]
Totals	**131**			**8,073.0**	

3.5. Power Delivery System (PDS)

The PDS units developed and manufactured by Mc^2 are computer-controlled to deliver the proper amount of energy to individual electrodes, both laterally and vertically, thus compensating for differences in the electrical resistance of the geological units. The ET-DSP™ PDS utilizes a system of time-distributed control (TDC) to control the power to the electrodes. This process effectively controls power consumption of individual electrodes. For example, should it become apparent that certain electrodes are in electrically resistive zones that may result in cold spots, the power to the electrodes can be increased in these areas to ensure uniform heating. This method controls the electrical sine wave of three-phase power to the millisecond such that each electrode can be individually manipulated. Additionally, the PDS units are equipped with a range of voltage taps to further control the heating process. This process results in heating the soil faster, more uniformly, and more efficiently than could otherwise be achieved. The PDS units are fully automated and can be accessed via the Internet for remote monitoring and adjustment.

PDS units are manufactured by Mc^2 in 12, 24 or 60-electrode systems. For PGDP C-400 Phase IIa, there are two options for PDS units:

1. Option A: 7 – 24 electrode PDS units; or

[2] The MW well near the C-400 building is to be converted into a DV well giving a total of 10 DV locations.

2. Option B: 2 – 60 electrode and 2 – 24 electrode PDS units.

The design configurations for the site are dynamic but, at a minimum, the PDS will be able to deliver approximately 15 kilowatts (kW) of power per electrode. The main function of the PDS is to provide the correct amount of power to each of the electrodes. Each of the PDS units has two transformers. The primary side of each transformer is fed from a disconnect switch. The utility connection of the PDS is made from one of the breakers at the PDP to each transformer's disconnect switch. The secondary side of the transformer has several output voltage settings to account for fluctuating soil conductivity due to heating effects and varying soil properties across the site. The secondary side of the transformer is connected to the electrodes via a series of breakers.

The suggested placement for PDS units in the well field is shown in Appendix B, drawings #E7DC40000C014 and #E7DC40000C015, for the two deployment options. Drawing #E7DC40000C017 illustrates the PDS electrical connections to electrodes and extraction wells the well field.

3.6. Water Circulation System (WCS)

The WCS is an Internet-controlled water injection system designed to maintain moisture content in the soil surrounding the electrodes during heating. If moisture content is not maintained, the soil matrix becomes highly resistive which causes a corresponding decrease in current and power at the electrodes and a reduction in overall effectiveness of the ET-DSP™ system. The WCS includes a pump that boosts the water supply pressure as required. Water injection to the electrodes is controlled using a series of solenoid valve manifolds that include flow meters to monitor the volume of water injected to the electrodes. The WCS is automated and controlled by the onsite server to adjust the injection rate to each electrode up to its maximum preset hourly volume.

WCS units are manufactured by Mc^2 in 12, 24 or 60-electrode systems. For PGDP C-400 Phase IIa, there are two options for WCS units:

1. Option A: 7 – 24 electrode WCS units; or
2. Option B: 2 – 60 electrode and 2 – 24 electrode WCS units

The suggested placement for WCS units in the well field is shown in Appendix B, drawings #E7DC40000C014 and #E7DC40000C015, for the two deployment options. For each WCS unit, bag filters for the water supplies will either be mounted in the unit or placed at a location between the header and the supplied WCS unit and connected with hose.

3.7. Power Distribution Panel (PDP)

The power distribution panels (PDPs) contain the main equipment breaker-feeder system. They are connected to the load side of the high voltage transformer. The PDP has one 3,000A/480V main breaker with up to four 800A/480V and eight 400A/480V downstream breakers. When the 3,000A breaker is engaged, a beacon light located above the panel will strobe.

The PDP configuration will depend on the availability of PDS units:

1. Option A: 7 – 24 electrode PDS units, requires 2 PDPs
2. Option B: 2 – 60 electrode and 2 – 24 electrode PDS units, requires 1 PDP.

4. Phase I Lessons Learned

The following design limitations were observed during PGDP C-400 Phase I operations:

1. The extraction wells did not provide sufficient vacuum level of -10 inHg over the treatment volume. Adequate vacuum levels are necessary to maximize capture of volatilized contaminants. This prevents re-condensation of the COC vapors above the heated zone and migration of COC vapors from this zone.
2. The overall vapor extraction flow rate was not high enough to prevent COC vapors from migrating through the heated vadose zone. The designed vapor extraction flow rate of 36 scfm per well could not be maintained during operations. Routine monitoring for Phase I indicated the maximum vapor flow rate at -10 inHg of vacuum was 12 scfm per well.
3. Extraction well vacuum levels were not adequate to prevent COC vapors from migrating through the heated vadose zone. The vacuum blower in the Phase I treatment system was only specified to achieve a vacuum level of -10 inHg in the well field.
4. Closer temperature monitoring was needed to monitor subsurface utilities and ensure temperature limits at the utilities were not exceeded during heating operations.
5. More vacuum monitoring points were needed to more accurately monitor vacuum across the treatment area and ensure sufficient, uniform vacuum levels over the treatment volume.
6. Synthetic ropes used in the MPE wells to support liquid extraction pumps failed in some instances when the pumps were removed from the wells during demobilization.
7. Excessive silting was observed in the MPE wells due to sizing of well screen and filter pack sand, as both were too coarse to prevent silt located at the UCRS depths from entering the wells.
8. Excessive condensate was observed in the vapor extraction header and vapor lines going to flush mounted components in the well vaults. Moisture traps were installed during Phase I operations to resolve this issue.
9. Steam breakthrough was observed at two locations during Phase I heating operations. This occurred where the ground surface was gravel rather than concrete.
10. DigiPAM™ pressure sensors did not provide useful water level measurements at sensor wells internal to the treatment area. This was due to a number of factors, including minimal water column in the wells above the DigiPAM™ sensing element, sensitivity errors due to high temperature in the treatment volume, and steam in the head space of the well affecting pressure measurements.
11. During an extended power outage that prevented operation of the ET-DSP system, temperature data could not be recorded from the digiTAMs™.

12. Metal wear was observed on liquid extraction fittings in the well field. This was likely due to corrosion where dissimilar metals were used at the extraction header connection, or erosion caused by liquid pumping velocity in the presence of mobilized silt.

These lessons learned have been incorporated into the ET-DSP™ PGDP C-400 Phase IIa design as follows:

1. To achieve adequate vacuum level across the treatment area, the applied vacuum to the extraction wells will be increased to -15 inHg. Improved vacuum extraction will also require using the contingency wells from the Phase I design for vapor extraction under normal operation (these are now designated as VX wells in the Phase IIa design). A vapor cap will also be installed to prevent short-circuiting of vacuum to atmosphere at the XE well locations.
2. The overall vapor extraction rate will be improved by increasing the relative number of extraction wells. The vapor flow calculation presented in Appendix A indicates a vapor flow rate of 20 scfm per well will be achieved with a radius of capture (ROC) of 15 ft and -15 inHg of vacuum. The vacuum blower component of the treatment system will be specified to achieve a vacuum of -15 inHg and a vapor flow rate of 1,000 scfm.
3. Vacuum levels at the vapor extraction wells will be improved to -15 inHg by increasing the vacuum blower capacity at the treatment system.
4. Temperature monitoring in the vicinity of subsurface utilities will be enhanced by increasing the number of digiTAM™ sensor wells and optimizing their placement.
5. The number of vacuum monitoring points will be increased to improve vacuum monitoring within the treatment area and on the treatment perimeter.
6. Mc² became aware of the failure of the synthetic rope supporting some extraction pumps the week of June 13, 2011. The support rope or an appropriate substitute will be specified when an investigation is completed with input from the manufacturer.
7. To minimize silt entry from the formation through the extraction well screens, the well screen and filter pack sizes will be specified according to the UCRS filter pack calculation in Appendix A. The filter pack will be finer RMC Lapis Lustre LSI-30 (30 x 70), or equivalent, rather than #20/30 sieve sand. The calculation results in a well screen size of 0.0067 inches, thus the well screen will be specified to 0.006 inches, which is the closest available Johnson screen size.
8. To minimize condensate in the vapor extraction lines, moisture traps will be installed where each header lateral joins the main header pipe and where vapor lines exit trenching for extraction wells placed in well vaults. Vertical sections of the vapor lines will have moisture traps placed to maximize condensate removal.
9. To prevent steam breakthrough at ground surface during heating operations, a vapor cap will be installed as described in Section 7.
10. Because digiPAM™ sensors did not provide useful water level readings internal to the treatment area in Phase I, digiPAM wells will not be utilized during Phase IIa remedial approach. Instead the hydraulic table will be

manually measured during startup operation and monitored during operation using the extraction to injection ratios.

11. To monitor digiTAM™ data in the event of a power outage exceeding 4 hours, either the data acquisition system will have an auxiliary power source in place; or a laptop may be used to acquire temperature data directly from the digiTAMs™, provided an appropriate security plan is established to transfer these data to the Mc2 site server or head office.
12. To limit corrosion on liquid extraction fittings, similar metals or dielectric materials will be used at all connection points. Proper sizing of the well screen and filter pack in the MPE wells will minimize silt entering the flow stream and thus limit erosion of liquid extraction fittings due to flow velocity

5. Well Development Requirements

Before vacuum is applied to the treatment volume, each well containing a well screen that penetrates the water table must be developed. For the Phase IIa design, this includes only the 22 MPE wells. Mc^2 recommends the following procedure for developing wells with groundwater screens, based on experience with C-400 Phase I and other remediation projects:

1. Record water level and extraction well depth;
2. Extraction rates should be slowly ramped up as need, where pumping rates should start at 1gpm and not exceed 5gpm during the development procedure;
3. Pump 3 pore volumes from the bottom of each well (use water level height in well to calculate volume);
4. Record final water level;
5. Record recharge time;
6. Take liquid sample and check for turbidity (use a sealed clear jar);
7. The well development process will continue until turbidity levels are less than 50NTU;

To minimize silt entry from the formation through the MPE well screens and prevent the need to redevelop MPE wells during operations, the well screen and filter pack sizes will be specified according to the UCRS filter pack calculation in Appendix A.

6. Extraction Header System Requirements

The well field extraction header is to be designed and constructed by LATA Kentucky based on the requirements described in this section. Full piping specifications are to be field determined with respect to minimum temperature and pressure ratings. Pressure ratings for liquid and vapor transfer pipes are to be at least three times the operating pressure of the transferred media. Materials for pipe connections and structural supports are also to be field determined. The operational parameters for well field piping are listed in Table 3.

Table 3 Operational Parameters for Wellfield Piping

Vapor Extraction	
Multiphase Extraction Well	-15 inHg @ 20 scfm
Vapor Extraction Well	-15 inHg @ 20 scfm
Extraction/Electrode Well	-15 inHg @ 8 scfm
Liquid Extraction	
Average discharge per pump is 1.39 gpm	
22 pumps average 30.6 gpm	
Maximum instantaneous extraction rate is 40.6 gpm	
Liquid Injection	
Average injection rate is 25.0 gpm	
Maximum instantaneous injection rate is 31.2 gpm	
Compressed Air Line	
Regulate between 15 and 85 psi	
One cycle of the pneumatic pump is 0.63 ft^3 air/liquid gallon at 40 psi air pressure with 60 ft of head	

6.1. Conveyance Piping

Conveyance piping for MPE and pump air lines is designed as follows (refer to the well field extraction header layout, drawing #C7DC40000C004 in Appendix B):

1. Pipes will be sized according to the number of wells connected and the desired flow rates.
2. Piping will include 4 lateral pipes south of the C-400 building running east to west and 1 lateral pipe running north to south, parallel to C-400.
3. Laterals will be sloped downward by approximately 1 degree towards the main pipe trunk.
4. Each lateral vapor extraction line will have a moisture trap located where it connects to the main pipe trunk.
5. Vapor extraction lines on main header trunk #4, running over or under the railway tracks, will have moisture traps placed to maximize condensate removal. Similarly, liquid extraction lines will have sediment traps installed at these locations. Main header trunk # 4 will also include wire raceway to accommodate power cable and CAT5 communication cables for equipment on the south side of the railway tracks.

6. Moisture traps will be connected to a condensate pump.
7. For each condensate pump, the discharge is to be piped into the liquid discharge line.
8. A vacuum gage (measurement range of 0 to -30 inHg) will be placed at the end of each lateral vapor line.
9. A liquid flow meter will be placed in line with each trunk of the discharge/injection piping.
10. Liquid discharge is to be sent to a clarifier tank and then pumped through a set of bag filters prior to being passed through the treatment system. Technical information on the treatment system can be found in section 4.4 of LATA Kentucky's RDR revision.
11. A pressure gage [measurement range of 0 – 100 pounds per square inch (psi)] is to be installed at the end of each lateral and at the main trunk of the discharge/injection piping.
12. The four piping spurs indicated on the north portion of the treatment area require V-block adjustable stands for mechanical support.

Requirements for conveyance piping header are summarized in Table 4.

Table 4 Piping Requirements for Extraction Header System

Connection	Pipe Size	Thermal Insulation
Vapor Extraction		Personnel protection
Main Trunk #1	14 inch Ø, 1000 scfm	
Main Trunk #2	8 inch Ø, 250 scfm	
Main Trunk #3	12 & 10 inch Ø, 750 scfm	
Main Trunk #4	6 inch Ø, 160 scfm	
Lateral #1	6 & 4 inch Ø, 160 scfm	
Lateral #2	6 & 4 inch Ø, 210 scfm	
Lateral #3	6 & 4 inch Ø, 180 scfm	
Lateral #4	6 & 4 inch Ø, 200 scfm	
Lateral #5	8 & 6 inch Ø, 250 scfm	
Spurs #1-6	6 inch Ø, 100 scfm	
Liquid Extraction	2 inch Ø	Personnel protection/freeze prevention
Liquid Injection	2 inch Ø	Freeze prevention
Pump Air Supply	2 inch Ø	Not required

Notes
1. Pipe lengths and connection points as shown in drawing #C7DC40000C004
2. Transfer lines from wellheads to header as shown in drawing #C7DC40000C009

6.2. Vapor Extraction Connections

Vapor extraction connections, including all X, VX, and XE extraction wells are designed as follows (refer to drawing #C7DC40000C009 in Appendix B):

1. Vapor extraction pipes will be thermally insulated;
2. A vacuum gage (measurement range of 0 to -30 inHg) will be placed at the end of each lateral pipe;

3. A contaminant sample port will be placed at the end of each lateral 3 ft from where it connects to main trunk;
4. A 2 inch brass ball valve will be connected to the lateral pipe for each extraction well connection;
5. The extraction well will be connected to the ball valve using a 2 inch high temperature vacuum hose with Cam-Locks at each end;
6. Each extraction wellhead will include a permanent flow tube in line with the vacuum hose for vapor flow measurement;
7. The vapor extraction wellhead will be electrically isolated from the vacuum hose using a Kynar nipple;
8. V-block adjustable stands will be used to support the vacuum hoses to prevent putting weight on the Kynar nipple.

6.3. Liquid Discharge

The liquid discharge line for liquid extraction pumps and electrode water return is constructed as follows:

1. Place a 1 inch brass ball valve on the liquid discharge pipe lateral using a 316 stainless steel union;
2. Connect a 1 inch brass 4-way coupler to the ball valve;
3. On each of the two sides of the 4-way coupler connect a 1 inch x 3/8 inch brass reducer and 3/8 inch brass ball valve, and,
    a. On one of the 3/8 inch brass ball valves connect a 3/8 inch brass check valve and a 3/8 inch brass male NPT X 3/8 inch hose barb for electrode water return,
    b. On the other 3/8 inch brass ball valve connect the fitting required for contaminant sampling;
4. On the end of the 1 inch brass 4-way coupler, connect:
    a. A 1-inch brass ball valve,
    b. A 1-inch brass check valve,
    c. A 1-inch male NPT X 3/4 inch female NPT brass reducer bushing,
    d. A ¾-inch brass male NPT X ¾- inch hose barb fitting for connection to the liquid extraction pump discharge from an X well.

6.4. Liquid Extraction Pump Air Supply

The compressed air supply for liquid extraction pumps is designed as follows:

1. All air lines are to be 2-inch diameter.
2. The main trunk airline in the well field is to have a 3-way valve to dump the line to atmosphere when necessary and will be configured for automatic shutdown in the event of a treatment system liquid high-high alarm.
3. At the MPE wells, each liquid pump airline will have:
    a. A 1/2 inch brass ball valve,
    b. A moisture trap, and,

c. A pump cycle counter.

4. A pressure regulator is to be placed on each lateral airline at the main trunk connection.

6.5. Water Injection Piping

Water injection piping supplying the WCS units is designed as follows:

1. Water injection piping on the conveyance header will be 2-inch diameter.
2. A flow meter and brass ball valve is to be installed at the feed connection for each WCS.
3. A pressure gage (measurement range of 0 – 100 psi) is to be installed at the end of each lateral water injection pipe.

7. Vapor Cap Requirements

The vapor cap acts as a barrier to prevent steam breakthrough to surface, as observed during Phase I heating operations, and prevent short-circuiting of vacuum to atmosphere at the vapor extraction wells. The vapor cap will aid in achieving sufficient vacuum level uniformly across the treatment area, in particular within the ROC of the XE wells. As the heated volume is below 15 ft BGS, the vapor cap is non-insulating.

Most of the C-400 Cleaning Building SE treatment area is currently covered by a concrete surface. The following are options to cover the remaining treatment area in order of Mc^2 preference:

1. Apply a 3-4 inch asphalt cap before drilling activities commence;
2. Apply a 3-4 inch concrete cap after drilling activities finish; or
3. Apply a 0.03-inch thick plastic sheet on top of the ground after drilling and cover with 2-3 inches of crushed stone.

There may be a requirement for repairs if cracks in the cap are apparent once installation and acceptance testing has been completed.

8. Below Grade Well Vaults

8.1. Well Vault Completion

The following table summarizes how the well vaults shall be constructed for the ERH well components installed below grade in front of the roll-up door on the SE corner of C-400 Cleaning Building:

Table 5 Well Vaults

Well Type	Well Numbers	Well Vault Description
Electrode Well	E216 U-SMD	Minimum 2 ft x 2 ft x 2 ft well vault, sheet metal lined, with removable cover
Extraction / Electrode Well	XE224, XE231	Minimum 3 ft x 3 ft x 3 ft well vault, sheet metal lined, with removable cover
Vapor Extraction Well	VX207 U-SMD	Minimum 3 ft x 3 ft x 3 ft well vault, sheet metal lined, with removable cover
DigiTAM™ Sensor Well	D212	Minimum 2 ft x 2 ft x 2 ft well vault, sheet metal lined, with removable cover
DigiTAM™ / Vacuum Monitoring Well	DV203	Minimum2 ft x 2 ft x 2 ft well vault, sheet metal lined, with removable cover

Trenches will be dug in order to run extraction pipe, wire, hose and communication cables to these wells in front of the roll-up door. One main trench can be dug and then ended past the edge of the roll-up door towards the rest of the well field. The lines for vacuum and liquid extraction must be piped separately from each wellhead to facilitate flow measurements above surface prior to the extraction header connections. Moisture traps are required where vapor extraction lines exit the trench.

Required well vaults are to be constructed per drawing #C7DC40000C007 for sensor wells, drawing #C7DC40000C008 for electrode wells, and drawing #C7DC40000C009 for extraction wells.

8.2. Routine Monitoring

As access to below grade vaults for ERH wells will be limited during normal site operations, it is recommended that routine monitoring of these locations occur using electronic instruments. Vacuum levels on wells XE224, XE231, VX207, and DV203 may be monitored electronically using analog-output, absolute pressure transmitters. Vapor temperatures on XE224, XE231, and VX207 may be monitored at the wellheads using a temperature sensor, either a digiTAM™ or an analog-output temperature transmitter, installed in a threaded, stainless-steel thermowell. These additional sensors will be connected to the nearest data acquisition panel using CAT5 cable via trenching in front of the roll-up door.[3] The site server will log vacuum and temperature readings automatically every 30 minutes.

---

[3] Trenching will require conduit runs for all CAT5 cable (not shown on drawings)

9. Operational Monitoring

This section describes the monitoring that will be performed during the operations phase of the project.

9.1. Project Web Page

To review remediation progress, a project website will be developed for management and review of pertinent thermal, energy, and process data. The information gathered from the digiTAMs™, PDS units, and meter and gage readings recorded by the on-site personnel will be posted on the website.

Data collected digitally by the server will be stored in a database, uploaded regularly to the Mc2 web server, and presented on the website. Manually collected readings will preferably be recorded in a spreadsheet and distributed to the project team daily. Data recorded in the spreadsheet will be presented on the website and updated on a weekly basis, at minimum.

All authorized project personnel will be issued a password and given access to the website. The website will give the user real-time and historical data for all monitoring data collected during the operations phase of the project.

9.2. Digitally/Manually Collected Data

9.2.1. Temperature Data

Subsurface temperature data will be gathered every 30 minutes from the digiTAMs™ installed in the well field. DigiTAMs™ are digital temperature sensing devices consisting of wire assemblies with imbedded sensors placed at strategic intervals (typically 3 ft). The sensors are individually addressed and are accurate to 0.5 °C with a measurement range of 0 to 125 °C.

Graphical presentation of the data on the web site will consist of:

1. Vertical temperature profiles for each digiTAM™ string;
2. Temperature history, 7-day and full history, for each sensor string;
3. Horizontal temperature slices from 0 to 66 ft BGS done at least twice per week.

9.2.2. Hydraulic Data

Hydraulic data will be manually gathered by using gages to determine the water table at selected wells within the well field before the extraction system is turned on and prior to the electrode injection starting. This data is used to determine if the extraction rates of the perimeter extraction wells need to be increased due to the up gradient ground water flow entering the treatment area.

9.2.3. Energy Data

The amount of energy consumed for each electrode, each PDS and total power will be posted on the website. The energy for individual electrodes will be compared with the design energy to determine if modifications are needed to the operations.

The digital current transducer (digiCT™) sensors will be continuously monitored to log electrode current amplitudes and verify time-distributed control module (TDCM) settings. The three-phase voltages at the secondary of each PDS transformer will be measured with an alternating current (AC) voltmeter during acceptance testing or following a tap change on a given PDS phase. With these measurements the power and energy of each electrode will be calculated.

9.2.4. *Water Input*

The amount of water injected to the electrodes will be monitored. This amount will be compared with the amount extracted to determine if the groundwater extraction rate is between 5% and 30% greater than the water injection rate at all times.

Injection rates and volumes will be continuously monitored at each electrode using digital flow meters internal to the WCS units. Flow meters will be either paddle wheel or ultrasonic technology depending on the WCS version, each with a flow measurement range of approximately 0.1 to 5.0 gpm.

9.3. Well field Monitoring

Vacuum and temperature measurements will be collected from gages on the MPE wells, vapor extraction wells, and electrode-vapor extraction wells. Low-level vacuum measurements will also be obtained from gages on the vacuum monitoring wells. Pressure gages will be placed on bag filters and liquid conveyance lines for extraction discharge and electrode injection.

In addition, flow measurements (groundwater and vapor) will be periodically collected from the extraction wells. Readings will be recorded and maintained at the site office. Groundwater extraction rates will be measured with an inline flow meter, Venturi type or similar, at the extraction wellheads. Vapor flow rates will be determined using a Capsuhelic™ gage and inline flow tube.

9.4. Summary of Monitoring Instruments

Table 6 lists the instrument types and specifications required for routine monitoring at the site.

Table 6 Instrumentation for Routine Monitoring

Parameter	Instrument	Measurement Range	Measurement Rate
Electrode Current (A)	DigiCT™ (automated)	0-250 A (AC)	Every minute
Current (A) – electrodes, neutrals, distribution equipment	Clamp-on ammeter	0-1000 A (AC)	Refer to O&M Plan
Voltage (V) – electrodes, distribution equipment, step and touch potentials	Voltmeter or multimeter	0-600 V (AC)	Refer to O&M Plan
Subsurface Temperature (ºC)	DigiTAM™ (automated)	0-125 ºC	Every 30 minutes
Groundwater Level (ft H_2O)	Interface probe (manual)	0-20 ft H_2O	Prior to start of operations and as required thereafter
Electrode Water Injection Rate (gpm)	WCS flow meter (automated)	0.1-5.0 gpm	Every minute
Vapor Extraction Flow Rate	Capsuhelic™ gage and inline flow tube	0.0-0.5 inH_2O (to calculate flow rate)	Weekly
Groundwater Extraction Flow Rate	Venturi flow meter or similar	0-30 gpm	Daily
Extraction Well Vapor Temperature	Temperature gage	0-120 ºC	Daily
Extraction Well and Piping Vacuum Level	Vacuum gage	0 to -30 inHg	Daily
Monitoring Well Vacuum	Vacuum gage	0 to -15 inH_2O	Daily
Overall Water Injection Rate	Flow totalizer	0-50 gpm	Daily
Water Pressure –extraction/injection lines and bag filters	Pressure gage	0-100 psi	Daily

10. ERH Utility Interfaces

10.1. Electrical

The existing power supply to the site will be upgraded to meet the electrical demand for the thermal remediation. The power supply required for ET-DSP™ is a three-phase service of approximately 3,000 kilo-Volt-Amperes (kVA). The service must be connected to the PDPs. From here Mc^2 will connect the PDS units to the PDP via Teck cables (250 and 350 MCM). The 3,000-kVA service does not include power supply for any other above ground equipment, such as the extraction and treatment system. The one line electrical drawings #E7DC40000C012 and #E7DC40000C013 for both PDS unit availability scenarios can be found in Appendix B.

10.2. Water

The maximum water requirement for the remediation of the C-400 Cleaning Building SE treatment area at any time will be approximately 31.2 gpm. This flow must be split evenly and conveyed in 2-inch hoses or hard-piped to each WCS. The total water requirement for the project is approximately 6,480,000 gallons (based on 25.0 gpm average usage rates over 180 days). Plant water for electrodes will come from the PGDP facility water supply for wet testing and system shakedown. This will also function as backup for recirculation of treated groundwater from the treatment system to the WCS, which will be the primary source of water for injection to the electrodes. Technical information on the treatment system can be found in section 4.4 of LATA Kentucky's RDR revision.

A totalizer with operator readout is to be installed to monitor overall water injection to the well field, whether recirculated from the treatment system or provided from the backup water supply.

10.3. Telecommunications

The telecommunications system to be used is comprised of a local area network (LAN) in the field for real-time data communications with the onsite server, telephone lines, and a high speed Internet connection for remote monitoring and control. This connection will be used by Mc^2 to connect the Internet router and site server, which will preferably be placed inside a temperature, controlled building.

10.4. Vacuum

The vacuum blower on the treatment system will be specified to achieve -15 inHg of vacuum in the well field and a vapor flow of 1000 scfm. The blower is connected to the extraction wells via the well field extraction piping.

10.5. Extraction Liquid

The average liquid discharge requirement for the remediation of the C-400 Cleaning Building SE treatment area is 30.6 gpm. This liquid stream is conveyed back to the treatment system via the well field MPE piping. This liquid stream is treated and can be re-injected back into the electrodes or discharged to an appropriate outfall. Technical information on the treatment system can be found in section 4.4 of LATA Kentucky's RDR revision.

10.6. Extraction Vapor

The vapor discharge requirement for the remediation of the C-400 Cleaning Building SE treatment area will range from 660 to 972 scfm. This vapor stream is conveyed back to the treatment system via the well field MPE piping. This vapor stream must be treated and then exhausted to atmosphere.

Appendix A – Design Calculations

Phase IIa C-400 Cleaning Building SE treatment area calculations are based on the simulation results submitted prior to Phase I operations (Remedial Design Report: C-400 Cleaning Building Phase I, Appendix B).

Table 7 gives the simulation results for the SE treatment area as compared to the SW and east areas of the Phase I project:

Table 7 Modeling Results for C-400 Phase I Design

Treatment Area	SE Area	SW Area	East Area	Units
Electrical				
Electrical Energy	6,588	1,900	864	MWh
Average Power	1,525	440	200	kW
Energy Density	330	370	340	kWh/m^3
Peak Power	1,980	572	260	kW
Operations				
Total Liquids Injected	35,907	13,048	7,652	m^3
Total Liquids Produced	37,703	13,701	8,035	m^3
Electrode Injection Rate	0.1 to 0.2	0.1 to 0.2	0.1 to 0.2	gpm
Extraction Well Rate	2.7	2.7	2.7	gpm
X-Well Vapor Flow Rate	36.0	36.0	36.0	scfm/well
XE-Well Vapor Flow Rate	8.0	8.0	8.0	scfm/well
Produced Energy (energy from vapor and groundwater extraction)	2,641.8	761.9	346.5	MWh

The Phase I Simulation results for the UCRS portion of the SE area are applicable to Phase IIa when scaled to account for the different number of electrodes. The calculation packages used to scale the simulation results are included in this appendix.

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CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations **Job No.:** N/A

Area: C-400 Phase II a JB

Discipline: Electrical ***Calc. No.:** CAE-PHC400-P001

Subject: Scaling of electrical results from simulation

Computer Program: N/A **Program No.:** N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Approval	Date
0	3	Jonathan Backs [signature]	Tyler [signature]	TS	20110626
1	2	[signature]	[signature]	ER	20110627
2	2	[signature]	[signature]	ER	20111214
3	2	[signature]	[signature]	[signature]	20120105

SUMMARY OF REVISION	
Rev. 1	- fixed typographical error - clarified symbol E_0 name
Rev. 2	Phase II → Phase IIa Refer to Table 7 ERH Design Report
Rev. 3	Do not refer to draft design report

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAE-PHC400-P001 **Rev. No.:** ~~2~~ 3 ER

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** [initials] **Date:** 20120105

1.0 Purpose

The purpose of this calculation is to adapt electrical results from the C-400 Phase I remedial design simulation to the present design, which targets the Upper Continental Recharge System (UCRS) of the Southeast (SE) Area.

2.0 Input Data

Data used for this calculation was taken from the C-400 Phase I Modelling Results Table 7. ~~table (Draft ERH Remedial Design Report: C-400 Cleaning Building Phase IIa, Appendix A, Table 8).~~ ER

3.0 Assumptions

Due to their similar geographic location, it is assumed that the SE Area UCRS and the East Area UCRS will behave similarly under treatment with ET-DSP™. Additionally, since the Phase I modelling of the East Area involved only the UCRS, the results of Phase I modelling in the East Area will be most representative of the Phase IIa system behaviour in the SE Area.

4.0 References

None.

5.0 Calculations

Symbols used:

E_D	Cumulative Energy Density in the Formation
P_p	Peak Power
P_{ave}	Average Power

Energy density for the East Area is quoted in the Phase I modelling results as $340\,\text{kWh}\cdot\text{m}^{-3}$. Thus,

$$E_D = 340\,\text{kWh}\cdot\text{m}^{-3} \times \left(\frac{1\,\text{m}}{1.0936\,\text{yd}}\right)^3 = 260\,\text{kWh}\cdot\text{yd}^{-3}. \quad (1)$$

From the Phase I modelling results for all three Areas (the Southeast, Southwest, and East Areas), the ratios of the peak power to the average power are found as follows:

$$\text{SE Area}: \frac{P_p}{P_{ave}} = \frac{1980\,\text{kW}}{1525\,\text{kW}} = 1.298 \approx 1.3,$$

$$\text{SW Area}: \frac{P_p}{P_{ave}} = \frac{572\,\text{kW}}{440\,\text{kW}} = 1.3,$$

$$\text{East Area}: \frac{P_p}{P_{ave}} = \frac{260\,\text{kW}}{200\,\text{kW}} = 1.3.$$

This ratio should then hold for the UCRS in the SE Area:

$$\therefore P_p = 1.3 P_{ave}. \quad (2)$$

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAE-PHC400-P001 **Rev. No.:** ~~2~~ 3

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** [signature] **Date:** 20120105

6.0 Conclusion

Electrical results from the C-400 Phase I modelling were adapted for the Phase IIa design. These results will be referenced in subsequent calculations.

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CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations

Job No.: N/A

Area: C-400 Phase IIa JB

Discipline: Electrical

***Calc. No.:** CAE-PHC400-P002

Subject: Calculation of average power over project lifetime (total and per-electrode)

Computer Program: N/A

Program No.: N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

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SUMMARY OF REVISION

Rev. 1	-clarified energy density E_D ~~sy~~ symbol name
Rev. 2	Phase II → Phase IIa ~~Refer to Table 7 ERH Design Report~~ ER 20120105

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ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAE-PHC400-P002 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 2011 12 14

1.0 Purpose

The purpose of this calculation is to find the total and per-electrode average power dissipated in the formation over the project lifetime. Note that these figures do not reflect the real or complex power demands on the utility; rather, they serve as indications of the power requirements for heating.

2.0 Input Data

Data used in this calculation was taken from calculations CAE-PHC400-P001 (energy density) and CAC-PHC400-P002 (heated volume).

3.0 Assumptions

The projected project duration is $t_p = 180$ days $= 4320$ h.

4.0 References

None.

5.0 Calculations

Symbols used:

E_D	Cumulative Energy Density in the Formation
P_{ave}	Average Power
$P_{ave,pE}$	Average Power Per Electrode
t_p	Project Durection
V_H	Heated Volume

From calculation CAE-PHC400-P001, we have $E_D = 260\,\text{kWh}\cdot\text{yd}^{-3}$, and from calculation CAC-PHC400-P002 we have $V_H = 25\,291\,\text{yd}^3$. Dimensionally, then, the average power dissipated by the electrodes will be given by the expression

$$P_{ave} = \frac{E_D V_H}{t_p} = \frac{(260\,\text{kWh}\cdot\text{yd}^{-3})(25\,291\,\text{yd}^3)}{4320\,\text{h}} = 1522\,\text{kW}.$$

Per electrode, with 156 electrodes in the design, this becomes

$$P_{ave,pE} = \frac{1522\,\text{kW}}{156} = 9.8\,\text{kW}.$$

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAE-PHC400-P002 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** CR **Date:** 20111214

6.0 Conclusion

The average powers dissipated over the lifetime of the project for each electrode and all electrodes together were calculated. These figures are useful for determining the power demand and heating capacity of the ET-DSP™ system.

CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations

Job No.: N/A

Area: C-400 Phase IIa JB

Discipline: Electrical

***Calc. No.:** CAE-PHC400-P003

Subject: Calculation of peak power over project lifetime (total and per-electrode)

Computer Program: N/A

Program No.: N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

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0	2	Jonathan Backs (signature)	Tyler Sostarof (signature)	TS	20110624
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SUMMARY OF REVISION

Rev. 1	Phase II → Phase IIa ~~Refer to Table 7 ERH Design Report~~ ER 20120105
Rev. 2	

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*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAE-PHC400-P003 **Rev. No.:** 1

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** CR **Date:** 20111214

1.0 Purpose

The purpose of this calculation is to find the total and per-electrode peak power dissipated by the project over the project lifetime. Note that these figures do not reflect the real or complex power demands on the utility; rather, they serve as indications of the power requirements for heating.

2.0 Input Data

Data used in this calculation was taken from calculations CAE-PHC400-P002 (average power) and CAE-PHC400-P001 (peak-to-average power ratio).

3.0 Assumptions

No assumptions are necessary for this calculation that have not already been made for the referenced calculations.

4.0 References

None.

5.0 Calculations

Symbols used:

P_{p} Peak Power
$P_{\mathrm{p,pE}}$ Peak Power Per Electrode

From calculation CAE-PHC400-P002, we have $P_{\mathrm{ave}} = 1522\,\mathrm{kW}$ and $P_{\mathrm{ave,pE}} = 9.8\,\mathrm{kW}$. From calculation CAE-PHC400-P001, we have the peak-to-average power ratio:

$$\begin{aligned} P_{\mathrm{p}} &= 1.3P_{\mathrm{ave}}. \\ \therefore P_{\mathrm{p}} &= 1.3(1522\,\mathrm{kW}) \\ &= 1979\,\mathrm{kW} \\ &\text{and} \\ P_{\mathrm{p,pE}} &= 1.3(9.8\,\mathrm{kW}) \\ &= 12.7\,\mathrm{kW}. \end{aligned}$$

6.0 Conclusion

The peak powers dissipated over the lifetime of the project for each electrode and all electrodes together were calculated. These figures are useful for determining the power demand and heating capacity of the ET-DSP™ system.

CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations

Job No.: N/A

Area: C-400 Phase IIa JB

Discipline: Electrical

***Calc. No.:** CAE-PHC400-P004

Subject: Calculation of accumulated energy in the soil over project lifetime

Computer Program: N/A

Program No.: N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

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1	1	Jonathan Backs	ER	ER	20110627
~~1~~ 2 ER 20120105	1	Jonathan Backs	ER	ER	2011.12.14

SUMMARY OF REVISION	
Rev. 1	- clarified E_{acc} symbol name
Rev. 2	Phase II → Phase IIa ER 20120105 ~~Refer to Table 7 EAH Design Report~~

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ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAE-PHC400-P004 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

1.0 Purpose

The purpose of this calculation is to find the total accumulated energy in the soil over the lifetime of the project.

2.0 Input Data

Data used in this calculation was taken from calculations CAE-PHC400-P001 (energy density) and CAC-PHC400-P002 (heated volume).

3.0 Assumptions

Only energy accumulated within the heated volume is taken into account in this calculation.

4.0 References

None.

5.0 Calculations

Symbols used:

E_{acc} Cumulative Energy in the Formation
E_{D} Cumulative Energy Density in the Formation
V_{H} Heated Volume

From calculation CAE-PHC400-P001, we have $E_{\mathrm{D}} = 260\,\mathrm{kWh \cdot yd^{-3}}$, and from calculation CAC-PHC400-P002 we have $V_{\mathrm{H}} = 25\,291\,\mathrm{yd^3}$. Thus, the cumulative energy is

$$\begin{aligned} E_{\mathrm{acc}} &= E_{\mathrm{D}} V_{\mathrm{H}} \\ &= (260\,\mathrm{kWh \cdot yd^{-3}})(25\,291\,\mathrm{yd^3})\frac{1\,\mathrm{MWh}}{1000\,\mathrm{kWh}} \\ &= 6\,576\,\mathrm{MWh} \end{aligned}$$

6.0 Conclusion

The total energy accumulated in the soil of the heated volume over the lifetime of the project was calculated. This figure can be used to estimate the cost of the electrical energy required to heat the soil.

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CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations **Job No.:** N/A

Area: C-400 Phase IIa

Discipline: Hydraulic ***Calc. No.:** CAC-PHC400-P001

Subject: Scaling of hydraulic results from simulation

Computer Program: N/A **Program No.:** N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

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3	2	[illegible]	[illegible] Rosbello	[illegible]	20120105

SUMMARY OF REVISION

Rev. 1	- clarified source of ~~[illegible]~~ average injection rate - changed extraction to injection ratio to reflect Phase I lessons learned.
Rev. 2	Phase II → Phase IIa Refer to Table 7 ERH Design Report
Rev. 3	Do not refer to draft design report

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P001 **Rev. No.:** ~~2~~ 3 ER

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** [signature] **Date:** 20120105

1.0 Purpose

The purpose of this calculation is to adapt hydraulic results from the C-400 Phase I remedial design simulation to the present design, which targets the Upper Continental Recharge System (UCRS) of the Southeast (SE) Area.

2.0 Input Data

Data used for this calculation was taken from the C-400 Phase I Modelling Results Table 7. ~~table (Draft ERH Remedial Design Report: C-400 Cleaning Building Phase IIa, Appendix A, Table 8).~~ ER

3.0 Assumptions

Due to their similar geographic location, it is assumed that the SE Area UCRS and the East Area UCRS will behave similarly under treatment with ET-DSP™. Additionally, since the Phase I modelling of the East Area involved only the UCRS, the results of Phase I modelling in the East Area will be most representative of the Phase IIa system behaviour in the SE Area.

The ratio of liquid extraction rate to liquid injection rate is a design choice based on past project experience.

4.0 References

None.

5.0 Calculations

Symbols used:

$Q_{\text{L Ext,min}}$	Liquid Extraction Rate
$Q_{\text{L Ext,max}}$	Liquid Extraction Rate
$Q_{\text{L Inj}}$	Liquid Injection Rate
$Q_{\text{E Inj}}$	Electrode Injection Rate

In order to maintain hydraulic control of a project site, the liquid extraction rate must exceed the liquid injection rate. Based on lessons learned from C-400 Phase I, McMillan-McGee has chosen the extraction-to-injection ratio to be within the range 1.15 and 1.30.

$$Q_{\text{L Ext,min}} = 1.15 Q_{\text{L Inj}}. \quad (1)$$

$$Q_{\text{L Ext,max}} = 1.30 Q_{\text{L Inj}}. \quad (2)$$

Electrode injection rate was quoted on a per-electrode basis in the Phase I modelling results, and so does not need to change:

$$Q_{\text{E Inj}} = 0.1\text{–}0.2\ \text{gpm},\ 0.16\ \text{gpm on average.} \quad (3)$$

Note that the average of 0.16 gpm is a designed figure, not the arithmetic average of the minimum and maximum.

Originator: Jonathan Backs	**Date:** December 14, 2011	**Calc No.:** CAC-PHC400-P001	**Rev. No.:** ~~2~~ 3 ER
Project: C-400 Phase IIa Design Calculations	**Job No.:** N/A	**Checked:** [signature]	**Date:** 20120105

6.0 Conclusion

Hydraulic results from the C-400 Phase I modelling were adapted for the Phase IIa design. These results will be referenced in subsequent calculations.

CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations

Job No.: N/A

Area: C-400 Phase IIa JB

Discipline: Civil

***Calc. No.:** CAC-PHC400-P002

Subject: Computation of total volume of soil in the heated zone

Computer Program: N/A

Program No.: N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Approval	Date
0	3	Jonathan Backs [signature]	[signature]	T.S.	20110624
1	2	[signature]	[signature]	GR	20110627
2	2	[signature]	[signature]	ER	20111214

SUMMARY OF REVISION

Rev. 1	fixed typographical error
Rev. 2	Phase II → Phase IIa ~~Refer to Table 7 ERH Design Report~~ ER 20120105

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P002 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 2011 12 14

1.0 Purpose

The purpose of this calculation is to compute the total volume of soil in the C-400 Phase IIa heated zone. This volume will be used in subsequent calculations.

2.0 Input Data

Data used in this calculation was taken from project AutoCAD drawings #E7DC40000A007 (Wellfield Drawing) and #E7DC40000A008 (Detail Section View Drawing of ET-DSP™ Electrode Well Installations).

3.0 Assumptions

The heated volume is defined as the volume beneath the heated area and between three feet above the top of the highest electrodes and three feet below the lowest electrodes. This definition is based on past project experience and modelling data.

4.0 References

None.

5.0 Calculations

Symbols used:

d_H Heated Depth
A_H Heated Area
V_H Heated Volume

From drawing #E7DC40000A008, the top of electrode (TOE) depth is 17.9 ft and the bottom of electrode (BOE) depth is the bottom of well (BOW) depth minus 0.5 ft for silica sand (see the referenced drawing):

$$\begin{aligned}\text{BOE} &= \text{BOW} - 0.5\text{ ft}\\ &= 63.65\text{ ft} - 0.5\text{ ft}\\ &= 63.15\text{ ft.}\end{aligned}$$

The heated depth, as defined above, is then

$$\begin{aligned}d_H &= (\text{BOE} + 3\text{ ft}) - (\text{TOE} - 3\text{ ft})\\ &= (63.15\text{ ft} + 3\text{ ft}) - (17.9\text{ ft} - 3\text{ ft})\\ &= 51.25\text{ ft.}\end{aligned}$$

Using AutoCAD, the heated area was computed from drawing #E7DC40000A007 as $A_H = 13\,324\text{ ft}^2$. The

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P002 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

heated volume is then

$$\begin{aligned} V_{\mathrm{H}} &= A_{\mathrm{H}} d_{\mathrm{H}} \\ &= (13\,324\ \mathrm{ft}^2)(51.25\ \mathrm{ft}) \\ &= 682\,855\ \mathrm{ft}^3 \times \left(\frac{1\ \mathrm{yd}}{3\ \mathrm{ft}}\right)^3 \\ &= 25\,291\ \mathrm{yd}^3. \end{aligned}$$

6.0 Conclusion

The total volume of soil in the heated volume was calculated. These results will be referenced in subsequent calculations.

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CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations **Job No.:** N/A

Area: C-400 Phase IIa

Discipline: Hydraulic ***Calc. No.:** CAC-PHC400-P003

Subject: Calculation of minimum and maximum liquid injection rates required by the electrodes

Computer Program: N/A **Program No.:** N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Approval	Date
0	3	Jonathan Backs	Tyler Sadecki	T.S.	20110624
1	2	Jonathan Backs	[signature]	CR	20110627
2	2	[signature]	[signature]	ER	20111214

SUMMARY OF REVISION	
Rev. 1	Check $Q_{E\,Inj\,Ave}$ number 0.16 gpm? -clarified source of $Q_{E\,Inj,ave}$
Rev. 2	Phase II → Phase IIa ~~Refer to Table 7 ERH Design Report~~ ER 20120105

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P003 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

1.0 Purpose

The purpose of this calculation is to find the minimum and maximum liquid injection rates required by the electrodes.

2.0 Input Data

Data used in this calculation was taken from calculation CAC-PHC400-P001 (per-electrode injection rate).

3.0 Assumptions

The number of electrodes requiring liquid injection will be 156.

4.0 References

None.

5.0 Calculations

Symbols used:

$Q_{\text{E Inj,min}}$	Minimum Per-Electrode Injection Rate
$Q_{\text{E Inj,max}}$	Maximum Per-Electrode Injection Rate
$Q_{\text{E Inj,ave}}$	Average Per-Electrode Injection Rate
$Q_{\text{L Inj,min}}$	Minimum Total Injection Rate
$Q_{\text{L Inj,max}}$	Maximum Total Injection Rate
$Q_{\text{L Inj,ave}}$	Average Total Injection Rate

From calculation CAC-PHC400-P001, we have $Q_{\text{E Inj,min}} = 0.1$ gpm, $Q_{\text{E Inj,max}} = 0.2$ gpm, and $Q_{\text{E Inj,ave}} = 0.16$ gpm. Note that $Q_{\text{E Inj,ave}} = 0.16$ gpm is a designed figure, not the arithmetic average of the minimum and maximum. Thus, for 156 electrodes,

$$\begin{aligned} Q_{\text{L Inj,min}} &= 156 Q_{\text{E Inj,min}} \\ &= 156(0.1\text{ gpm}) \\ &= 15.6\text{ gpm}; \end{aligned}$$

$$\begin{aligned} Q_{\text{L Inj,max}} &= 156 Q_{\text{E Inj,max}} \\ &= 156(0.2\text{ gpm}) \\ &= 31.2\text{ gpm}; \end{aligned}$$

$$\begin{aligned} Q_{\text{L Inj,ave}} &= 156 Q_{\text{E Inj,ave}} \\ &= 156(0.16\text{ gpm}) \\ &= 25.0\text{ gpm}. \end{aligned}$$

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P003 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

6.0 Conclusion

The range of required liquid injection rates was calculated for the electrodes. These figures are used to determine the water demand for the project and to determine the water circulation system requirements.

CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations **Job No.:** N/A

Area: C-400 Phase IIa

Discipline: Hydraulic ***Calc. No.:** CAC-PHC400-P004

Subject: Calculation of minimum and maximum liquid extraction rates (total and per-extraction-well)

Computer Program: N/A **Program No.:** N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Approval	Date
0	3	Jonathan Backs	Tyler Sanders	TS.	20110624
1	2			GR	20110627
2	2			ER	20111214

SUMMARY OF REVISION

Rev. 1	Check $Q_{LExt\,Ave}$ number. -updated calculations for new extraction to-injection ratios
Rev. 2	Phase II → Phase IIa ~~Refer to Table 7 ERH Design Report~~ ER 20120105

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P004 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** GR **Date:** 20111214

1.0 Purpose

The purpose of this calculation is to find the minimum and maximum liquid extraction rates for the project, total and per-extraction-well.

2.0 Input Data

Data used in this calculation was taken from calculations CAC-PHC400-P003 (injection rates) and CAC-PHC400-P001 (extraction-to-injection ratio).

3.0 Assumptions

The number of extraction wells with pneumatic pumps will be 22.

4.0 References

None.

5.0 Calculations

Symbols used:

$Q_{\text{L Ext,min}}$	Minimum Total Extraction Rate
$Q_{\text{L Ext,max}}$	Maximum Total Extraction Rate
$Q_{\text{L Ext,ave}}$	Average Total Extraction Rate
$Q_{\text{L Inj,min}}$	Minimum Total Injection Rate
$Q_{\text{L Inj,max}}$	Maximum Total Injection Rate
$Q_{\text{L Inj,ave}}$	Average Total Injection Rate
$Q_{\text{W Inj,min}}$	Minimum Per-Well Extraction Rate
$Q_{\text{W Inj,max}}$	Maximum Per-Well Extraction Rate
$Q_{\text{W Inj,ave}}$	Average Per-Well Extraction Rate

From calculation CAC-PHC400-P003, we have $Q_{\text{L Inj,min}} = 15.6$ gpm, $Q_{\text{L Inj,max}} = 31.2$ gpm, and $Q_{\text{L Inj,ave}} = 25.0$ gpm. Additionally, from CAC-PHC400-P001, we have the designed extraction-to-injection ratio of be-

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P004 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

tween 1.15 and 1.30. Thus,

$$\begin{aligned} Q_{\text{L Ext,min}} &= 1.15 Q_{\text{L Inj,min}} \\ &= 1.15(15.6\text{ gpm}) \\ &= 17.9\text{ gpm}; \end{aligned}$$

$$\begin{aligned} Q_{\text{L Ext,max}} &= 1.30 Q_{\text{L Inj,max}} \\ &= 1.30(31.2\text{ gpm}) \\ &= 40.6\text{ gpm}; \end{aligned}$$

$$\begin{aligned} Q_{\text{L Ext,ave}} &= 1.05 Q_{\text{L Inj,ave}} \\ &= \frac{1.15+1.30}{2}(25.0\text{ gpm}) \\ &= 30.6\text{ gpm}. \end{aligned}$$

Then, per each of the 22 wells,

$$\begin{aligned} Q_{\text{W Ext,min}} &= Q_{\text{L Ext,min}} \div 22 \\ &= (17.9\text{ gpm}) \div 22 \\ &= 0.81\text{ gpm}; \end{aligned}$$

$$\begin{aligned} Q_{\text{W Ext,max}} &= Q_{\text{L Ext,max}} \div 22 \\ &= (40.6\text{ gpm}) \div 22 \\ &= 1.85\text{ gpm}; \end{aligned}$$

$$\begin{aligned} Q_{\text{W Ext,ave}} &= Q_{\text{L Ext,ave}} \div 22 \\ &= (30.6\text{ gpm}) \div 22 \\ &= 1.39\text{ gpm}. \end{aligned}$$

6.0 Conclusion

The range of projected liquid extraction rates were computed, total and per-extraction-well. These figures are used to design the liquid treatment system.

CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations **Job No.:** N/A

Area: C-400 Phase IIa JB

Discipline: Hydraulic ***Calc. No.:** CAC-PHC400-P006

Subject: Calculation of expected flow rate for extraction wells, assuming a given radius of capture (radius of influence)

Computer Program: N/A **Program No.:** N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Approval	Date
0	5	Jonathan Backs	Tyler Sestero	TS	20110624
1	4	Jonathan Backs	Eric Yeh	ER	20110627
2	4	Jonathan Backs	Eric Yeh	ER	20111214
3	4	Eric Yeh	CB	ER	20120522

SUMMARY OF REVISION	
Rev. 1	- corrected typographical ~~error~~ error. - added conversion factors for clarity
Rev. 2	Phase II → Phase IIa ~~Refer to Table 7 ERH Design Report~~ ER 20120105
Rev. 3	Design ROC is 15 ft. Extraction well screen extends to 15 ft BGS.

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Eric Ringdahl **Date:** May 22, 2012 **Calc No.:** CAC-PHC400-P006 **Rev. No.:** 3

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** [signature] **Date:** 22/May/2012

1.0 Purpose

The purpose of this calculation is to find the flow rate for the vapor extraction wells given an assumed radius of capture.

2.0 Input Data

- Based on past project experience, the designed radius of capture or radius of influence is 15 ft. 1 ft = 0.3048 m, so 15 ft = 4.572 m.
- The radius of the extraction well as designed is 2 in. 1 in = 0.0254 m, so 2 in = 0.051 m.
- Also based on past project experience, the target vacuum level for the well is 15.0 $inHg$.
- Paducah, Kentucky is approximately 340 ft above sea level. Thus, the ambient air pressure is approximately 100 kPa.
- The well screen on the extraction wells (as designed) exists from 15 ft BGS to 65 ft BGS, giving a total screened length of 50 ft. However, the water table is at 55 ft BGS, so only 40 ft of the screen are available for vapor extraction. 40 ft = 12.19 m.
- The soil permeability measurements provided by the client range from 300 mD to 30 000mD. However, based on lessons learned from C-400 Phase I, the 300 mD figure represents the majority of soil conditions for the Phase IIa treatment zone. 1 darcy is equivalent to 9.869×10^{-13} m^2, so 300 mD = 2.96×10^{-13} m^2.
- The target treatment temperature is 90 °C.
- From the CRC Handbook, the dynamic viscosity of air was taken to be 1.8×10^{-5} Pa·s at T_w = 20 °C and 2.1×10^{-5} Pa·s at T_w = 90 °C.

3.0 Assumptions

- Permeability data on site soil samples were provided by the client. There is some risk that these data will not be representative of the geology of the entire site.
- The permeability of the site soil samples varied by at least two orders of magnitude, and thus extraction flow rates could also vary by up to two orders of magnitude.
- The formula presented by Johnson *et al.* (shown below) was derived from assumptions of steady state and purely radial compressible flow. Additionally, the formula is designed to be valid for wells of radius 2 in with a 40 ft radius of influence. For our targeted radius of influence of 15 ft, Johnson *et al.* suggest multiplying the resultant standard flow rate by a factor of approximately 1.2.
- The ambient temperature is 20 °C.
- For standard conditions (standard temperature and pressure), we use the current International Union of Pure and Applied Chemistry (IUPAC) standard of 0 °C and 100 kPa.

Originator: Eric Ringdahl **Date:** May 22, 2012 **Calc No.:** CAC-PHC400-P006 **Rev. No.:** 3

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** C. K[signature] **Date:** 22/May/2012

- While Johnson *et al.* use ambient pressure as the boundary pressure for their radius of influence formula, we will set the boundary pressure to $P_{\text{edge}} = \text{-}1.0\,inHg$ (relative) to reflect the fact that the extraction well array will provide some small vacuum throughout the treatment volume (i.e., there will be no opportunity for the soil pressure to equalize with ambient pressure near the edge of the radius of influence).

4.0 References

P. C. Johnson, C. C. Stanley, M. W. Kemblowski, D. L. Byers, and J. D. Colthart, "A Practical Approach to the Design, Operation, and Monitoring of In Situ Soil-Venting Systems," Ground Water Monit. Rem. **10**(2), 159–178 (1990).

CRC Handbook of Chemistry and Physics, 55th edition, R. C. Weast, ed. (CRC Press, 1974).

5.0 Calculations

Symbols used:

Q	Vapor Extraction Rate
k	Soil Permeability
H	Screened Length of Extraction Well
P_{w}	Pressure in Extraction Well (Absolute)
P_{atm}	Ambient Pressure (Absolute)
P_{edge}	Pressure at Edge of R_{i}(Absolute)
V_{w}	Vacuum Level in Extraction Well (Relative)
V_{edge}	Vacuum Level at Edge of R_{i}(Relative)
μ	Dynamic Viscosity of Air
R_{w}	Radius of Well
R_{i}	Radius of Influence or Capture
Q^*	Standard Vapor Extraction Rate
P_{std}	Standard Pressure (Absolute)
T_{w}	Temperature in Extraction Well (Absolute)
T_{std}	Standard Temperature (Absolute)

The expression for flow rate given by Johnson *et al.* is as follows:

$$Q = \frac{\pi k H P_{\text{w}} \left[1 - \left({}^{P_{\text{atm}}}/_{P_{\text{w}}}\right)^2\right]}{\mu \ln \frac{R_{\text{w}}}{R_{\text{i}}}}, \tag{1}$$

and we will substitute $P_{\text{atm}} \equiv P_{\text{edge}}$. To convert this to the standard flow rate,

$$Q^* = Q \frac{P_{\text{w}}}{P_{\text{std}}} \frac{T_{\text{std}}}{T_{\text{w}}}. \tag{2}$$

Finally, we are required by our target radius of influence to multiply the result by a factor of 1.2 (extrapolating from Johnson *et al.*):

$$Q^* := 1.2 \times Q^*. \tag{3}$$

Originator: Eric Ringdahl **Date:** May 22, 2012 **Calc No.:** CAC-PHC400-P006 **Rev. No.:** 3

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** C.K [signature] **Date:** 22/MAY/2012

The pressure in the extraction well is found by subtracting the vacuum pressure from the ambient pressure:

$$\begin{aligned} P_{\mathrm{w}} &= P_{\mathrm{atm}} - V_{\mathrm{w}} \\ &= 100\,\mathrm{kPa} - 15.0\,inHg \frac{3.386\,\mathrm{kPa}}{1\,inHg} \\ &= 49.2\,\mathrm{kPa}. \end{aligned}$$

Similarly, for the pressure at the edge of the radius of influence,

$$\begin{aligned} P_{\mathrm{edge}} &= P_{\mathrm{atm}} - V_{\mathrm{edge}} \\ &= 100\,\mathrm{kPa} - 1.0\,inHg \frac{3.386\,\mathrm{kPa}}{1\,inHg} \\ &= 96.6\,\mathrm{kPa}. \end{aligned}$$

We then proceed as follows, using the minimum value for permeability and the initial temperature for the project, 20 °C:

$$\begin{aligned} Q &= \frac{\pi(2.96\times10^{-13}\,\mathrm{m}^2)(12.19\,\mathrm{m})(49.2\,\mathrm{kPa})\left(\frac{1000\,\mathrm{Pa}}{1\,\mathrm{kPa}}\right)\left[1-\left(\frac{96.6\,\mathrm{kPa}}{49.2\,\mathrm{kPa}}\right)^2\right]}{(1.8\times10^{-5}\,\mathrm{Pa\cdot s})\ln\frac{0.051\,\mathrm{m}}{4.572\,\mathrm{m}}} \\ &= 2.0\times10^{-2}\,\mathrm{m}^3\cdot\mathrm{s}^{-1}\ \text{(at 20 °C)}, \end{aligned}$$

or equivalently,

$$\begin{aligned} Q &= 2.0\times10^{-2}\,\mathrm{m}^3\cdot\mathrm{s}^{-1}\left(\frac{1\,ft}{0.3048\,\mathrm{m}}\right)^3\left(\frac{60\,\mathrm{s}}{1\,\mathrm{min}}\right) \\ &= 43\,ft^3\mathrm{min}^{-1}\ \text{(at 20 °C)}. \end{aligned}$$

Then, in standard units,

$$\begin{aligned} Q^* &= Q\frac{P_{\mathrm{w}}}{P_{\mathrm{std}}}\frac{T_{\mathrm{std}}}{T_{\mathrm{w}}} \\ &= 43\,ft^3\mathrm{min}^{-1}\left(\frac{49.2\,\mathrm{kPa}}{100\,\mathrm{kPa}}\right)\left(\frac{0+273.15\,\mathrm{K}}{20+273.15\,\mathrm{K}}\right) \\ &= 20\,\mathrm{scfm}\ \text{(at 20 °C)}. \end{aligned}$$

Multiplying by the factor of 1.2, we find

$$\boxed{Q^* = 24\,\mathrm{scfm}\ \text{(at 20 °C)}.}$$

Similarly, at 90 °C,

$$\begin{aligned} Q &= \frac{\pi(2.96\times10^{-13}\,\mathrm{m}^2)(12.19\,\mathrm{m})(49.2\,\mathrm{kPa})\left(\frac{1000\,\mathrm{Pa}}{1\,\mathrm{kPa}}\right)\left[1-\left(\frac{96.6\,\mathrm{kPa}}{49.2\,\mathrm{kPa}}\right)^2\right]}{(2.1\times10^{-5}\,\mathrm{Pa\cdot s})\ln\frac{0.051\,\mathrm{m}}{4.572\,\mathrm{m}}} \\ &= 1.7\times10^{-2}\,\mathrm{m}^3\cdot\mathrm{s}^{-1}\ \text{(at 90 °C)}, \end{aligned}$$

Originator: Eric Ringdahl **Date:** May 22, 2012 **Calc No.:** CAC-PHC400-P006 **Rev. No.:** 3

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** [signature] **Date:** 22/May/2012

or equivalently,

$$Q = 1.7\times10^{-2}\,\mathrm{m}^3\cdot\mathrm{s}^{-1}\left(\frac{1\,ft}{0.3048\,\mathrm{m}}\right)^3\left(\frac{60\,\mathrm{s}}{1\,\mathrm{min}}\right)$$
$$= 37\,ft^3\mathrm{min}^{-1}\ (\text{at } 90\,^\circ\mathrm{C}).$$

Then, in standard units,

$$Q^* = Q\frac{P_\mathrm{w}}{P_\mathrm{std}}\frac{T_\mathrm{std}}{T_\mathrm{w}}$$
$$= 37\,ft^3\mathrm{min}^{-1}\left(\frac{49.2\,\mathrm{kPa}}{100\,\mathrm{kPa}}\right)\left(\frac{0+273.15\,\mathrm{K}}{90+273.15\,\mathrm{K}}\right)$$
$$= 13.7\,\mathrm{scfm}\ (\text{at } 90\,^\circ\mathrm{C}).$$

Multiplying by the factor of 1.2, we find

$$\boxed{Q^* = 16\,\mathrm{scfm}\ (\text{at } 90\,^\circ\mathrm{C}).}$$

Due to the significant number of approximations and assumptions made for this calculation, it should be noted that these can only be taken as order-of-magnitude estimates. We will use an average figure of $Q^* = 20\,\mathrm{scfm}$ for subsequent design calculations, since this is consistent with lessons learned from C-400 Phase I.

6.0 Conclusion

The expected vapor flow rates at starting temperature and target temperature were calculated. An average figure of $Q^* = 20\,\mathrm{scfm}$ will be used for subsequent design calculations.

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CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations **Job No.:** N/A

Area: C-400 Phase IIa

Discipline: Hydraulic ***Calc. No.:** CAC-PHC400-P005

Subject: Calculation of normal and maximum vapor extraction rates

Computer Program: N/A **Program No.:** N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Approval	Date
0	2	Jonathan Backs	Tyler Sandeen	TS	20110624
1	1	Jonathan Backs	[illegible]	ER	20110627
2	1	Jonathan Backs	[illegible]	ER	20111214
3	1	[illegible]	[illegible]	ER	20120522

SUMMARY OF REVISION	
Rev. 1	- corrected maximum number of extraction wells
Rev. 2	Phase II → Phase IIa ~~Refer to Table 7 ERH Design Report~~ ER 20120105
Rev 3	Rename contingency wells to vapor extraction wells.

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Eric Ringdahl **Date:** May 22, 2012 **Calc No.:** CAC-PHC400-P005 **Rev. No.:** 3

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** [signature] **Date:** 22/May/2012

1.0 Purpose

The purpose of this calculation is to find the normal extraction rates, with the multi-phase and vapor extraction wells active, and the maximum extraction rates, with additional extraction from the extraction/electrode wells.

2.0 Input Data

This calculation uses no data from previous calculations.

3.0 Assumptions

The present design includes 22 multi-phase extraction wells and 11 vapor extraction wells. In addition, 39 of the electrode wells are designed to accomodate contingency vapor extraction. Based on lessons learned from C-400 Phase I, multi-phase and vapor extraction wells are each expected to produce 20 scfm of vapor, while extraction/electrode wells will be each designed to produce 8 scfm of vapor.

4.0 References

None.

5.0 Calculations

Symbols used:

$Q_{\text{V Ext,norm}}$	Minimum Total Extraction Rate
$Q_{\text{V Ext,max}}$	Maximum Total Extraction Rate

We need only multiply the number of wells by the projected extraction rate per well:

$$Q_{\text{V Ext,norm}} = (11 + 22)20 \text{ scfm} \\ = 660 \text{ scfm};$$

$$Q_{\text{V Ext,max}} = (11 + 22)20 \text{ scfm} + (39)8 \text{ scfm} \\ = 972 \text{ scfm};$$

6.0 Conclusion

The normal and maximum expected total extraction rates were calculated. These figures are important in the design of the vapor treatment system.

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CALCULATION COVER SHEET

Project Title: C-400 Phase IIa Design Calculations

Job No.: N/A

Area: C-400 Phase IIa JB

Discipline: Hydraulic

***Calc. No.:** CAC-PHC400-P007

Subject: Determination of extraction well filter pack and screen size

Computer Program: N/A

Program No.: N/A

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Approval	Date
0	5	Jonathan Backs [signature]	Tyler Sauterweg [signature]	TS	2011/06/27
1	4	[signature]	[signature]	GR	20110627
2	4	[signature]	[signature]	ER	20111214

SUMMARY OF REVISION	
Rev. 1	- fixed typographical errors - added data tables for plot (Fig. 1) - added well screen specification.
Rev. 2	Phase II → Phase IIa ~~Refer to Table 7 ERH Design Report~~ GR 20120105

Microfilmed	Rev.	Date	Reel No.	Rev.	Date	Reel No.

*Obtain Calculation Number from Engineering and Technical Services Manager

ENG-F-0036 (8-10)
PAD-ENG-1026

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P007 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

1.0 Purpose

The purpose of this calculation is to design the filter pack and screen size for the multi-phase extraction wells. This will allow selection of a commercial filter pack and well screen.

2.0 Input Data

- The depth of the treatment zone is from 20 ft below ground surface (BGS) to 60 ft BGS. Based on past project experience, extraction wells will be screened from five feet above the treatment zone to five feet below the treatment zone to improve contaminant capture and allow maintenance hydraulic control.
- Sieve analysis data for site soil samples provided by the client (WAG 6 Remedial Investigation, Ken Davis, PRS) showed that the finest soil was found in sample 026001SA045, which was taken at 44 ft BGS (see Figure 1). This is consistent with other samples taken at the site, which found similarly fine material in the vicinity of 45 ft BGS.
- Sieve analysis data for commercial filter packs was obtained from data sheets produced by the manufacturers of RMC Lapis Lustre, FilterSil, and Colorado Silica Sand.

3.0 Assumptions

The procedure from Driscoll (referenced below), though practical, is highly empirical and relies in part on the experience of the well designer. However, this reference is well-respected in its field and the procedure has been followed closely. Some time may be needed to fully develop the well before sediment-free extraction can occur.

We also assume in this calculation that the soil samples taken at the site accurately represent conditions throughout the site.

4.0 References

F. G. Driscoll, *Groundwater and Wells*, 2nd ed. (Johnson Screens, 1986).

5.0 Calculations

Symbols used:

C_u	Coefficient of Uniformity for the Fine Limit Curve
D_{40}	Sieve Size That Retains Cumulatively 40% of a Sample
D_{90}	Sieve Size That Retains Cumulatively 90% of a Sample

The procedure used in this calculation was adapted from Driscoll (referenced above):

1. Determine depths to be screened in the extraction wells.

   The remedial design calls for a screened interval of 15 ft BGS to 65 ft BGS (as mentioned in the Input Data section above).

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P007 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

2. Determine the finest material present along the screened length.

   The finest material is the most important to consider in the design of the filter pack and well screen, since it is the material most likely to pass into the well if the filter pack and screen are too course. Based on the input data, the finest material at the site will be found at depths in the vicinity of 45 ft BGS.

3. Determine the 70% cumulative percent retained size for the filter pack.

   To get this 70% cumulative percent retained size, the 70% cumulative percent retained particle size of the finest treatment zone subsurface material is multiplied by a factor between 5 and 10. To find an acceptability range for filter packs, we designate a fine limit using the multiplier 5 and a course limit using the multiplier 10. We begin by extrapolating the 70% retained size for the 44 ft BGS sample by referring to the corresponding sieve analysis curve plotted in Figure 1. An acceptable estimate for this size is 0.025 mm. Thus, the fine limit size is $0.025\,\text{mm} \times 5 = 0.13\,\text{mm} \approx 0.15\,\text{mm}$ and the course limit size is $0.025\,\text{mm} \times 10 = 0.25\,\text{mm}$. Note that Cumulative Percent Retained = 100% − Cumulative Percent Passing.

4. On the sieve analysis plot, draw a smooth curve through the calculated 70% cumulative percent retained size representing a material with a uniformity coefficient of 2.5 or less.

   We draw one curve each for the fine and course limit sizes found. The shape of these curves is based on experience and the desired value for the uniformity coefficient. Both curves are drawn with the same shape, and so the resultant uniformity coefficients are similar. For the fine limit curve, for instance,

$$\begin{aligned} C_u &= \frac{D_{40}}{D_{90}} \\ &= \frac{0.20\,\text{mm}}{0.093\,\text{mm}} \\ &= 2.2. \end{aligned}$$

   This uniformity coefficient is less than 2.5 and is thus acceptable.

5. Select a commercial filter pack that meets the dimensional and uniformity requirements set out by the two filter pack curves drawn.

   Several commerical filter pack materials come close to meeting these criteria. Of the filter pack products surveyed, RMC Lapis Lustre LSI-30 sand (nominal sieve size 30×70; see Figure 1) provides the closest dimensional match while meeting uniformity requirements.

6. Select a screen opening size based on the chosen filter pack. The screen opening size should correspond to the sieve opening size that retains about 90% of the filter pack material.

   Looking at the plot of Figure 1, we can see that a screen size opening of 0.17 mm (0.0067 in) would retain about 90% of the filter pack material. The nearest smaller screen size that is commercially available is the Johnson #6 screen from Johnson Screens, with an opening of 0.006 in.

One should also note the chemical composition of the chosen filter pack. The composition should be mainly silica or siliceous material, with no more than 5% calcareous material. This is necessary to avoid dissolution of the filter pack material if the groundwater at the site is slightly acidic. Chemical composition data of Lapis Lustre LSI-30 sand was not available at the time of origination for this calculation, but if this sand does not meet the chemical requirements, an equivalently sized and equivalently uniform sand may be used instead that meets the chemical requirements.

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P007 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

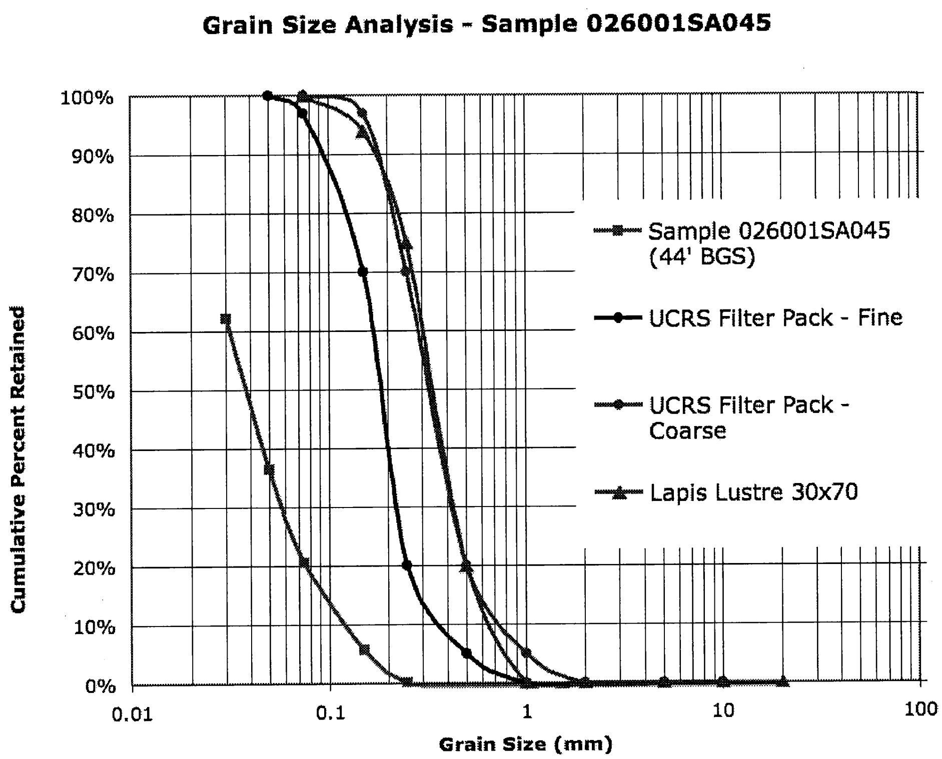

Figure 1: Cumulative percent retained (percent larger) measurements obtained by sieve analysis of sample 026001SA045 (44 ft BGS), compared with fine and course designed filter pack curves and an approximate sieve analysis for RMC Lapis Lustre LSI-30 (30 × 70) sand.

Table 1: Sieve analysis data given by manufacturer for RMC Lapis Lustre LSI-30 (30 × 70) sand. All percentages indicate cumulative percent retained (percent larger) measurements.

Sieve size (mm)	0.150	0.212	0.300	0.425	0.600	0.850
Lapis Lustre 30 × 70	2–10%	6–25%	20–40%	45–80%	90–96%	100%

Originator: Jonathan Backs **Date:** December 14, 2011 **Calc No.:** CAC-PHC400-P007 **Rev. No.:** 2

Project: C-400 Phase IIa Design Calculations **Job No.:** N/A **Checked:** ER **Date:** 20111214

Table 2: Data table for Figure 1. All percentages indicate cumulative percent retained (percent larger) measurements obtained by sieve analysis. Data for the Lapis Lustre sand was obtained by approximate extrapolation from the data of Table 1.

Grain size (mm)	0.03	0.05	0.075	0.15	0.25	0.5	1	2
Sample 026001SA045	62.2%	36.4%	20.5%	5.7%	0.1%	0.0%	0.0%	0.0%
Filter Pack Design - Fine	—	100.0%	97.0%	70.0%	20.0%	5.0%	0.0%	0.0%
Filter Pack Design - Course	—	—	100.0%	97.0%	70.0%	20.0%	5.0%	0.0%
Lapis Lustre 30 × 70	—	—	100.0%	94.0%	75.0%	20.0%	0.0%	0.0%

6.0 Conclusion

It was determined that RMC Lapis Lustre LSI-30 (30 × 70) sand (or another dimensionally similar sand) should be used as the filter pack for C-400 Phase IIa extraction wells if it is found to be chemically appropriate for site conditions. Otherwise, a similarly sized and similarly uniform sand should be used with an appropriate chemical composition. The well screen should have an opening of approximately 0.17 mm (0.0067 in). The Johnson #6 well screen has the nearest smaller opening at 0.006 in.

Appendix B – Design Drawings

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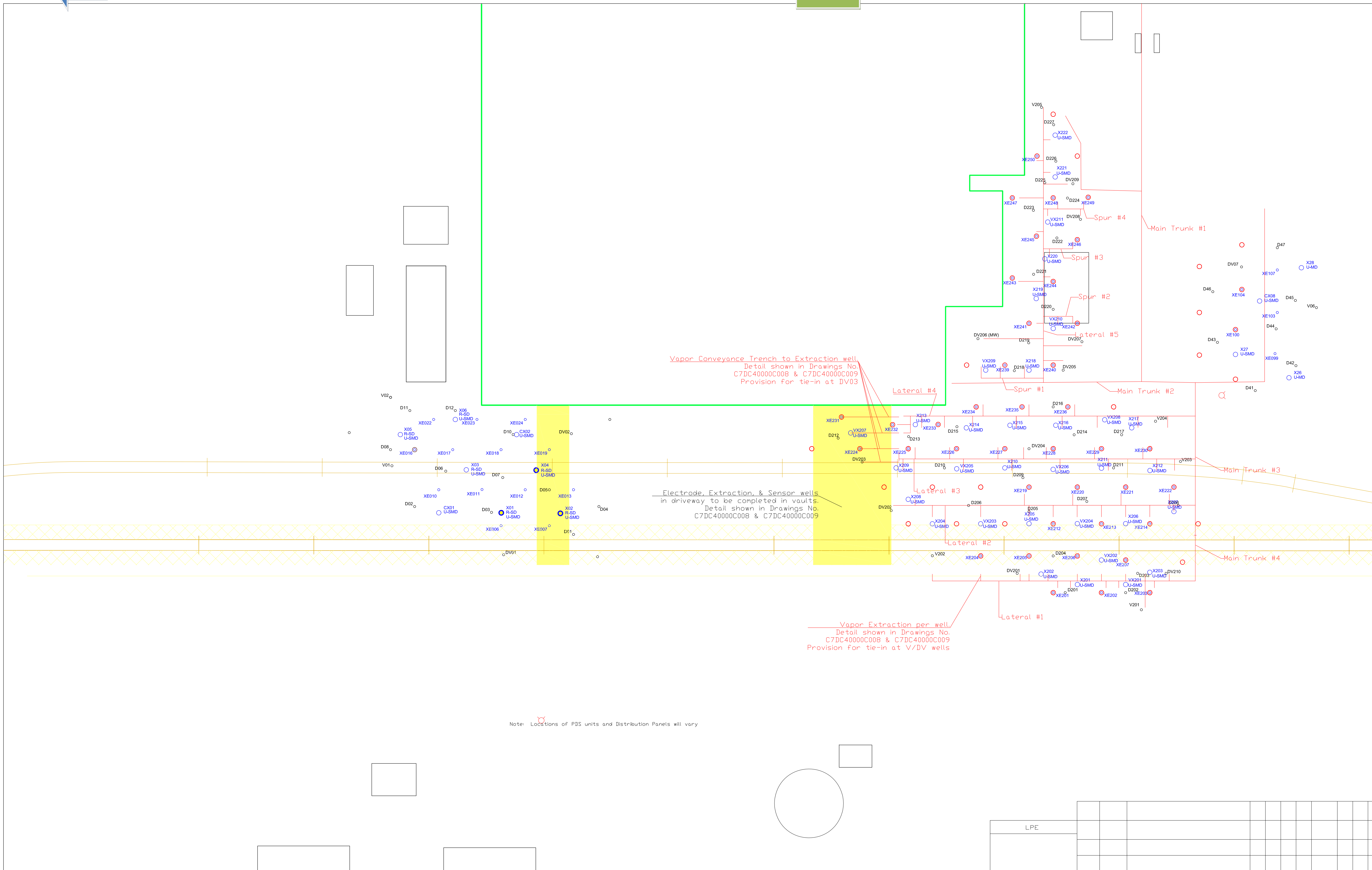

Legend

Electrode Well ###
UCRS Depth - U
Shallow - S
Middle - M
Deep - D

20-60 ft Contour 3-Electrode Well

XE088 Electrode Well w/ Upper Vapor Extraction

X18 U-SMD Multi-phase Extraction Well

VX201 U-SMD Vapor Extraction Well

D40 digiTAM Temperature Sensor Well

DV04 Vacuum Monitoring/digiTAM Well
(MW) indicates combined vacuum/ digiTAM / monitoring well location

V02 Vacuum Monitoring

SVE Treatment Contour
0-20 ft Depth

ERH Treatment Contour
20-40 ft Depth

ERH Treatment Contour
40-60 ft Depth

Notes:

1. Placement of subsurface components made according to utility locations and drill spacing guidelines provided by LATA.
2. Due to security concerns with the facility, utility line types could not be identified at the time of drawing.
3. Final construction approval will require:
- All utility spacing for drilling locations to adhere to relevant codes and regulations, and
- Well installation to occur within operational limitations of the drilling contractor.

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
E	22/05/12	Rename CX wells, move sensor wells	ER	CK	ER	BM			
D	24/04/12	Technical Edits	AW	WR	ER	BM			
C	26/01/12	Technical Edits	AW	CK	ER	BM			
B	05/01/12	Technical Edits	WR	ER	ER	BM			
A	21/06/11	Initial 90% Design Layout	WR	ER	ER	BM			

DRAWING REVISIONS

LPE

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

PROJECT NAME:
Paducah PGDP C-400 Remediation Project

TITLE:
C-400 Complex Detail Drawing of Wellfield Connection Piping for ET-DSP Subsurface Components Phase IIa

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-C400-ETDSP-Layout.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
1" = 22'	C7DC40000C004	E

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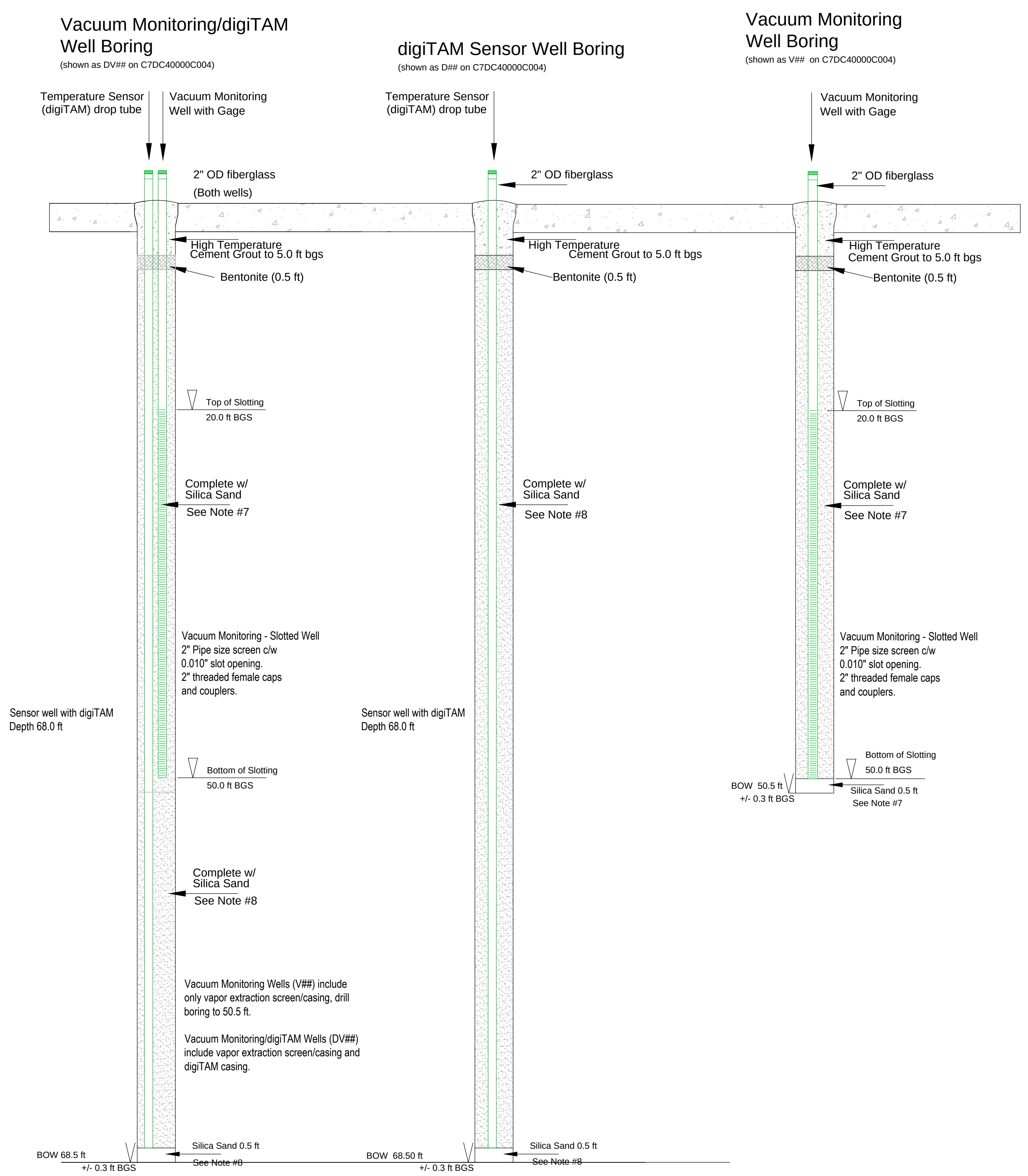

Notes:
1. All wellhead details are shown in drawing #C7DC40000C007.
2. All fiberglass drop tubes are high-temperature red-thread.
3. Actual depths will be adjusted based on observed field conditions.
4. Vacuum Monitoring and Vacuum Monitoring/digiTAM Wells can be used as contingency wells for vapor extraction.
5. BOW - Bottom of Well.
6. One Vacuum/ digiTAM Monitoring well will be installed in an existing monitoring well borehole shown as DV## (MW) on drawing #C7DC40000C004.
7. Sand is #00N or equivalent.
8. Sand is #1 or equivalent.

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(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: Paducah PGDP C-400 Remediation Project

TITLE: C-400 Complex Detail Section View Drawing of Sensor Wells for ET-DSP Phase IIa

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
D	24/04/12	Technical Edits	AW	WR	ER	BM			
c	26/01/12	Technical Edits	AG	CK	ER	BM			
B	05/01/12	Technical Edits	WR	WR	ER	BM			
A	24/06/11	Initial 90% Design Drawing	WR	WR	ER	BM			

DRAWING REVISIONS

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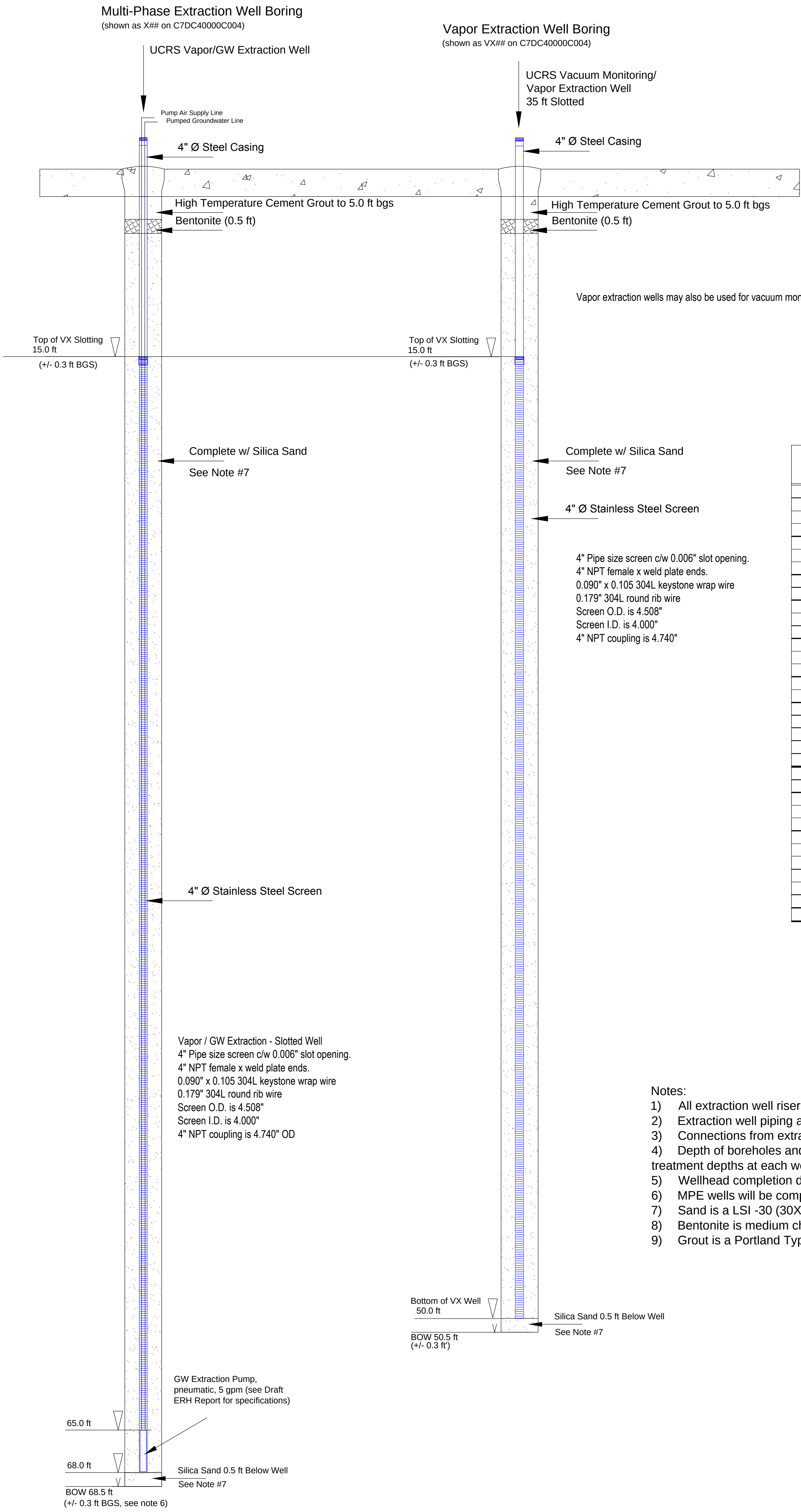
CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-SensorWellDetails.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
Not To Scale	C7DC40000C005	C



Legend
BOW - Bottom of Well

Vapor extraction wells may also be used for vacuum monitoring.

Well #	Depth of Well (ft bgs)	Vapor Screen Interval (ft bgs)	GW Screen Interval (ft bgs)	Area
X201	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X202	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X203	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X204	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X205	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X206	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X207	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X208	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X209	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X210	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X211	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X212	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X213	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X214	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X215	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X216	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X217	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X218	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X219	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X220	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X221	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
X222	68.5	15.0 to 55.0	55.0 to 68.5	Southeast
VX201	50.5	15 to 50.0	no gw screen	Southeast
VX202	50.5	15 to 50.0	no gw screen	Southeast
VX203	50.5	15 to 50.0	no gw screen	Southeast
VX204	50.5	15 to 50.0	no gw screen	Southeast
VX205	50.5	15 to 50.0	no gw screen	Southeast
VX206	50.5	15 to 50.0	no gw screen	Southeast
VX207	50.5	15 to 50.0	no gw screen	Southeast
VX208	50.5	15 to 50.0	no gw screen	Southeast
VX209	50.5	15 to 50.0	no gw screen	Southeast
VX210	50.5	15 to 50.0	no gw screen	Southeast
VX211	50.5	15 to 50.0	no gw screen	Southeast
XE wells	varies	6.5 to 13.1	no gw screen	Southeast

Notes:
1) All extraction well riser pipes grounded to ET-DSP neutral system above surface.
2) Extraction well piping at the wellhead will be isolated with electrical insulating coating.
3) Connections from extraction wellhead to treatment system must be electrically isolated.
4) Depth of boreholes and vertical extents of extraction wells are determined by the treatment depths at each well location.
5) Wellhead completion details are shown in drawing #C7DC40000C009.
6) MPE wells will be completed 3 ft with a sump.
7) Sand is a LSI -30 (30X70) or equivalent.
8) Bentonite is medium chips.
9) Grout is a Portland Type 1 or Type 2 (no Bentonite flour added to grout).

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	DWG	LEAD ENGR	QA	CONF CTRL/ NUCL SFTY	FAC MGR	PROJ ENGR
D	22/05/12	Rename CX wells, start X wells at 15'	ER	CK	ER	BM				
C	24/04/12	Technical Edits	AW	WR	ER	BM				
B	05/01/12	Technical Edits	WR	ER	ER	BM				
A	10/01/07	Initial 90% Design Drawing	WR	ER	ER	BM				

DRAWING REVISIONS

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U.S. DEPARTMENT OF ENERGY
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(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
Paducah PGDP C-400 Remediation Project

TITLE:
C-400 Complex
Detail Section View Drawing of
ET-DSP Extraction Wells Phase IIa

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-ExtractionWellDetails.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
Not To Scale	C7DC40000C006	D

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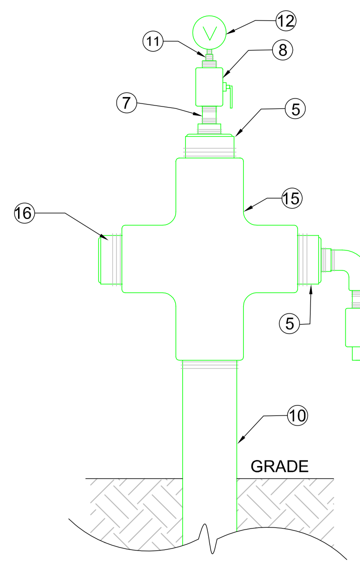
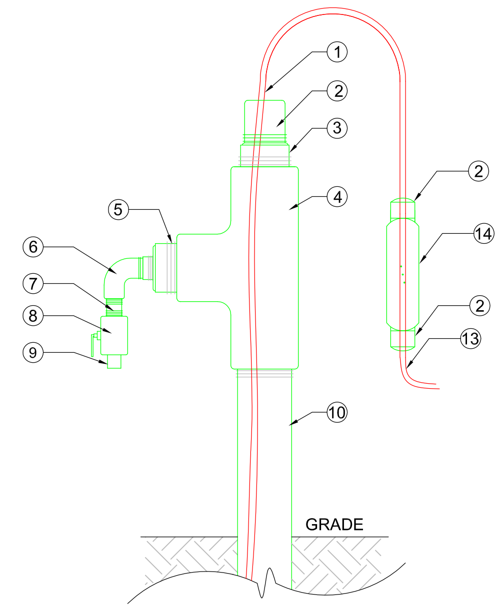
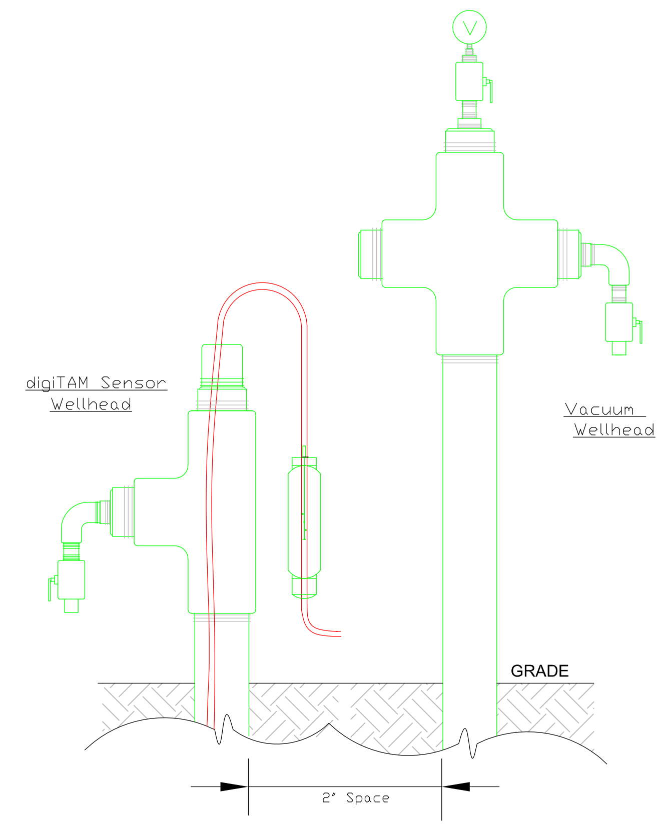
Vacuum Monitoring WELLHEAD DETAIL



digiTAM WELLHEAD DETAIL



DV Dual Monitoring WELL DETAIL



DigiTAM/Vacuum WELLHEAD COMPONENTS

Description/Material

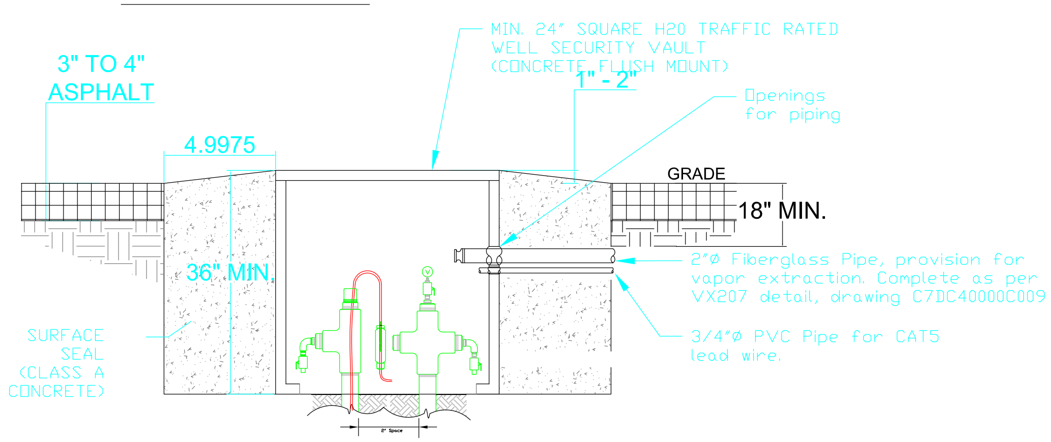
1. digiTAM SENSOR
2. STRAIN RELIEF / CPVC Schedule 40.
3. 2"M x 1"F Reducing BUSHING / Galvanized or Brass.
4. 2"F x 2"F x 2"F TEE / Galvanized.
5. 2"M x 3/8"F Reducing Bushing / Galvanized.
6. 3/8"FM Street Elbow / Galvanized or Brass.
7. 3/8"M Close Nipple / Galvanized or Brass.
8. 3/8"FF Ball Valve / Brass.
9. 3/8"M Plug / Brass.
10. 2" FIBERGLASS CASING / Details shown in drawing #C7DC40000C005.
11. 3/8"M x 1/4"F Reducing Bushing, Brass
12. Vacuum Gage 0 to -15"H₂0
13. CAT 5 Cable to data acquisition Panel.
14. 1" CPVC Junction box, NEMA-3R.
15. 2"F x2"F x 2"F x 2"F CROSS / Galvanized
16. 2"M Plug / Galvanized - Provision for vapor extraction tie-in

Notes:
1) Unless other wise stated pipe threads will meet or exceed ANSI B1.20.1 requirements.
2) All parts will meet or exceed a standard specification of Schedule 40.

Legend:
1) M - represents Male NPT
2) F - represents Female NPT.
3)FF - represents Female by Female NPT.

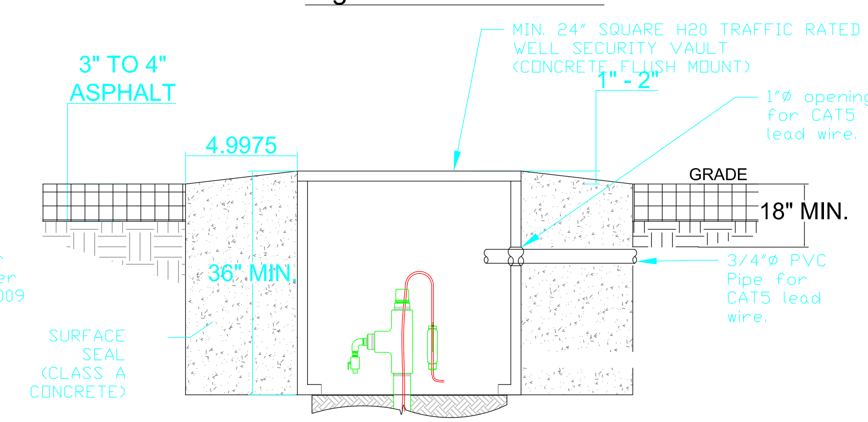
DV Dual Monitoring WELL DETAIL Within Vault.

DV Well No. DV203



DigiTAM WELL DETAIL Within Vault.

DigiTAM Well No. D212



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(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
Paducah PGDP C-400 Remediation Project

TITLE:
C-400 Complex
Detail Drawing of Wellheads for
ET-DSP Sensor Well Locations Phase IIa

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-SensorWellheadDetails.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
Not To Scale	C7DC40000C007	E

LPE

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	QA	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
E	01/06/12	Remove DigiPAM Reference	ER	CK	ER	BM				
D	22/05/12	Provisions for Vapor Extraction	ER	CK	ER	BM				
C	26/01/12	Technical Edits	AG	CK	ER	BM				
B	05/01/12	Technical Edits	WR	PP	ER	BM				
A	23/06/11	90% Design Drawing	WR	PP	ER	BM				

DATE

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DRAWING REVISIONS

BACK

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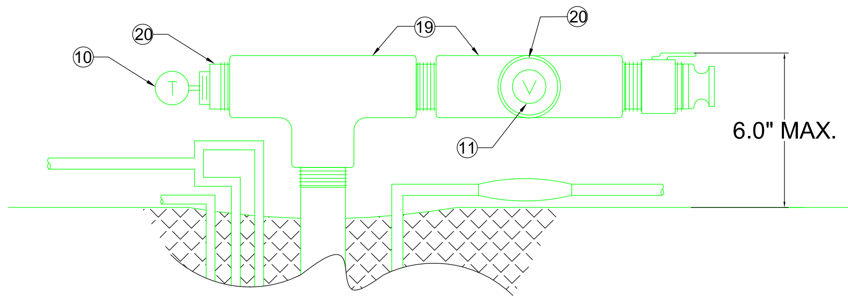
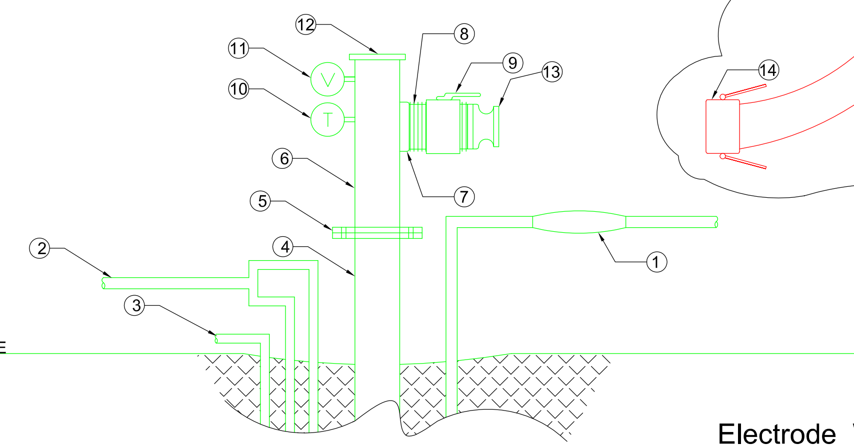
Electrode Well surface connections with Upper Vapor Extraction Detail South of Railway tracks. Extraction well locations XE204, XE205, XE206, & XE207.

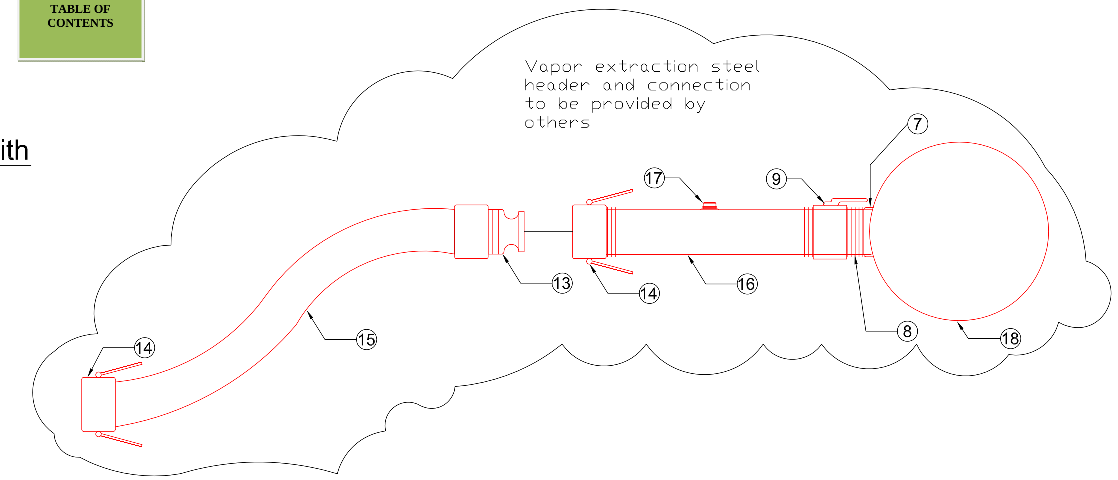
(Connections for one Electrode Shown)



Electrode Well surface connections with Upper Vapor Extraction Detail

(Connections for one Electrode Shown)





Electrode / Upper Vapor Extraction WELLHEAD COMPONENTS

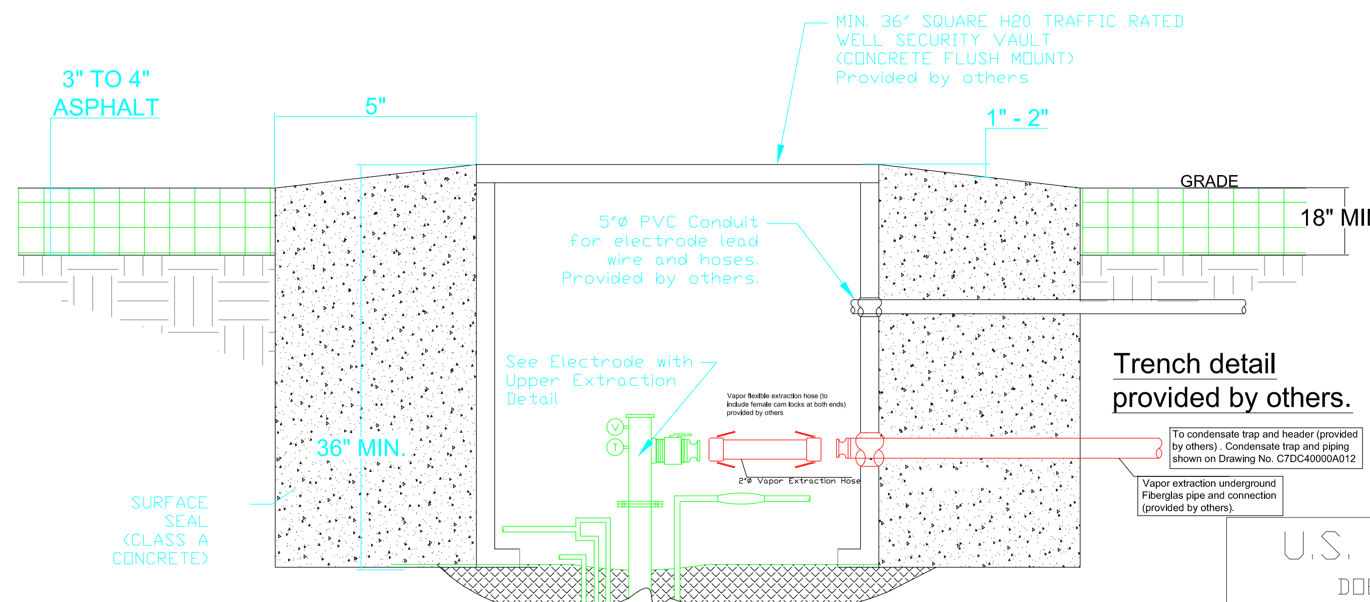
Description/Material

1. Electrode power cable 3 per well / #2AWG Bostrig or Exane wire connected with
- Butt Splice / #2 AWG crimped or inline splice.
- Insulated with rubber splicing tape and electrical tape.
2. Water Injection Lines 3 per well / 3/8" EPDM rubber hose.
- Feed from WCS units.
- Connected with Barbed T fitting.
3. Water Return line 1 per well / 3/8" EPDM rubber hose.
- Connected to liquid return line to treatment system.
- Connected with Barbed hose mender fitting and check valve.
4. 2" Ø Fiberglass Well Casing / Details shown in drawing #C7DC40000C005.
5. 2" Ø Flange or coupler / Galvanized Steel.
6. 2" Ø Well Head / STD Seamless Steel Pipe A106 GRB B.E.
7. 2"X4"-36 FS Threaded Pipe O -Let / CL 3000 A105N
8. 2" (Length will have to adjusted per Extraction Location) Nipple / Galvanized Steel.
9. 2" Ball Valve / Brass Alloy.
10. Temperature Gage / 0-250°F
11. Vacuum Gauge / 0-30 inHg.
12. 2" Ø Well Cap / Galvanized Steel.
13. 2" Male Cam X 2"F NPT / CamLock Aluminum Steel.
14. 2" Female Cam X 2"F NPT / CamLock Aluminum Steel.
15. 2" MWH Vapor Extraction Hose /Temperature (Operating Temperatures: -40°F to 200°F (-40°C to 93°C)), 150psi pressure rated, chemical, UV rated (Cover: Black Neoprene) / or equivalent chemical, temperature and pressure hose.
16. 2" X 3' MM Flow and Sample tube / STD Seamless Steel Pipe A106 GRB B.E .
17. 1/2" X3/4" Flow and Sample port / FS Threaded Pipe O -Let CL 3000 A105N
18. Vapor Conveyance Pipe / TBD by others.
19. 2"F X 2"F X 2"F Tee / Galvanized Steel.
20. 2"M X 1/2"F Reducer bushing / Galvanized Steel.

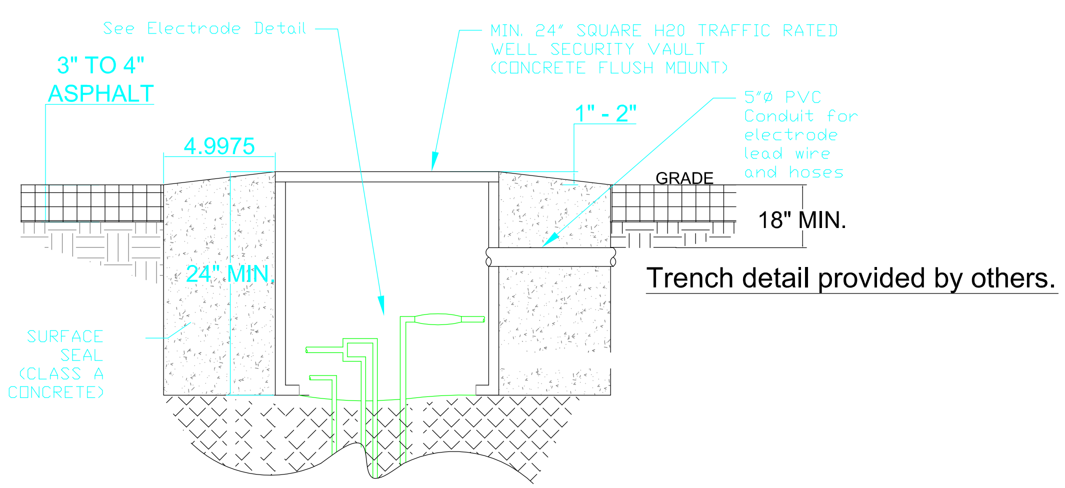
Legend:
1) M - represents Male NPT
2) F - represents Female NPT.
3)FF - represents Female by Female NPT.
4)MM - represents Male by Male NPT.
5)FS - represents Female NPT by Socket.
6)TBD - To Be Determined

Electrode Well connections with Upper Vapor Extraction Detail within Vault. Electrode Wells No. E224 U-SMD & E231 U-SMD

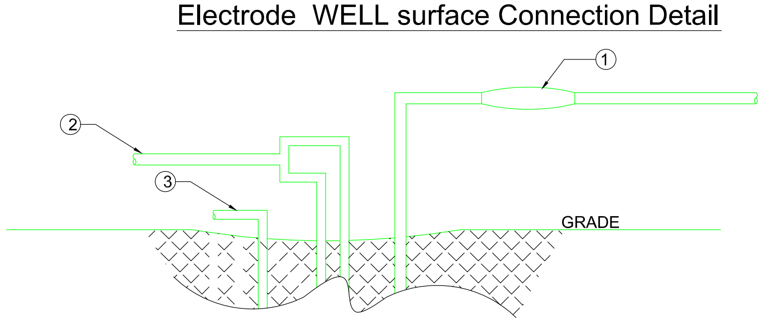
(Connections for one Electrode Shown)



Electrode WELL Connection within Vault. Electrode Wells No. E216 U-SMD & E223 U-SMD



Electrode WELL surface Connection Detail



Notes:
1) Unless other wise stated pipe threads will meet or exceed ANSI B1.20.1 requirements.
2) All parts will meet or exceed a standard specification of Schedule 40.
3) Pitot tube will be installed on vapor line for flow measurement and sampling.
4) Dielectric coating will be applied, as required to reduce step and touch potentials to less than 15 volts.
5) If connected as a vapor extraction well, vapor connections same as multi-phase well.
6) For wellheads in a vault, vacuum gauge located on side.

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	ORG/	LEAD ENGR	QA	CONF CTRL/ NUCL SFTY	FAC MGR	PROJ ENGR
C	05/01/12	Technical Edits	WR	ER	ER	BM				
B	19/06/11	Technical Edits	WR	PP	ER	BM				
A	28/05/11	Separate Wellhead Drawing-Electrodes	WR	PP	ER	BM				

DRAWING REVISIONS

LPE

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020 Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: Paducah PGDP C-400 Remediation Project

TITLE: C-400 Complex Detail Drawing of Wellheads for ET-DSP Electrode Locations

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-ElectrodeWellheadDetails.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
Not To Scale	C7DC40000C008	C

Multi-Phase / Vapor Extraction WELLHEAD COMPONENTS

1. 4" Ø Steel Well Casing / Details shown in drawing #C7DC40000C006.
2. 4" Ø 150 SCRD Flange / RF A105N.
3. 4" Ø 150 S/O Flange / RF A105N.
4. 6" X 4" STD BW Conc Reducer / A234-WPB.
5. 3/4" GW Extraction Hose / Teflon.
6. 1/2" Pump Vent line / Teflon.
7. 1/4" Air Supply line / Teflon.
8. ET-DSP Neutral Wire / #2AWG Ground wire.
9. 3/8" FM Street Elbow / Brass.
10. 3/8" Close Nipple / Brass.
11. 3/8" Ball Valve (Pressure Relief Valve), with plug / Brass.
12. Temperature Gage / 0-250°F.
13. Vacuum Gage / 0-30Hg.
14. Strain Relief / Galvanized Steel.
15. 1/2"-13 Eye Bolt (Pump support) / Forged ASTM A489.16 ANSI B 18.15 WLL 2,600Lbs.
16. 6" Ø Well Seal / 3/16" Thickness Viton "A" FKM Sheet.
17. 2" X 4"-36 FS Thread Pipe O -Let / CL 3000 A105N.
18. 2" X Close Nipple / Galvanized Steel.
19. 2" Ball Valve / Brass.
20. 2" Insulation Nipple /Kynar 150Lb.
21. 2" Male Cam X 2" F NPT / Cam Lock Aluminum Alloy.
22. 4" Ø Steel Well Casing / Details shown in drawing #C7DC40000C006.
23. 4" Ø 150 SCRD Flange / RF A105N. or 4" Ø coupler / Galvanized steel.
24. 4" Ø 150 S/O Flange w/ Well Seal / RF A105N w/3/16" Thickness Viton "A" FKM Sheet.
25. 4" Ø Blind Flange w/ Well Seal / 150 S/O Flange / RF A105N w/ 3/16" Thickness Viton "A" FKM Sheet.
26. 2" Female Cam X 2" NPT / Cam Lock Aluminum Alloy.
27. 2" MWH Vapor Extraction Hose /Temperature (Operating Temperatures: -40°F to 200°F (-40°C to 93°C)), 150psi pressure rated, chemical, UV rated (Cover: Black Neoprene) / or equivalent chemical, temperature and pressure hose.
28. 2" X 3' MM Flow and Sample tube / STD Seamless Steel Pipe A106 GRB B.E .
29. 1/2" X3/4" Flow and Sample port / FS Threaded Pipe O -Let CL 3000 A105N.
30. 1/2" M Pipe plug / Galvanized Steel.
31. Vapor Conveyance Pipe / TBD by others.
32. 2" Air Supply Conveyance Pipe / TBD by others.
33. 1/2" X3/4" FS Threaded Pipe O -Let / CL 3000 A105N.
34. 1/2" Close Nipple / Brass.
35. 1/2" Ball Valve / Brass.
36. 1/2" X 3/8" Reducer bushing / Brass.
37. 3/8"Air filter/Moisture trap / QED 40 - 200PSI.
38. 3/8" X 1/4" Reducer bushing / Brass.
39. 1/4" Pump Cycle Counter / QED 40 - 200PSI.
40. 1/4" FM Street Elbow / Brass.
41. 1/4" NPT X 1/4" Hose barb / Brass.
42. Liquid Discharge Conveyance Pipe / TBD by others.
43. 1" FS Threaded Pipe O -Let / CL 3000 A105N.
44. 1" Close Nipple / 316 Stainless Steel.
45. 1" FF Ball Valve / Brass.
46. 1" 45° Street L / 316 Stainless Steel.
47. 1"F X 1"F X 1"F X 1"F Cross / 316 Stainless Steel.
48. 3/8" FF Ball Valve / Brass.
49. 3/8" FF Spring Check Valve / Brass.
50. Electrode return line connection 3/8" Male NPT X 3/8" Barb.
51. 3/8" (Length will have to adjusted per Extraction Location) Nipple / Galvanized Steel.
52. 1" Male X 3/8" Female Reducer / Galvanized Steel.
53. 1" Spring Check Valve / Brass.
54. 3/4" Male NPT X 3/4" Barb (Pump discharge connection) / Brass.
55. 1" Male X 3/4" Female Reducer / Brass.
56. Sample Port quick connect / TBD by Others.
57. 2"Ø Fiberglass Pipe (Underground vapor extraction pipe) / Fiberglass Schedule 450.
58. 2"F X 2"F X 2"F Tee / Galvanized Steel.
59. 1/2" Slurper tube / Teflon.
60. 6" Well Head / STD Seamless Steel Pipe A106 GR B B.E.
61. 4" Well Head / STD Seamless Steel Pipe A106 GR B B.E.
62. 4" Well Head / STD Seamless Steel Pipe A106 GR B B.E.
63. 1" FF Union / 316 Stainless Steel.
64. 2" Nipple (Length will have to adjusted per Extraction Location) / STD Seamless Steel Pipe A106 GR B B.E.
65. 4"F X 4"F X 4"F Tee / Galvanized Steel.
66. 4"M X 2"F Reducer bushing / Galvanized Steel.
67. 2"M X 1/2"F Reducer bushing / Galvanized Steel.

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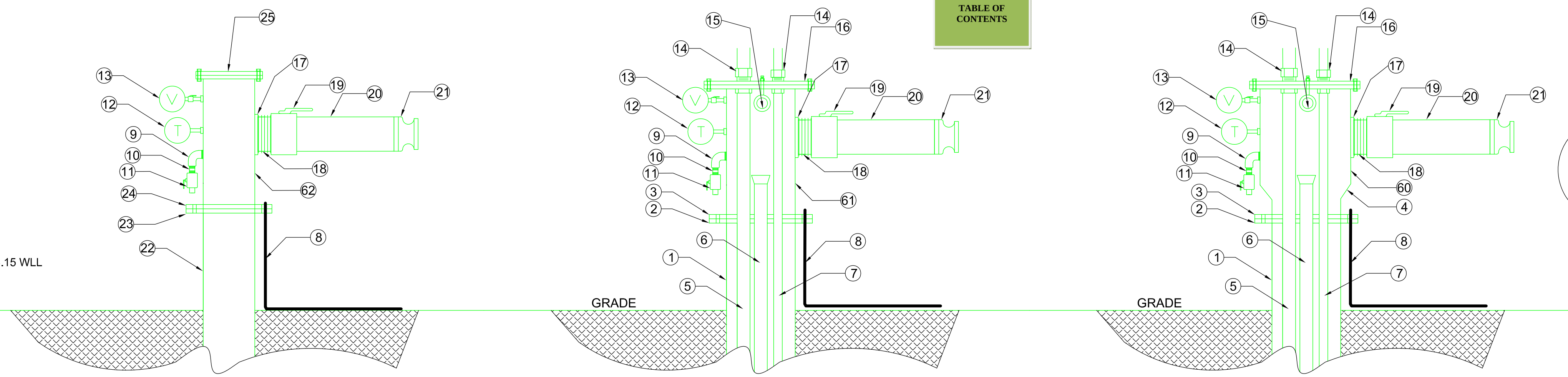
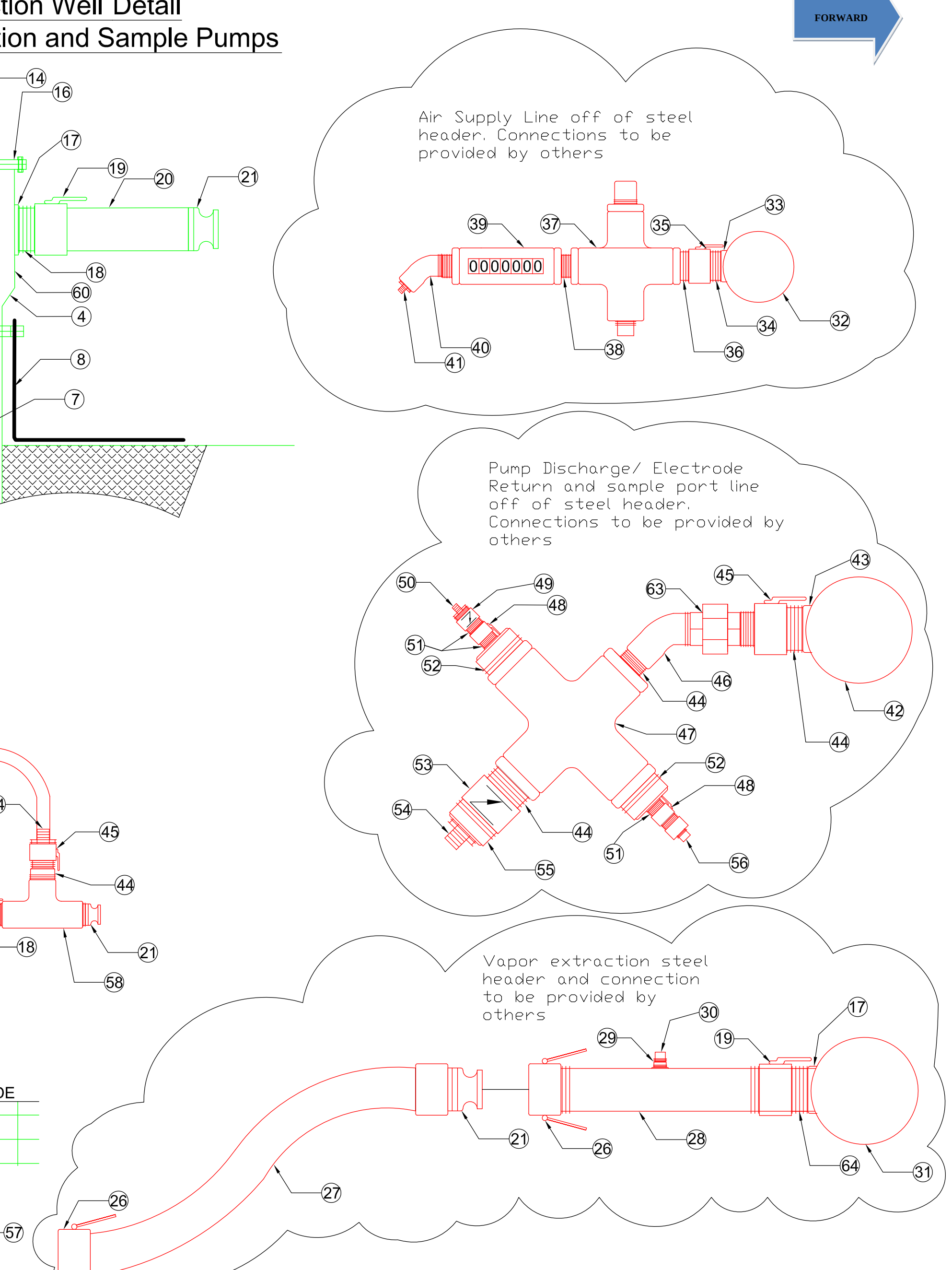
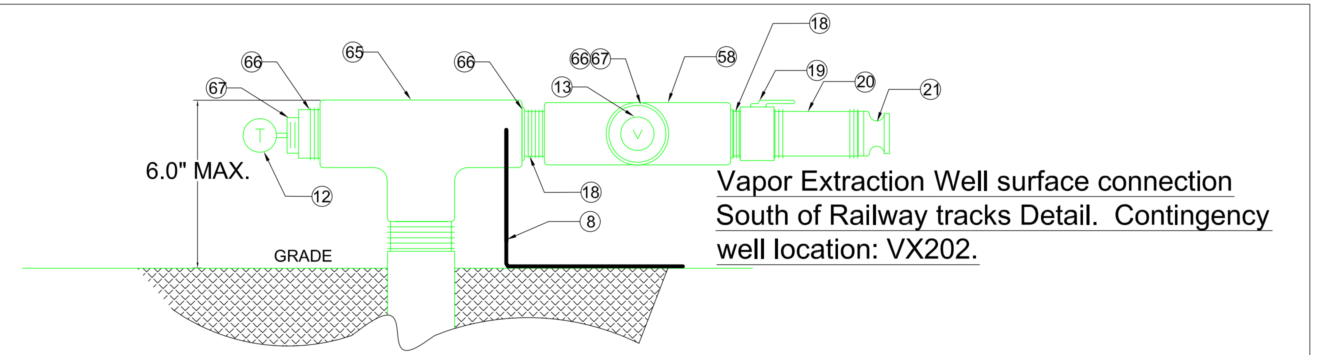
Vapor Extraction Well Detail / Multi-Phase Extraction Well Detail w/ ports for Extraction Pump / Multi-Phase Extraction Well Detail w/ ports for Extraction and Sample Pumps

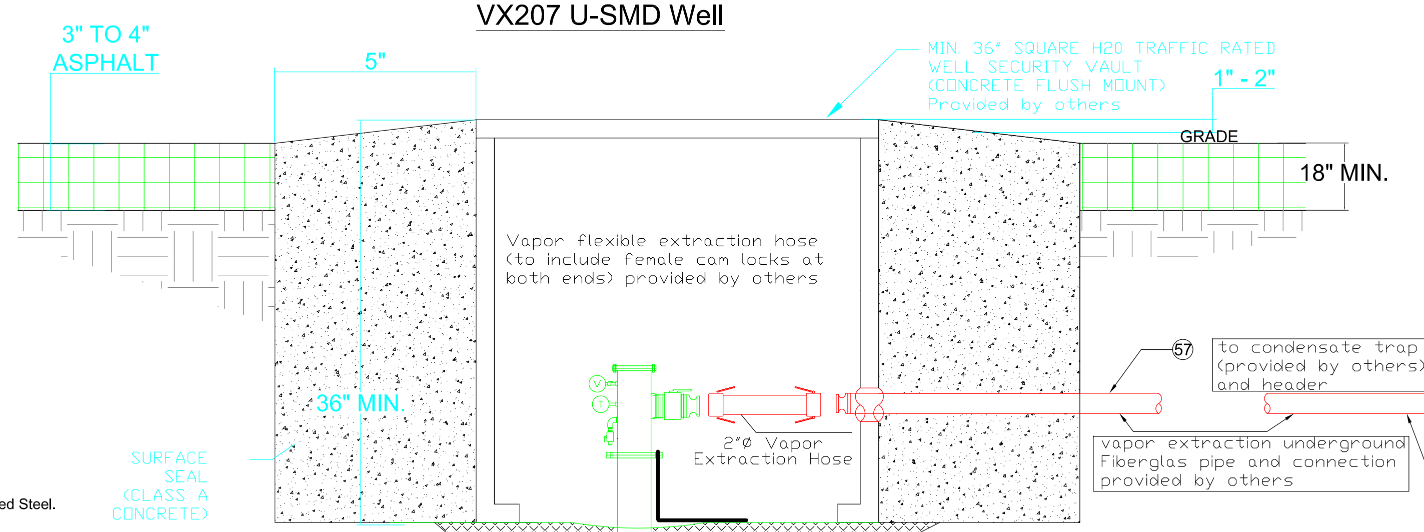


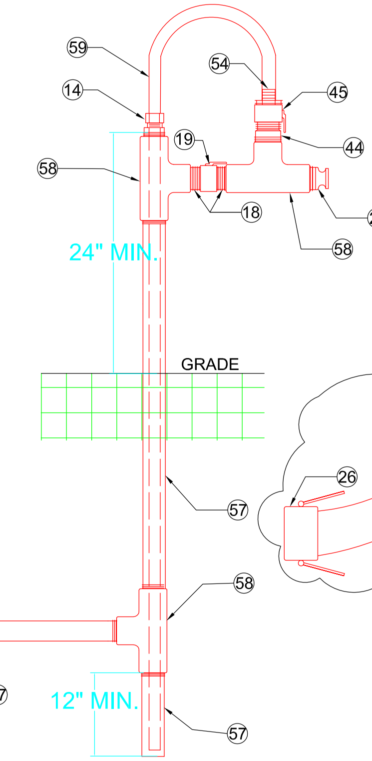


Vapor Extraction Well surface connection South of Railway tracks Detail. Contingency well location: VX202.



Vapor Extraction Well Detail within Vault / VX207 U-SMD Well





Notes:
1) Unless other wise stated pipe threads will meet or exceed ANSI B1.20.1 requirements.
2) All parts will meet or exceed a standard specification of Schedule 40.
3. Pitot tube will be installed on vapor line for flow measurement and sampling.
4. Dielectric coating will be applied, as required to reduce step and touch potentials to less than 15 volts.
5. If connected as a vapor extraction well, vapor connections same as multi-phase well.
6. Excluding conveyance piping all parts connecting the conveyance piping to the extraction well can be provided by McMillan-McGee Corp. upon request'
7. The slurper tube(59) is used to remove any condensate that will accumulate within the vapor extraction pipe(57).

Legend:
1) M - represents Male NPT
2) F - represents Female NPT.
3)FF - represents Female by Female NPT.
4)MM - represents Male by Male NPT.
5)FS - represents Female NPT by Socket.
6)TBD - To be determined.

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	ORG/	LEAD ENGR	QA	CONF CTRL/ NUCL SFTY	FAC MGR	PROJ ENGR
C	22/05/12	Rename CX wells, use 4" casing	ER	CK	ER	BM				
B	05/01/12	Technical Edits	WR	ER	WR	BM				
A	19/06/11	90% Design Drawing	WR	ER	WR	BM				

DRAWING REVISIONS

LPE

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020 Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
Paducah PGDP C-400 Remediation Project

TITLE:
C-400 Complex
Detail Drawing of Wellheads for ET-DSP Extraction Well Locations Phase IIa

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-Extraction-WellheadDetails	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
Not To Scale	C7DC40000C009	C

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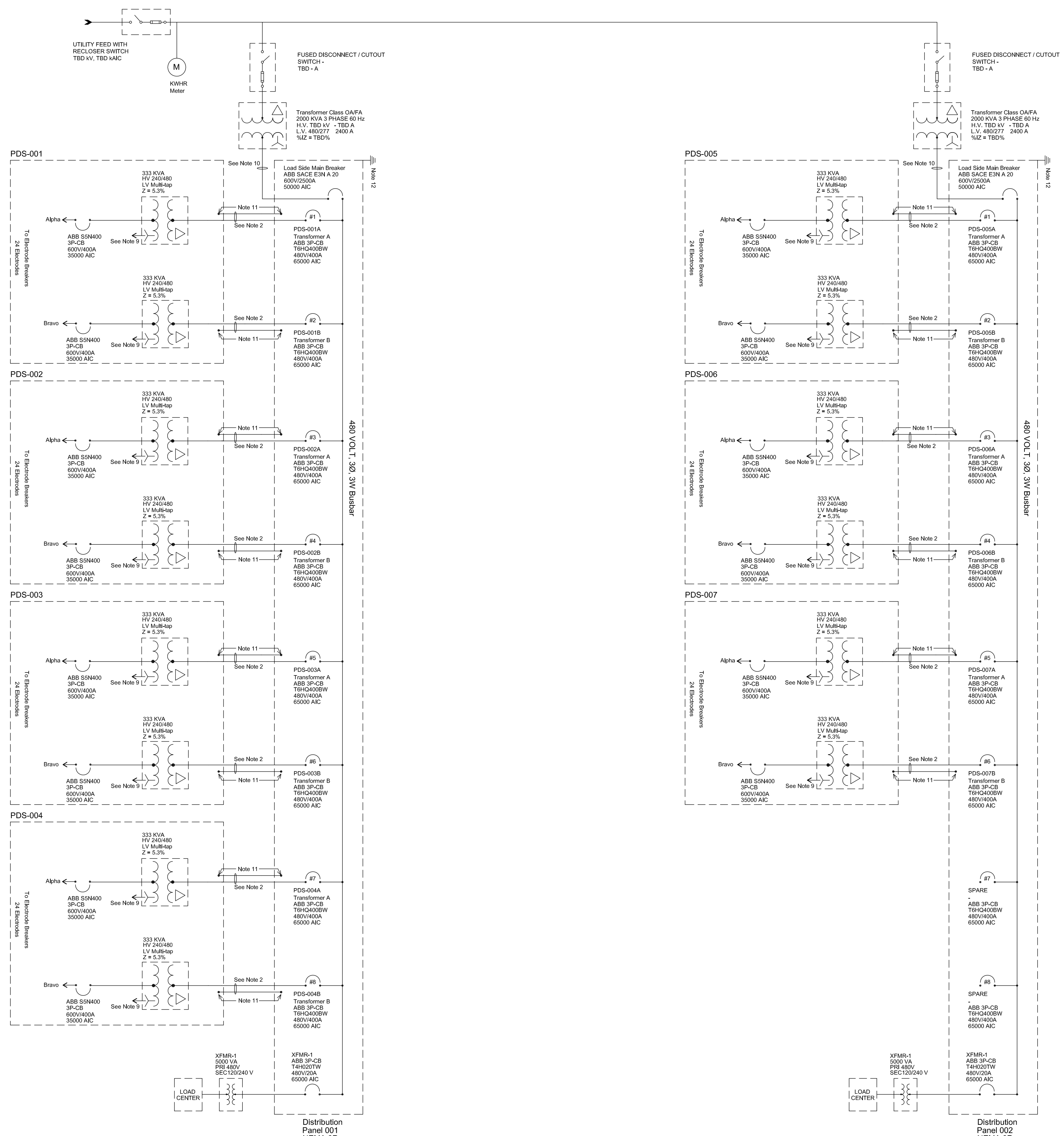


General Notes

1. Construction and material shall comply with Kentucky building code, CSA/UL, National Electrical Code and applicable local and state codes.
2. Cable from distribution breaker to PDS- XXX, will be 2 parallel 3C-250 kcmil AWG AL c/w #2 Ground to each A and B transformer: STR AL NUAL Alcan Type ACWU90 XLPE INS AIA BLK PVC JKT 600V 90C HL CSA C22.2 NO.51. Above Ground.
3. Cable from PDS-XX to E-XXX: 1C, No. 2 AWG
4. ET-DSP neutral cable: RWU-90 Copper AWG No. 2 INS 90 C PVC. Above ground.
5. Maximum operating load for a single PDS unit (24 electrodes) with a 1.5 margin factor is 24 x 10kW x 1.5 = 360kW.
6. All cable from PDS-XX to E-XXX is above ground rated.
7. All ET-DSP N-Cable is above ground rated.
8. All electrical equipment shall be grounded in accordance with NEC section 250.
9. ET-DSP neutral grounding scheme determined during system commissioning and shall include all metal-constructed extraction wells. Derived from secondary neutral of main PDS transformers and separate from utility ground.
10. Cable from substation transformer to distribution panel, Five (5) parallel 4C-750 kcmil to main distribution breaker: Copper conductor TECK cable.
11. Grounding terminals of PDS feed conductors in panels: bolted AL/ CU grounding lugs.
12. Power Distribution panel is to be grounded to the service ground.

Symbols

Amp — Load: Load Detail, Nominal Current, Amp

XXA Circuit Breaker CB XXXV Variable Current Variable Trip

Utility Switch 3 Pole Fuseable Disconnect

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020 Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: Paducah PGDP C-400 Remediation Project

TITLE: C-400 Complex Southeast Area Schematic of ET-DSP Power Delivery System OPTION A Phase IIa

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
B	05/01/12	Technical Edits	WR	ER	ER	BM			
A	30/05/11	PDS Feed Schematic	DP	ER	ER	BM			

DRAWING REVISIONS

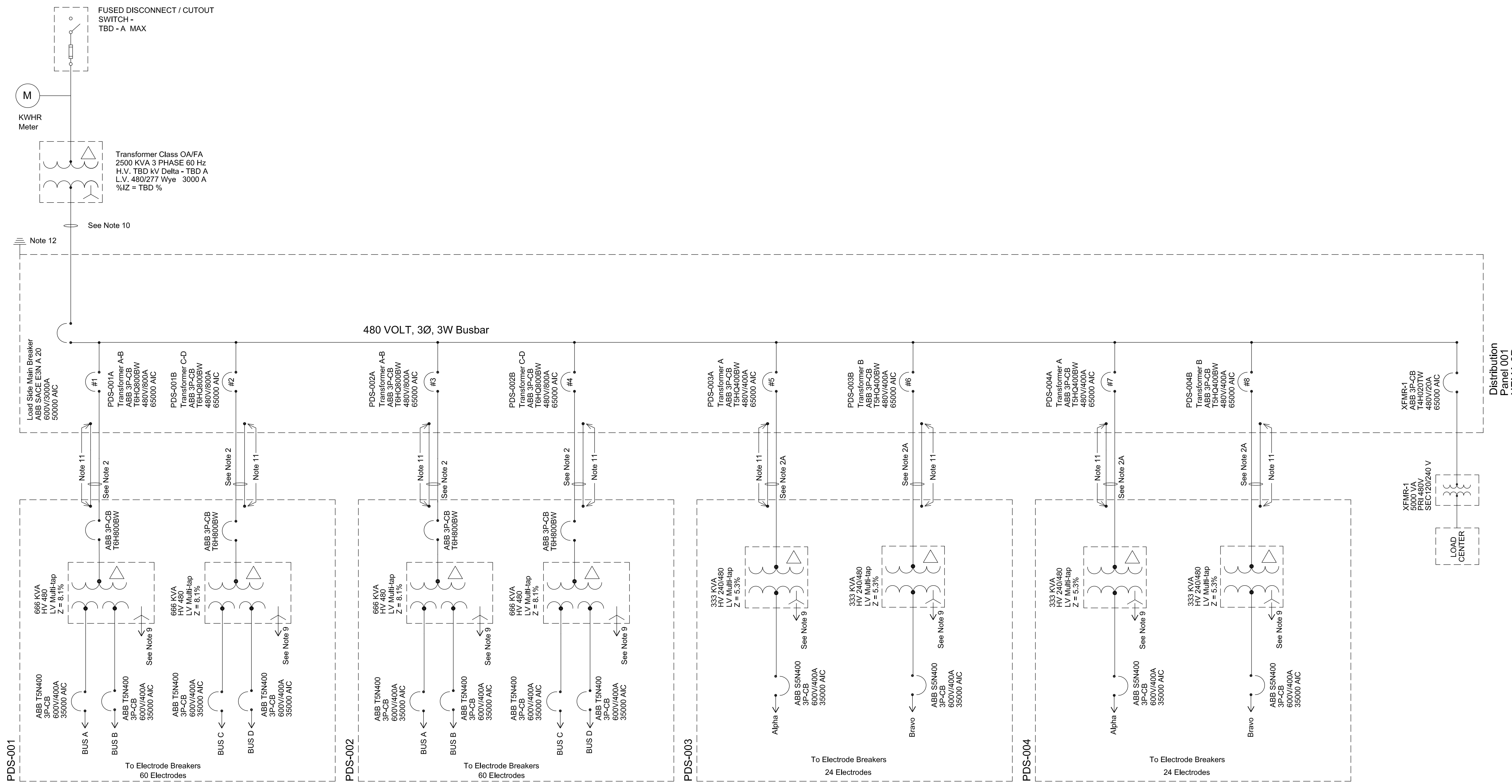
LPE

DATE

PROFESSIONAL SEAL

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-PDS-SingleLineDiagrams.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
To Scale	E7DC40000C012	B



General Notes

1. Construction and material shall comply with Kentucky building code, CSA/UL, National Electrical Code and applicable local and state codes.

2. Cable from distribution breaker to PDS-001 & 002, will be 3 parallel 3C-350 kcmil AWG AL c/w #2 Ground to each A-B and C-D transformer: STR AL NUAL Alcan Type ACWU90 XLPE INS AIA BLK PVC JKT 600V 90C HL CSA C22.2 NO.51. Above Ground.

2A. Cable from distribution breaker to PDS-003 & 004, will be 2 parallel 3C-250 kcmil c/w #2 AWG AL Ground to each Alpha and Bravo transformer: STR AL NUAL Alcan Type ACWU90 XLPE INS AIA BLK PVC JKT 600V 90C HL CSA C22.2 NO.51. Above Ground.

3. Cable from PDS-XX to E-XXX: 1C, No. 2 AWG

4. ET-DSP neutral cable: RWU-90 Copper AWG No. 2 INS 90 C PVC. Above ground.

5. Maximum operating load for 60E PDS unit (60 electrodes) with a 1.5 margin factor is 60 x 10kW x 1.5 = 900 kW. Maximum operating load for the 24E PDS unit (24 electrodes) with a 1.5 margin factor is 24 x 10kW x 1.5 = 360 kW.

6. All cable from PDS-XX to E-XXX is above ground rated.

7. All ET-DSP N-Cable is above ground rated.

8. All electrical equipment shall be grounded in accordance with NEC section 250.

9. ET-DSP neutral grounding scheme determined during system commissioning and shall include all metal-constructed extraction wells. Derived from secondary neutral of main PDS transformers and separate from utility ground.

10. Cable from substation transformer to distribution panel, Six(6) parallel 4C-750 kcmil to main distribution breaker: Copper conductor TECK cable.

11. Grounding terminals of PDS feed conductors in panels: bolted AL/ CU grounding lugs.

12. Power Distribution panel is to be grounded to the service ground.

Symbols

Amp / Load — Load Detail, Nominal Current, Amp

XXA / XXXV — Circuit Breaker CB, Variable Current, Variable Trip

Utility Switch, 3 Pole, Fuseable Disconnect

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC — managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020, Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: Paducah PGDP C-400 Remediation Project

TITLE: C-400 Complex SoutheAst Corner Schematic of ET-DSP Power Delivery System OPTION B Phase IIa

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR
B	05/01/12	Technical Edits	WR	ER	ER	BM
A	30/05/11	PDS Feed Schematic	DP	ER	ER	BM

DRAWING REVISIONS — CONF CTRL/NUCL SFTY, FAC MGR, ESTS MGR

LPE — DATE — PROFESSIONAL SEAL

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-PDS-SingleLineDiagrams.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
To Scale	E7DC40000C013	B

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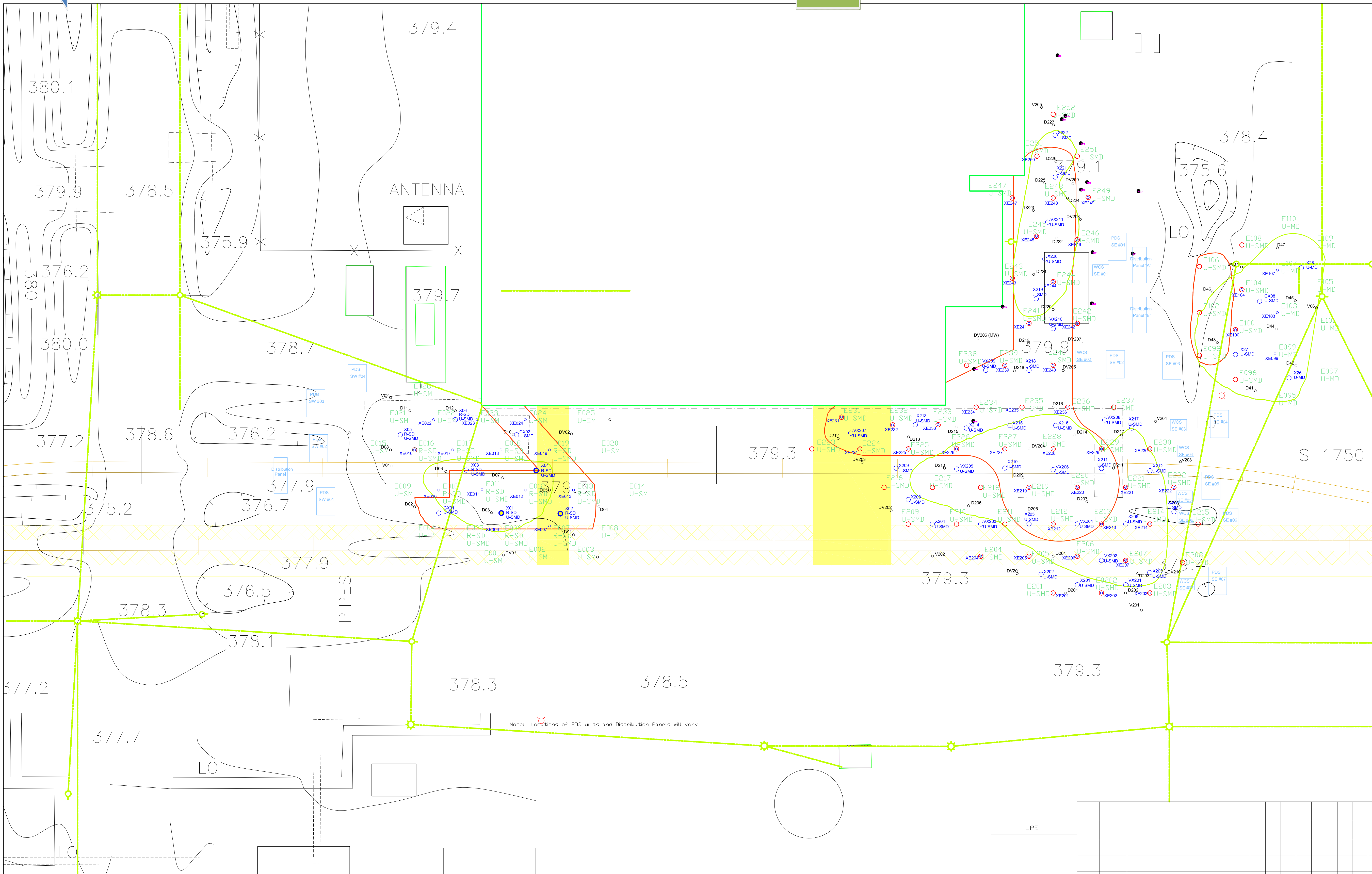

Legend

E057 U-SMD	Electrode Well ### UCRS Depth - U Shallow - S Middle - M Deep - D
○	20-60 ft Contour 3-Electrode Well
XE088 ◎	Electrode Well w/ Upper Vapor Extraction
X18 U-SMD	Multi-phase Extraction Well
VX201 U-SMD	Vapor Extraction Well
D40 ○	digiTAM Temperature Sensor Well
DV04 ○	Vacuum Monitoring/digiTAM Well (MW) indicates combined vacuum/ digiTAM / monitoring well location
V02 ○	Vacuum Monitoring

SVE Treatment Contour 0-20 ft Depth

ERH Treatment Contour 20-40 ft Depth

ERH Treatment Contour 40-60 ft Depth

Notes:

1. Placement of subsurface components made according to utility locations and drill spacing guidelines provided by LATA.
2. Due to security concerns with the facility, utility line types could not be identified at the time of drawing.
3. Final construction approval will require:
- All utility spacing for drilling locations to adhere to relevant codes and regulations, and
- Well installation to occur within operational limitations of the drilling contractor.

LPE

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
E	22/05/12	Rename CX wells, move sensor wells	ER	CK	ER	BM			
D	24/04/12	Technical Edits	AW	WR	ER	BM			
C	26/01/12	Technical Edits	AW	CK	ER	BM			
B	05/01/12	Technical Edits	WR	ER	ER	BM			
A	21/06/11	Initial 90% Design Layout	WR	ER	ER	BM			

DRAWING REVISIONS

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020 Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

PROJECT NAME:
Paducah PGDP C-400 Remediation Project

TITLE:
C-400 Complex
Plan View Layout of ET-DSP Components
PDS Option A Phase IIa

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-C400-ETDSP-Layout.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
1" = 22'	C7DC40000C014	E

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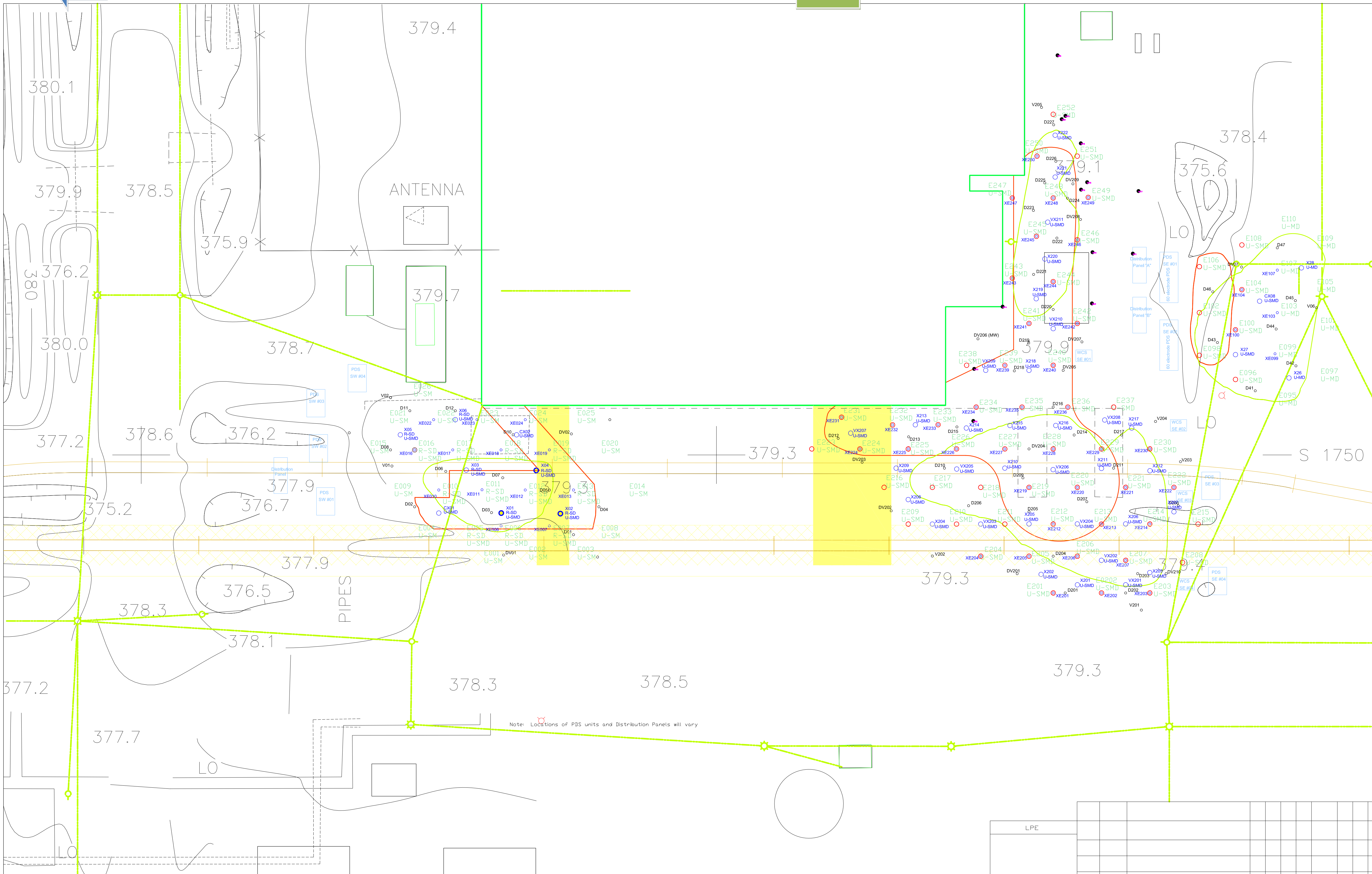


Legend

E057 U-SMD	Electrode Well ### UCRS Depth - U Shallow - S Middle - M Deep - D
○	20-60 ft Contour 3-Electrode Well
XE088	Electrode Well w/ Upper Vapor Extraction
X18 U-SMD	Multi-phase Extraction Well
VX201 U-SMD	Vapor Extraction Well
D40	digiTAM Temperature Sensor Well
DV04	Vacuum Monitoring/digiTAM Well (MW) indicates combined vacuum/ digiTAM / monitoring well location
V02	Vacuum Monitoring

SVE Treatment Contour 0-20 ft Depth

ERH Treatment Contour 20-40 ft Depth

ERH Treatment Contour 40-60 ft Depth

Notes:

1. Placement of subsurface components made according to utility locations and drill spacing guidelines provided by LATA.
2. Due to security concerns with the facility, utility line types could not be identified at the time of drawing.
3. Final construction approval will require:
- All utility spacing for drilling locations to adhere to relevant codes and regulations, and
- Well installation to occur within operational limitations of the drilling contractor.

LPE

DATE

PROFESSIONAL SEAL

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
E	22/05/12	Rename CX wells, move sensor wells	ER	CK	ER	BM			
D	24/04/12	Technical Edits	AW	WR	ER	BM			
C	26/01/12	Technical Edits	AW	CK	ER	BM			
B	05/01/12	Technical Edits	WR	ER	ER	BM			
A	21/06/11	Initial 90% Design Layout	WR	ER	ER	BM			

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

PROJECT NAME:
Paducah PGDP C-400 Remediation Project

TITLE:
C-400 Complex
Plan View Layout of ET-DSP Components
PDS Option B Phase IIa

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-C400-ETDSP-Layout.DWG	C-400	PGDP	U

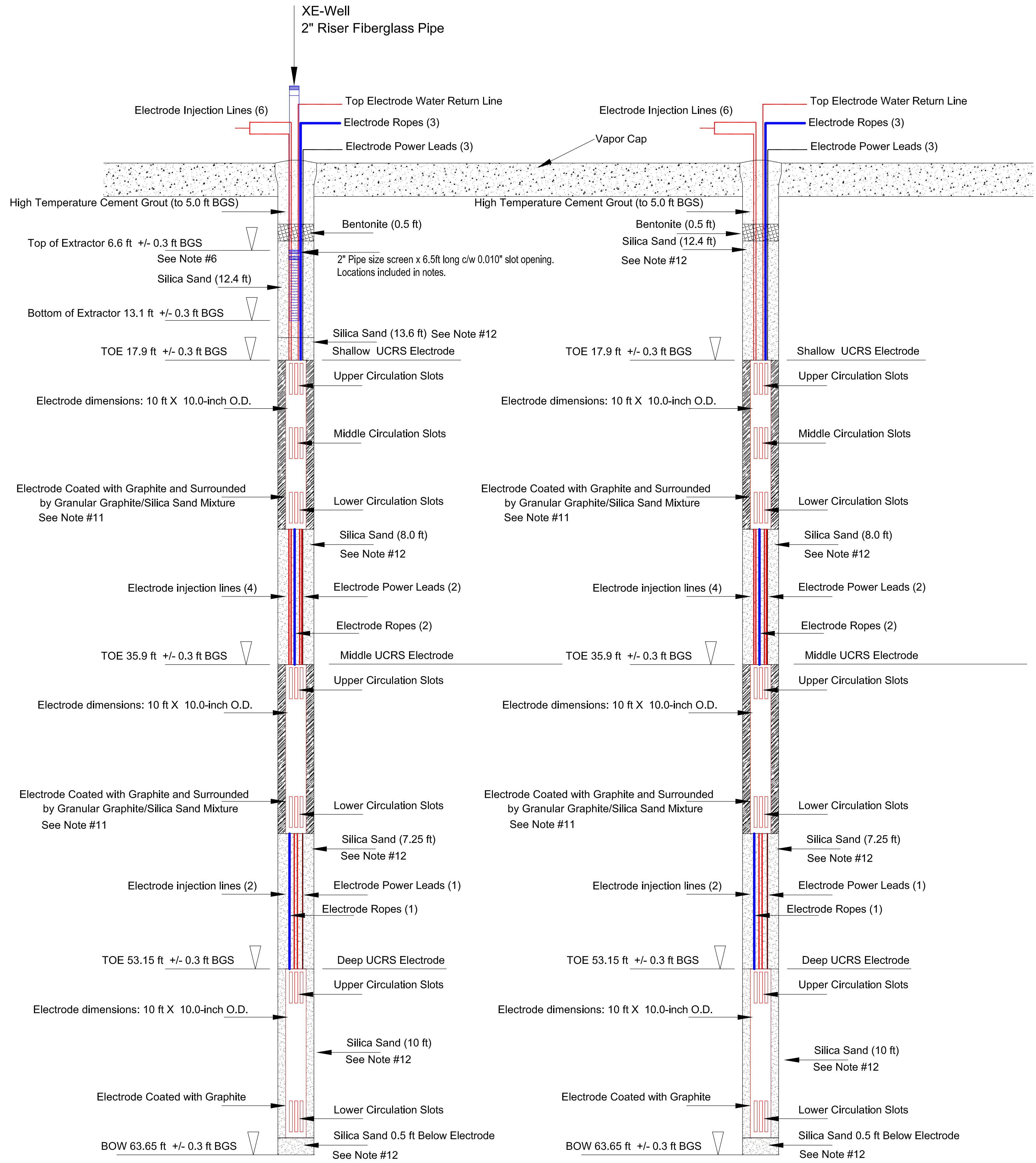
SCALE:	DRAWING NUMBER	REV
1" = 22'	C7DC40000C015	E

20-60 ft Electrode Well with Upper Vapor Extraction

(shown as XE### on C7DC40000C004)

20-60 ft Electrode Well

(shown as E### on C7DC40000C004)



Notes:
1) Electrode power lead for each electrode in the well is connected to its own PDS control channel.
2) Top and bottom water injection lines for each electrode are connected to a T fitting at surface from a WCS control valve.
3) Water return line to the uppermost electrode is connected to the input of the water treatment system.
4) XE Wellhead connection shown in drawing #C7DC40000C008.
5) Slot sizes on electrodes exaggerated to show feature.
6) Silica sand is #00N or equivalent.
7) Bentonite is medium chips.
8) Grout is a Portland Type 1 or Type 2 (no Bentonite flour added to grout).
9) Electrodes are connected to a rope for lowering into the hole and as an additional safety factor to prevent movement in case the sand settles within the boring. Rope is constructed of Technora material. Technora is rated for continuous operations at 250 degrees °C and has high resistance to organic solvents.
10) Only electrodes with XE well designation have upper vapor extraction. XE locations XE201, XE202, XE203, XE204, XE205, XE206, XE207, XE212, XE213, XE214, XE219, XE220, XE221, XE222, XE224, XE225, XE226, XE227, XE228, XE229, XE230, XE231, XE232, XE233, XE234, XE235, XE236, XE239, XE240, XE241, XE242, XE243, XE244, XE245, XE246, XE247, XE248, XE249, XE250.
11) Graphite/Sand Mixture consists of 1 50 lb bag granular graphite and 2 50 lb bags #1 Sand or equivalent.
12) Sand is #1 or equivalent.

Legend
BOW - Bottom of Well
BOE - Bottom of Electrode
TOE - Top of Electrode

LPE

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	DRG/	LEAD ENGR	QA	CONF CTRL/ NUCL SFTY	FAC MGR	PROJ ENGR
D	25/05/12	Top of Extraction, XE List	ER	CK	ER	BM				
C	24/04/12	Technical Edits	AW	WR	ER	BM				
B	05/01/12	Technical Edits	WR	ER	ER	BM				
A	30/05/11	Initial 90% Design Drawing	WR	ER	ER	BM				

DATE
PROFESSIONAL SEAL
DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020 Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: Paducah PGDP C-400 Remediation Project

TITLE: C-400 Complex Detail Section View Drawing of ET-DSP Electrode Well Installations Phase IIa

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-ElectrodeWellDetails.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
Not To Scale	E7DC40000C016	D

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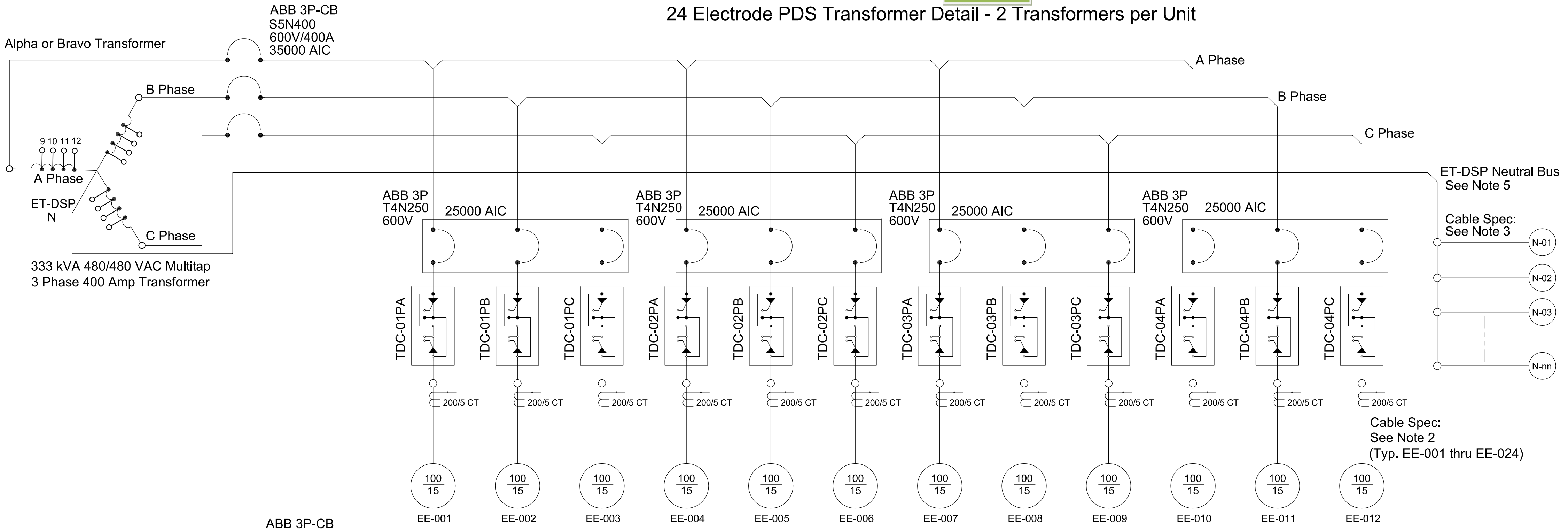
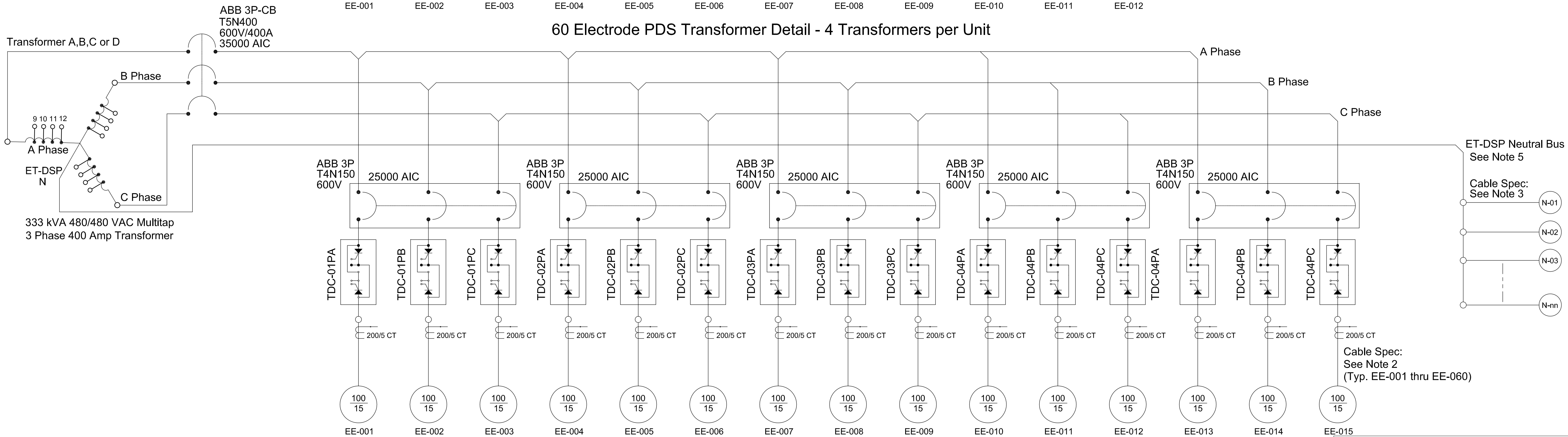
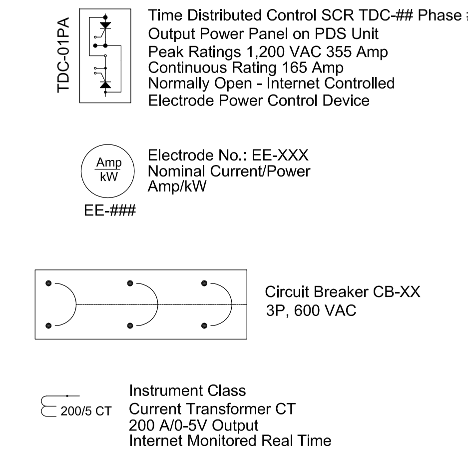
24 Electrode PDS Transformer Detail - 2 Transformers per Unit



60 Electrode PDS Transformer Detail - 4 Transformers per Unit



Symbols



General Notes

1. Construction and material shall comply with Kentucky building code, CSA/UL, National Electrical Code and applicable local and state codes.

2. Cable from PDS-XX to E-XXX: 1C No. 2 AWG, Rockbestos Type DAA1048B EXANE XLPE STR TNC 110C FT4, 600V CSA CSA/UL MARINE GRYJKT. Above ground rated.

3. ET-DSP neutral cable: RWU-90 Copper AWG No. 2 INS 90 C PVC. Above ground rated.

4. All electrical equipment shall be connected to utility ground in accordance with local code.

5. ET-DSP neutral grounding scheme determined during system commissioning and shall include all metal-constructed extraction wells.

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
B	05/01/12	Technical Edits	WR	ER	ER	BM			
A	30/05/11	Initial 90% Design Schematic	WR	ER	ER	BM			

DRAWING REVISIONS

LPE

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020 Paducah, Kentucky

McMillan-McGee Corp
CALGARY, ALBERTA CANADA
(403) 279-7948
FAX (403) 272-7201

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
Paducah PGDP C-400 Remediation Project

TITLE:
C-400 Complex East Area
Electrical Schematic of Electrode and Neutral PDS Connections Phase IIa

CAD FILE NAME	BUILDING	PLANT	CLASS
Mc2-Paducah-PDS-WellfieldSchematic.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
Not To Scale	E7DC40000C017	B

Appendix C – Equipment Data Sheets

McMillan-McGee Corp.

Creators of ET-DSP™

McMillan-McGee Corp.
60 Electrode Power Delivery System (PDS)

ET-DSP™ Power Delivery System. 60 Electrode Unit Specifications		
Electrical Performance	Principle	Two 3-phase high voltage utility transformers
	Power Rating	1330 kVA - 2-660 kVA Transformers
	Amperage	4-15 Electrode Busses at 400A Per Phase
		100 A per electrode. 5 Electrodes/Phase/Buss
	Voltage	Multi-tap secondary, 600 V max. phase to phase
		Field adjustable tap settings
Power Control	Principle	Time distributed control - Half-wave AC switching rectifiers SCR triggering-electronics with internet capability
	Power Selection	Current duty cycle from off to 100% Adjustment increment to 5%
Power Monitoring	Principle	High performance current transducers Internet-enabled, full wave CT monitoring electronics
	Measurement	Current amplitude; rms and effective values Independent TDCM duty cycle verification

McMillan-McGee Corp.
4895 35B. St. SE. Calgary, Ab. Canada. T2B 3M9
www.mcmillan-mcgee.com

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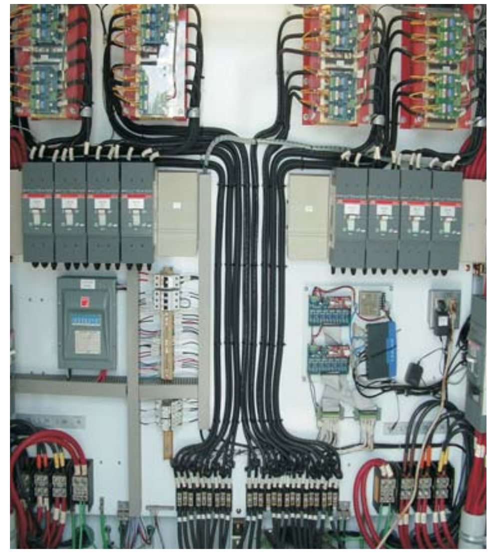
McMILLAN-McGEE CORP.
CREATORS OF ET-DSP™



ET-DSP™ Power Delivery System. 24 Electrode Unit Specifications		
Electrical Performance	Principle	Two 3-phase high voltage utility transformers
	Power Rating	2-330 kVA Transformers
	Amperage	2-12 Electrode Busses at 400A Per Phase
		100 A per electrode. 4 Electrodes/Phase/Buss
	Voltage	Multi-tap secondary, 600 V max. phase to phase
		Field adjustable tap settings
Power Control	Principle	Time distributed control - Half-wave AC switching rectifiers SCR triggering-electronics with internet capability
	Power Selection	Current duty cycle from off to 100% Adjustment increment to 5%
Power Monitoring	Principle	High performance current transducers Internet-enabled, full wave CT monitoring electronics
	Measurement	Current amplitude; rms and effective values Independent TDCM duty cycle verification

MCMILLAN-MCGEE CORP.
CREATORS OF ET-DSP™

McMillan-McGee Corp.
60 Electrode Water Circulation System

Water Circulation System 60 Electrode Unit Specifications		
Flow Performance	Principle	Utility water supply with internal pump Individual electrode injection valves
	Pressure	Rated at 100 psi
	Temperature	Water at 90ºC
Injection Control	Principle	One voltage fired solenoid valve per electrode Proportional Valve 0-100%
Injection Monitoring	Operation	Designed for simultaneous injection to 6 electrodes
	Principle	Inline ultrasonic flow meters Internet-enabled pulse counting electronics
	Operation	One flow meter per solenoid valve assembly Each meter monitors injection to 10 electrodes

McMillan-McGee Corp.
4895 35B. St. SE. Calgary, Ab. Canada. T2B 3M9
www.mcmillan-mcgee.com

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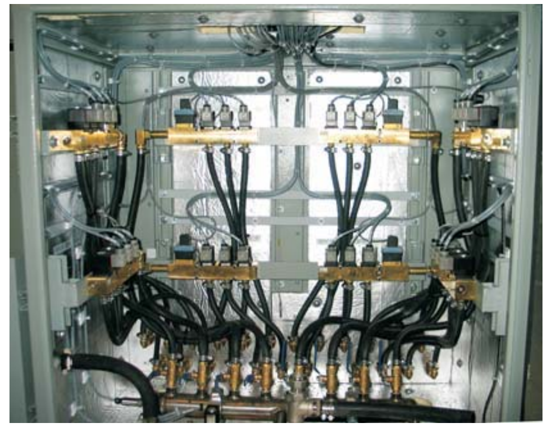
MCMILLAN-MCGEE CORP.

CREATORS OF ET-DSP™

McMillan-McGee Corp.
24 Electrode Water Circulation System



Water Circulation System 24 Electrode Unit Specifications		
Flow Performance	Principle	Utility water supply with internal pump Individual electrode injection valves
	Pressure	Rated at 100 psi
	Temperature	Water at 90ºC
Injection Control	Principle	One voltage fired solenoid valve per electrode Electronic Relay
	Operation	Designed for simultaneous injection to 8 electrodes
Injection Monitoring	Principle	Inline paddle turbine flow meters Internet-enabled pulse counting electronics
	Operation	One flow meter per solenoid valve assembly Each meter monitors injection to 3 electrodes

McMillan-McGee Corp.
4895 35B. St. SE. Calgary, Ab. Canada. T2B 3M9
www.mcmillan-mcgee.com

McMILLAN-McGEE CORP.
CREATORS OF ET-DSP™

McMillan McGee Corp.
digiTAM Temperature Acquisition Module

digiTAM Sensor String Specifications

Temperature	Principle	Integrated silicon temperature sensors
	Range	-55 to 125°C
	Accuracy	±0.5 °C
	Resolution	±0.125 °C
Environmental	Media compatibility	Air, water, steam, fuels, oils (Contact Mc^2 for specific contaminants)
	Wetted material	Teflon
Dimensions	Bottom Seal	1-1/16" (max)
	Cable	1/2 "
	Sensor interval (typ)	3.0 ft
Weight	Cable	50g/ft.
Connection	Power	External supply, 3.0 to 5.5 V DC; no batteries needed Power consumption of 7.5 mW per sensor during measurement
	Communication	Data acquisition occurs using Mc^2's 3 line digital serial bus Individual temperature measurements occur within 750 ms Data immediately accessible via the internet
	Sensor string	Placed in a drop-tube at required depth and anchored to surface
	Data server	Data lines connected with CAT5 cable Connects to site server through Mc^2 communication hub

Networking
Multiple digiTAMs are accessed from a data server using Mc^2's communication protocols. Temperatures are immediately accessible via the Internet.

Easily Powered
DigiPAMs require only 7.5 mW of power per sensor during temperature conversions. External power supply over the 3 line digital bus means no batteries are required.

Digital at the Source
The temperatures are converted directly to digital signals to limit the effects of high electromagnetic interference due to thermal remediation systems. DigiTAMs and digiPAM pressure sensors are connected on the same digital bus for simple installation, automated process monitoring and real-time data access.

Instantaneous Temperature Profiling
The digiTAM strings make use of multiple temperature sensors on a common 3 line digital bus. Up to 30 temperature sensors are embedded in the Teflon cable, typically at 3 ft intervals. Thus a complete temperature profile is obtained for a narrow borehole within seconds.

Extreme Environments
DigiTAMs are fully submersible and measure temperatures of up to 125°C. The sensor is compatible with most chemical contaminants seen at remediation sites.

Fast Installation
DigiTAMs are simply lowered into a monitoring well and anchored to the surface. The sensor is linked to the data server using standard CAT5 network cable and Mc^2's communication.

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Real-time Site Monitoring
During remediation, it is crucial to ensure chemicals are contained within the impacted area. The DigiPAM™ enables automated water level monitoring to continuously verify hydrodynamic control.

Networking
Multiple digiPAM™ sensors are accessed from a server over data lines. Pressure readings are immediately accessible via the internet.

Easily Powered
A DigiPAM™ requires only 1/2 W of power to read pressure. External supply over the 3 wire digital bus means no batteries are required.

DigiSource™
Pressure readings are converted to digital signals using MC2's digital at the source technology. DigiPAM™ devices are connected on the same data bus as digiTAM™ temperature sensors for simple installation and automated monitoring.

Automatic Compensation
All digiPAM™ sensors include a vent tube integrated in the cable for atmospheric correction. The sensor compensates for barometric pressure at surface for accurate water level measurement.

Extreme Environments
The digiPAM™ is permanently submersible and operates at temperatures up to 125°C. With a Hastelloy housing and Teflon cable, the sensor is compatible with harsh chemical contaminants. The sensor will withstand pressures up to five times the measured range.

Fast Installation
The DigiPAM™ is lowered into a monitoring well and connected at surface. The leads are run into an interface box to three screw terminals through a watertight strain relief. The sensor is linked to the data server using a standard network cable.

digiPAM™		
Sensor Specifications		
Pressure	Principle	Piezoresistive Strain Bridge
	Pressure range	Absolute or Gauge Pressure Vacuum measurement capability Custom range up to 1,000 ft H_2O
	Sensor venting	Compensation for atmospheric pressure
	Accuracy	±0.125% of full scale at 20°C (30 psi sensor provides ±1 inH_2O accuracy)
		±0.02% error per °C
		Data processing improves accuracy to ±0.0625% of full scale
	Resolution	16-bit A/D converter - ±0.02in water depth for 30 psi sensor
	Pressure rating	Proof at 5X maximum range
Environmental	Temperature	-30 to 125°C
	Pressure media	Water, steam, fuels, oils, solvents (Contact MC2 for other media)
	Wetted materials	Hastelloy steel, Teflon (cable)
Dimensions	Sensor housing	1.06in OD, 5.12 in length
	Cable	0.25in OD, custom length
	Interface box	6 in X 6 in X 2.5 in Depth
Weight	Sensor housing	0.20 kg
	Cable	0.03 kg / ft
Connection	Power	External supply, 10-30 V DC; no batteries needed Power consumption of 1/2 W during measurement
	Communication	Data acquisition occurs using MC2's 3 line digital bus Pressure measurements occur within 10 ms Data immediately accessible via the internet
	Sensor	Placed in a drop-tube at required depth and anchored at surface
	Interface board	Sensor leads connected to screw terminals through strain relief Data lines connected with CAT5 cable
	Data server	Connects to MC2 communication hub via CAT5 network cable

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O P E R A T I O N S M A N U A L

QED Environmental Systems

Leaders in Environmental Compliance Products

AP4/SPG4

Combo Pump

AutoPump/Specific Gravity Skimmer Controllerless System (for 4-inch wells or larger)

PO Box 3726
6095 Jackson Road
Ann Arbor, Michigan 48106-3726

(800) 624-2026 — North America Only
(734) 995-2547 — Tele.
(734) 995-1170 — Fax
info@qedenv.com — E-mail
www.qedenv.com

550 Adeline Street
Oakland, California 94607

(800) 537-1767 — North America Only
(510) 891-0880 — Tele.
(510) 444-6789 — Fax

Document No. **602452-03**

Specifications & Operating Requirements	
Model	**4" - Long AP4 Bottom Inlet**
Liquid Inlet Location	Bottom
OD	3.5 in. (8.9 cm)
Length Overall (pump & fittings)	53 in. (135 cm)
Max. Flow Rate	14 gpm (53 lpm) - See Flow Rate Chart
Pump Volume / Cycle	0.58 - 0.78 gal (2.2 - 3.0L)
Min. Actuation Level	35 in. (89 cm)
Standard Pump	
Max. Depth	250 ft. (76 m)
Air Pressure Range	5 - 120 psi (0.4 - 8.4 kg/cm2)
Air Usage	0.4 - 1.1 scf / gal. (3.0 - 8.5 liter of air /
	fluid liter) - See Air usage chart
Min. Liquid Density	0.7 SpG (0.7 g/cm3)
Construction Materials[1]	
Pump Body	Stainless Steel
Pump Ends	Stainless Steel
Internal Components	Stainless Steel, Viton, PVDF*
Tube & Hose Fittings	Stainless Steel
Fitting Type	Barbs or Quick Connects

*PVDF - Polyvinylidene Fluoride

AutoPump Configuration No 302143
Bottom Loading AutoPump – Specifications

Use when:

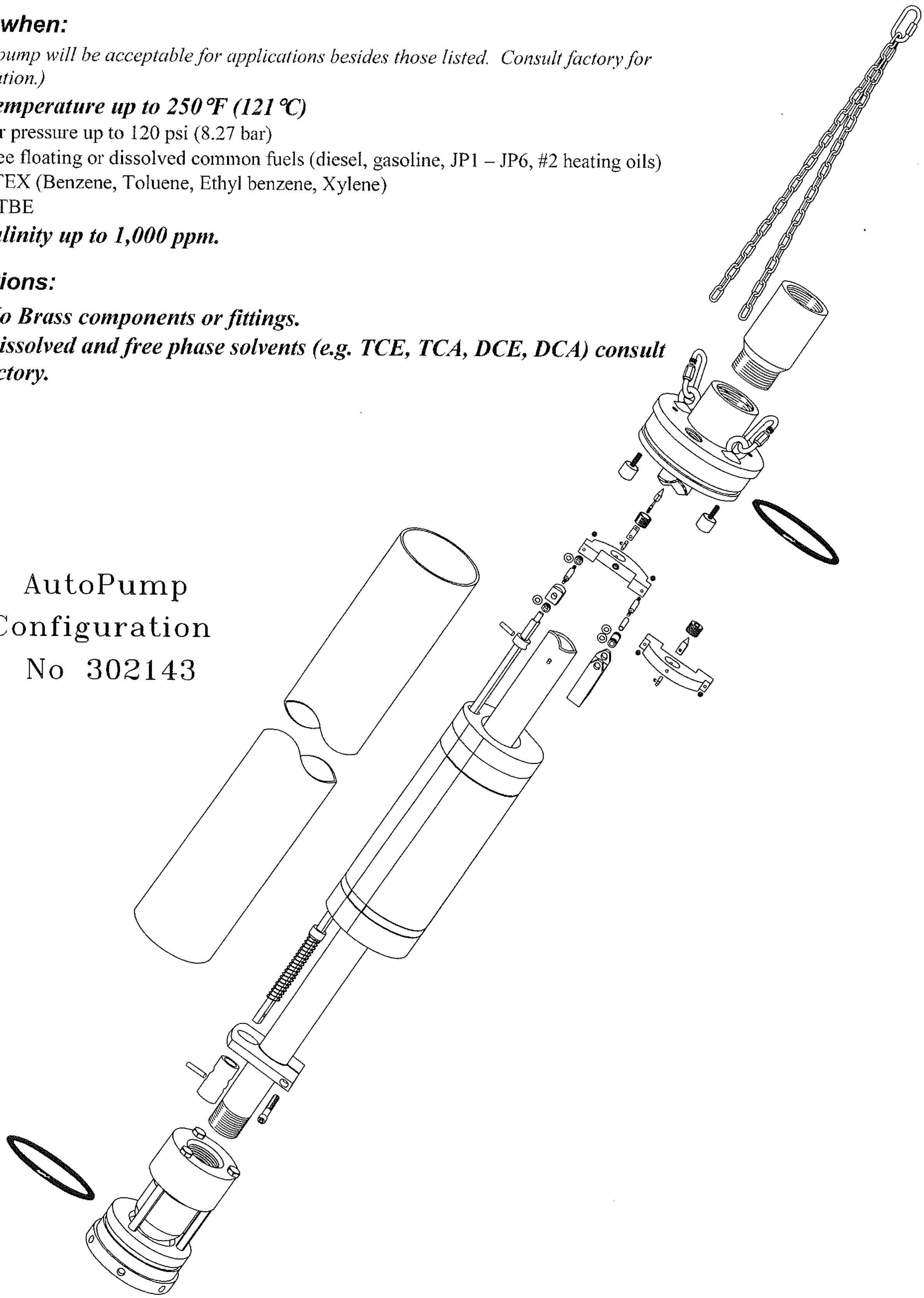
(This pump will be acceptable for applications besides those listed. Consult factory for evaluation.)

- ***Temperature up to 250°F (121°C)***
- Air pressure up to 120 psi (8.27 bar)
- Free floating or dissolved common fuels (diesel, gasoline, JP1 – JP6, #2 heating oils)
- BTEX (Benzene, Toluene, Ethyl benzene, Xylene)
- MTBE
- ***Salinity up to 1,000 ppm.***

Cautions:

- ***No Brass components or fittings.***
- ***Dissolved and free phase solvents (e.g. TCE, TCA, DCE, DCA) consult factory.***

AutoPump Configuration No 302143



QED Environmental Systems

734-995-2547	-US HEADQUARTERS
734-995-1170	-FAX
800-624-2026	-NORTH AMERICA TOLL FREE
WWW.QEDENV.COM	-WEB PAGE

TOLERANCES UNLESS OTHERWISE SPECIFIED ANGULAR : .5° FRAC : .XX : .01 .XXX : .005 .XXXX : .0005	APPROVALS	DATE	TITLE CONFIG. No 302143 BOTTOM LOADING AutoPump SPECIFICATION
	DRAWN TONY RAMIREZ	6-3-08	
MATERIAL	DESIGNER RW	6-3-08	DWG No. 602200 / REV 01
	CHECKED RW/DS	6-3-08	
FINISH	APPROVED RW/DS	6-3-08	SCALE NONE / SHT 1 OF 2

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OPERATIONS MANUAL

QED

Environmental Systems

Leaders in Environmental Compliance Products

PCC

Pump Cycle Counter

PO Box 3726
Ann Arbor, Michigan 48106-3726

(800) 624-2026 — North America Only
(734) 995-2547 — Tele.
(734) 995-1170 — Fax
info@qedenv.com — E-mail
www.qedenv.com

1133 Seventh Street
Oakland, California 94607

(800) 537-1767 — North America Only
(510) 891-0880 — Tele.
(510) 444-6789 — Fax

Document No. **600473-05**

Introduction

QED Environmental Systems (QED) Pump Cycle Counters (PCC) are air pulse detecting units that are placed in-line between a pump and its air supply. They require no external power source. A digital readout displays the number of times a pump cycles. PCCs consist of a magnet housing, an internally located magnet shuttle, and a digital display.

The position of the digital display is adjustable, allowing the counter to be used on many different kinds of pumps and at various distances from the well. (See Figure 1)

The PCC can be used on at least 150 feet (45.7 m) of 3/8 inch (9.5mm) or 1/4 inch (6.4mm) air hose with air pressure supply 30% higher than the total developed head.

Performance of the PCC is dependent upon the air hose size and the length, the type of pump and the system pressure. Air flow control valves can affect counter performance. Please contact *QED* for application assistance.

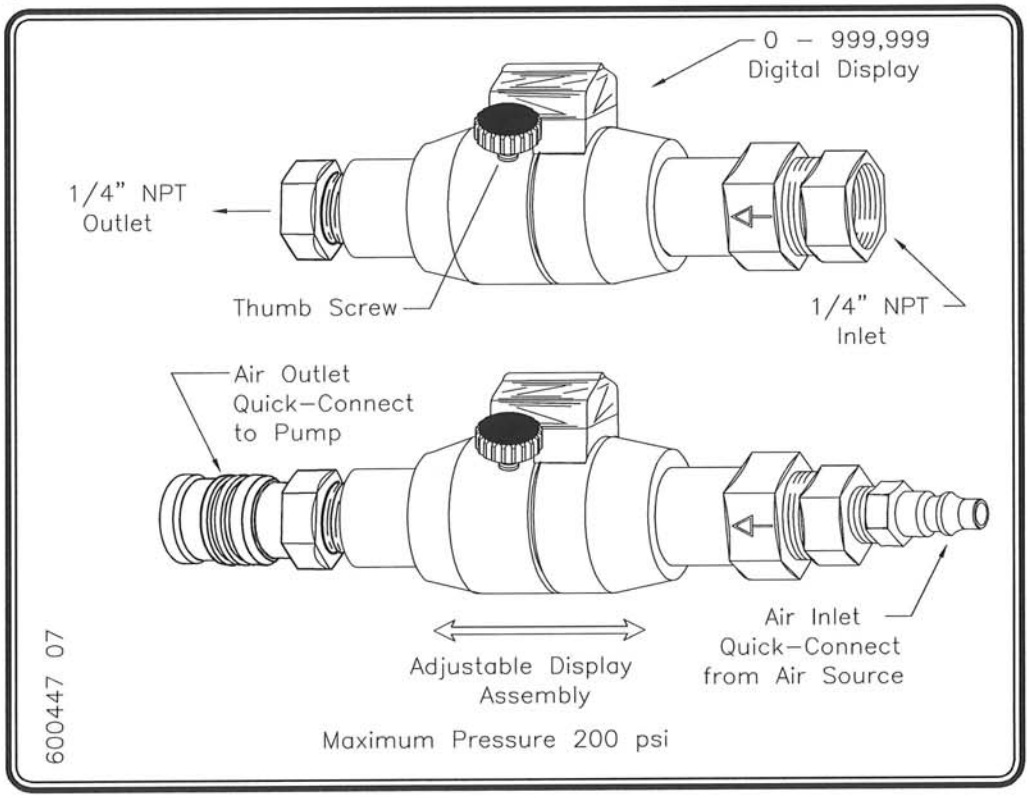

Figure 1 - Pump Cycle Counter

Pump Cycle Counter Operation/Installation

When a pneumatically operated pump such as the *QED* AutoPump® has filled, it triggers itself "On". This allows air to flow to the pump until a certain volume of fluid has discharged. The air stops; the pump fills; then the cycle continues to repeat.

A PCC mounted between a filter/regulator and a pump senses air flow to the pump. In a piston-like action, the internally located magnet shuttle moves forward (in the direction of air flow) during the "On" pulse and returns to a seated position in the "Off" period. (See Figure 2)

The digital display senses the completion of this "to-and-from" movement and records the cycle, increasing the number one digit that is shown in the clear plastic display.

This process repeats itself for each pump cycle.

Note:
The PCC will not function properly beyond certain distance limits from the pump, or, above or below optimum air line diameters. Safe limits are as follows:

AP-4: 250 ft. maximum with 1/4 inch or 3/8 inch ID air hose.
AP-3: 150 ft. maximum with 1/4 inch or 3/8 inch ID air hose.
AP-2: 75 ft. maximum with 1/4 inch or 3/8 inch ID air hose.

Contact *QED* for advice.

Digital Display

The digital display has the following features:

- A six digit counter that counts from 0 - 999,999 before resetting itself.
- A clear viewing lens that is water-and-impact resistant.
- **Optional**: Switch for remote electronic readout available upon request.

Magnet Housing

The magnet housing has the following features:

- A clear mark on the outside that indicates the correct direction of air flow.
- It is made of anodized aluminum.
- It has a 1/4-inch FNPT inlet and a 3/8-inch or 1/4-inch FNPT outlet.
- It handles air pressures from 40 - 200 psi.

Hardware Options

Inlet and outlet openings can be fit with no-mix quick-connects or barb connections depending on site requirements.

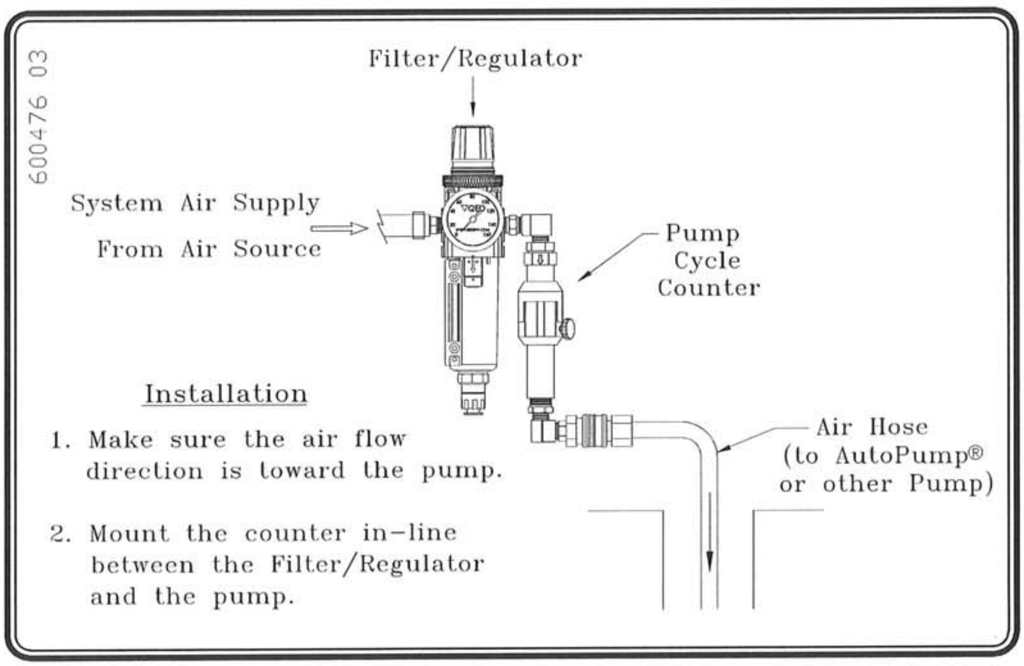

Figure 2 - Pump Cycle Counter Installation

Materials of Construction

QED PCCs are made of the following:

- Anodized Aluminum
- Stainless Steel
- Engineering Plastics
- Brass
- Viton

Pump Cycle Counter Weight - 0.4 lbs (0.2 kg)

Adjusting the Pump Cycle Counter

Note:
To get the most reliable performance, adjust the counter after it is installed and the pump is running. Typically, the Display Assembly that holds the digital readout is set 1/2-inch (13mm) from the upstream hex. Before adjusting the PCC be sure there is no air leak downstream of the counter. A leak could influence the travel **of the magnet** shuttle when the pump cycles.

STEP 1 - Loosen, but do not remove, the thumb screw (item #3) that **locks the** Display Assembly. (See Figure 3)

STEP 2 - Slide the Display Assembly on the magnet housing (item #6) (back and forth or up and down as the case may be) while the pump is cycling until the digital disp**lay (item** #4) advances once per pump cycle.

STEP 3 - Slowly slide the Display Assembly upstream towards the air source until the digital display (item #4) stops counting. Using a pencil, mark **this point** on the magnet housing (item #6).

STEP 4 - Slowly slide the Display Assembly in the opposite direction, towards the pump, past where the counting occurs until the digital display (item #4) stops counting. Using a pencil, mark **this point** on the magnet housing (item #6).

STEP 5 - Position the Display Assembly between the two extremes where counting did not occur. Lock the Display Assembly in place with the thumb screw. (item #3)

Appendix D – Component Coordinate Tables

Electrode Well Coordinates			
Well Designation	Easting	Northing	Name
E201	-4103.8142	-1809.9879	Electrode
E202	-4082.8142	-1809.9879	Electrode
E203	-4061.8142	-1809.9879	Electrode
E204	-4135.3142	-1794.0146	Electrode
E205	-4114.3142	-1794.0146	Electrode
E206	-4093.3142	-1794.0146	Electrode
E207	-4072.3142	-1795.8036	Electrode
E208	-4047.5892	-1796.7337	Electrode
E209	-4166.8142	-1780.0388	Electrode
E210	-4145.8142	-1780.0388	Electrode
E211	-4124.8142	-1780.0388	Electrode
E212	-4103.8142	-1780.0388	Electrode
E213	-4082.8142	-1780.0388	Electrode
E214	-4061.8142	-1780.0388	Electrode
E215	-4040.8142	-1780.0388	Electrode
E216	-4177.3142	-1764.0655	Electrode
E217	-4156.3142	-1764.0655	Electrode
E218	-4135.3142	-1764.0655	Electrode
E219	-4114.3142	-1764.0655	Electrode
E220	-4093.3142	-1764.0655	Electrode
E221	-4072.3142	-1764.0655	Electrode
E222	-4051.3142	-1764.0655	Electrode
E223	-4208.7461	-1747.3722	Electrode
E224	-4187.8142	-1747.3722	Electrode
E225	-4166.8142	-1747.3722	Electrode
E226	-4145.8142	-1747.3722	Electrode
E227	-4124.8142	-1747.3722	Electrode
E228	-4103.8142	-1747.3722	Electrode
E229	-4082.8142	-1747.3722	Electrode
E230	-4061.8142	-1747.3722	Electrode
E231	-4195.8148	-1733.5708	Electrode
E232	-4173.6148	-1736.9304	Electrode
E233	-4153.8148	-1736.8283	Electrode
E234	-4137.2960	-1729.1856	Electrode
E235	-4117.3504	-1729.1856	Electrode
E236	-4097.4374	-1729.1856	Electrode
E237	-4077.5405	-1729.1853	Electrode
E238	-4141.4302	-1710.9989	Electrode
E239	-4124.8145	-1710.9989	Electrode
E240	-4103.8145	-1710.9989	Electrode
E241	-4114.3145	-1692.8124	Electrode
E242	-4093.3145	-1692.8124	Electrode
E243	-4121.5746	-1673.1073	Electrode
E244	-4103.8145	-1674.6259	Electrode
E245	-4111.0746	-1654.9208	Electrode
E246	-4093.3145	-1656.4393	Electrode
E247	-4121.5746	-1638.2528	Electrode
E248	-4103.8145	-1638.2528	Electrode
E249	-4088.5775	-1638.0000	Electrode
E250	-4110.8283	-1620.0663	Electrode
E251	-4093.3145	-1620.0663	Electrode
E252	-4103.8145	-1601.8797	Electrode

Extraction Well Coordinates			
Well Designation	**Easting**	**Northing**	**Name**
XE201	-4103.8142	-1809.9879	Extraction
XE202	-4082.8142	-1809.9879	Extraction
XE203	-4061.8142	-1809.9879	Extraction
XE204	-4135.3142	-1794.0146	Extraction
XE205	-4114.3142	-1794.0146	Extraction
XE206	-4093.3142	-1794.0146	Extraction
XE207	-4072.3142	-1795.8036	Extraction
XE212	-4103.8142	-1780.0388	Extraction
XE213	-4082.8142	-1780.0388	Extraction
XE214	-4061.8142	-1780.0388	Extraction
XE219	-4114.3142	-1764.0655	Extraction
XE220	-4093.3142	-1764.0655	Extraction
XE221	-4072.3142	-1764.0655	Extraction
XE222	-4051.3142	-1764.0655	Extraction
XE224	-4187.8142	-1747.3722	Extraction
XE225	-4166.8142	-1747.3722	Extraction
XE226	-4145.8142	-1747.3722	Extraction
XE227	-4124.8142	-1747.3722	Extraction
XE228	-4103.8142	-1747.3722	Extraction
XE229	-4082.8142	-1747.3722	Extraction
XE230	-4061.8142	-1747.3722	Extraction
XE231	-4195.8148	-1733.5708	Extraction
XE232	-4173.6148	-1736.9304	Extraction
XE233	-4153.8148	-1736.8283	Extraction
XE234	-4137.2960	-1729.1856	Extraction
XE235	-4117.3504	-1729.1856	Extraction
XE236	-4097.4374	-1729.1856	Extraction
XE239	-4124.8145	-1710.9989	Extraction
XE240	-4103.8145	-1710.9989	Extraction
XE241	-4114.3145	-1692.8124	Extraction
XE242	-4093.3145	-1692.8124	Extraction
XE243	-4121.5746	-1673.1073	Extraction
XE244	-4103.8145	-1674.6259	Extraction
XE245	-4111.0746	-1654.9208	Extraction
XE246	-4093.3145	-1656.4393	Extraction
XE247	-4121.5746	-1638.2528	Extraction
XE248	-4103.8145	-1638.2528	Extraction
XE249	-4088.5775	-1638.0000	Extraction
XE250	-4110.8283	-1620.0663	Extraction

Extraction Well Coordinates			
Well Designation	**Easting**	**Northing**	**Name**
X201	-4093.2758	-1806.4524	Extraction
X202	-4109.0642	-1801.9027	Extraction
X203	-4061.8142	-1801.1280	Extraction
X204	-4156.3142	-1780.0388	Extraction
X205	-4114.3144	-1779.9753	Extraction
X206	-4072.3144	-1779.9753	Extraction
X207	-4051.3142	-1774.7144	Extraction
X208	-4166.8142	-1769.3899	Extraction
X209	-4172.0642	-1755.7188	Extraction
X210	-4124.8231	-1755.7038	Extraction
X211	-4082.8142	-1755.8465	Extraction
X212	-4061.7363	-1756.8538	Extraction
X213	-4163.7148	-1736.8794	Extraction
X214	-4141.5551	-1738.2789	Extraction
X215	-4122.6004	-1737.1723	Extraction
X216	-4102.6874	-1737.1719	Extraction
X217	-4069.6773	-1738.2787	Extraction
X218	-4114.3146	-1713.1861	Extraction
X219	-4111.1767	-1682.0626	Extraction
X220	-4107.4445	-1664.7733	Extraction
X221	-4102.9429	-1629.1595	Extraction
X222	-4102.9429	-1610.9730	Extraction
VX201	-4072.3142	-1806.4524	Extraction
VX202	-4082.8142	-1795.8036	Extraction
VX203	-4135.3142	-1780.0388	Extraction
VX204	-4093.3144	-1779.9753	Extraction
VX205	-4145.7385	-1756.1058	Extraction
VX206	-4103.8256	-1756.3639	Extraction
VX207	-4191.8145	-1740.5068	Extraction
VX208	-4081.4148	-1734.7855	Extraction
VX209	-4133.1223	-1713.1861	Extraction
VX210	-4103.7892	-1695.0528	Extraction
VX211	-4106.1714	-1648.7572	Extraction

Data Acquisition Well Coordinates			
Well Designation	**Easting**	**Northing**	**Name**
D201	-4098.5642	-1809.9879	Sensor
D202	-4072.3142	-1809.9879	Sensor
D203	-4067.0642	-1801.6045	Sensor
D204	-4103.8142	-1794.0146	Sensor
D205	-4114.3144	-1774.7145	Sensor
D206	-4140.5642	-1772.0522	Sensor
D207	-4089.1814	-1770.3198	Sensor
D208	-4049.4517	-1772.0522	Sensor
D209	-4116.9651	-1759.9320	Sensor
D210	-4151.0642	-1755.7188	Sensor
D211	-4077.5642	-1755.7188	Sensor
D212	-4197.2584	-1742.7717	Sensor
D213	-4166.6329	-1742.1003	Sensor
D214	-4094.6886	-1741.3100	Sensor
D215	-4145.6416	-1737.7954	Sensor
D216	-4103.8148	-1729.1856	Sensor
D217	-4074.0563	-1741.3099	Sensor
D218	-4120.6919	-1713.4271	Sensor
D219	-4114.4500	-1701.3000	Sensor
D220	-4103.8145	-1686.7502	Sensor
D221	-4112.3121	-1671.4952	Sensor
D222	-4102.1945	-1655.6800	Sensor
D223	-4112.4022	-1643.6627	Sensor
D224	-4097.5842	-1638.3323	Sensor
D225	-4107.4681	-1631.6652	Sensor
D226	-4102.6524	-1622.2980	Sensor
D227	-4103.6020	-1606.4433	Sensor
V201	-4065.5000	-1817.4597	Sensor
V202	-4156.3728	-1793.9813	Sensor
V203	-4048.4756	-1752.9188	Sensor
V204	-4059.3244	-1735.4139	Sensor
V205	-4108.8677	-1598.8616	Sensor
DV201	-4118.5839	-1801.6045	Sensor
DV202	-4174.1932	-1774.2744	Sensor
DV203	-4186.8434	-1753.1551	Sensor
DV204	-4114.3142	-1747.3722	Sensor
DV205	-4099.4520	-1713.2138	Sensor
DV206	-4136.5000	-1699.5000	Sensor
DV207	-4091.3072	-1700.8295	Sensor
DV208	-4091.9329	-1647.5870	Sensor
DV209	-4095.2355	-1632.1063	Sensor
DV210	-4054.7017	-1801.6045	Sensor

APPENDIX D

LAND USE CONTROL IMPLEMENTATION PLAN

(The following is a historical document reprinted in its original format. Pagination and formatting from original document retained.)

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DOE/OR/07-2151&D2/R2
Secondary Document

Land Use Control Implementation Plan: Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

This document is approved for public release per review by:

FEB 11 08

Paducah Classification and Control Office — Date
Swift and Staley Team

PADUCAH REMEDIATION SERVICES, LLC;
SCIENCE APPLICATIONS INTERNATIONAL CORPORATION;
and BECHTEL JACOBS COMPANY LLC

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

DOE/OR/07-2151&D2/R2
Secondary Document

Land Use Control Implementation Plan: Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—February 2008

Prepared for the
U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Environmental Management Activities at the
Paducah Gaseous Diffusion Plant
Paducah, Kentucky 42001

managed by
Paducah Remediation Services, LLC

for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC30-06EW05001

PREFACE

This *Land Use Control Implementation Plan: Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2151&D2/R1, was prepared in accordance with the approved *Land Use Control Assurance Plan for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1799&D2, dated January 2000. This implementation plan identifies the area that is under restriction, identifies each land use control objective for the area of volatile organic compound contamination at the C-400 Cleaning Building area, and identifies the specific controls and mechanisms required to achieve each identified objective.

CONTENTS

FIGURES

TABLES

ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
E/P	excavation/penetration
EPA	U.S. Environmental Protection Agency
ERH	electrical resistance heating
FFA	Federal Facility Agreement
IRA	Interim Remedial Action
KDEP	Kentucky Department for Environmental Protection
KEPPC	Kentucky Environmental and Public Protection Cabinet
KRS	Kentucky Revised Statutes
LUC	land use control
LUCAP	land use control assurance plan
LUCIP	land use control implementation plan
MOA	Memorandum of Agreement
PGDP	Paducah Gaseous Diffusion Plant
ROD	record of decision
TCE	trichloroethene
VOC	volatile organic compound

1. INTRODUCTION

The *Record of Decision* (ROD) *for Interim Remedial Action* (IRA) *for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant (PGDP), Paducah, Kentucky*, DOE/OR/07-2150&D2/R2, issued August 2005, incorporates land use controls (LUCs) as a component of the selected remedy (DOE 2005).

The selected remedy consists of the following primary elements:

- A remedial design investigation to further determine areal and vertical extent of the contamination in the C-400 Cleaning Building area to determine optimum placement of the remediation system;

- Removal and treatment of trichloroethene (TCE) and other volatile organic compounds (VOCs) from the contaminant source zone in the Upper Continental Recharge System and Regional Gravel Aquifer at the C-400 Cleaning Building area using Electrical Resistance Heating (ERH);

- Implementation, maintenance, and reporting of LUCs on the C-400 Cleaning Building area; and

- Continuation of groundwater monitoring of the source and dissolved-phase plumes, since contamination would remain in place following the interim remedial actions.

Further description of the full scope of the interim remedial action is presented in the ROD.

A Memorandum of Agreement (MOA) among the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Commonwealth of Kentucky establishes and implements a *Land Use Control Assurance Plan* (LUCAP) *for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1799&D2, (DOE 2000). The LUCAP is applicable when LUCs are selected as part of a remedial action being taken (EPA 2000). The PGDP LUCAP specifies that a unit-specific Land Use Control Implementation Plan (LUCIP) will be developed as a component of the post-ROD documentation for each waste unit that requires LUCs as part of the corrective measure/remedial action selected on or after the effective date of the MOA. This LUCIP is part of a Primary Document, the C-400 Remedial Design (90% Design) Report and will be appended to the LUCAP once approved by EPA and the Kentucky Environmental and Public Protection Cabinet (KEPPC).

2. PURPOSE

As stated in the LUCAP (DOE 2000), the specific purposes of this LUCIP are to accomplish the following:

- Identify the area that is under restriction (i.e., subject to LUCs);
- Identify each LUC objective; and
- Specify the specific controls and mechanisms required to achieve each identified objective.

The C-400 Cleaning Building area (C-400 Area) that is to be addressed by Property Record Notice, Deed Restrictions, Environmental Covenant, Access Controls, and the Excavation/Penetration Permits Program is depicted in Figure 1., LUC Boundary for the C-400 Area (as the hatched area). The LUC objectives are presented in Section 3 and the specific LUCs for the C-400 Area are described in Section 4 below.

3. LAND USE CONTROL OBJECTIVES

The following LUC objectives are applicable to the interim remedial action:

- Maintain the integrity of any current or future remedial or monitoring system;
- Prohibit the development and use of the C-400 Cleaning Building area for residential housing, elementary and secondary schools, child care facilities, and playgrounds;
- Prevent exposure of current and future on-site industrial workers to groundwater/soils and prevent use of the groundwater at the C-400 Cleaning Building area through institutional controls (e.g., the current Excavation/Penetration, (E/P) Permits Program) and through Deed Restrictions; and
- Provide notice in property records regarding contamination and response actions at the C-400 Cleaning Building area.

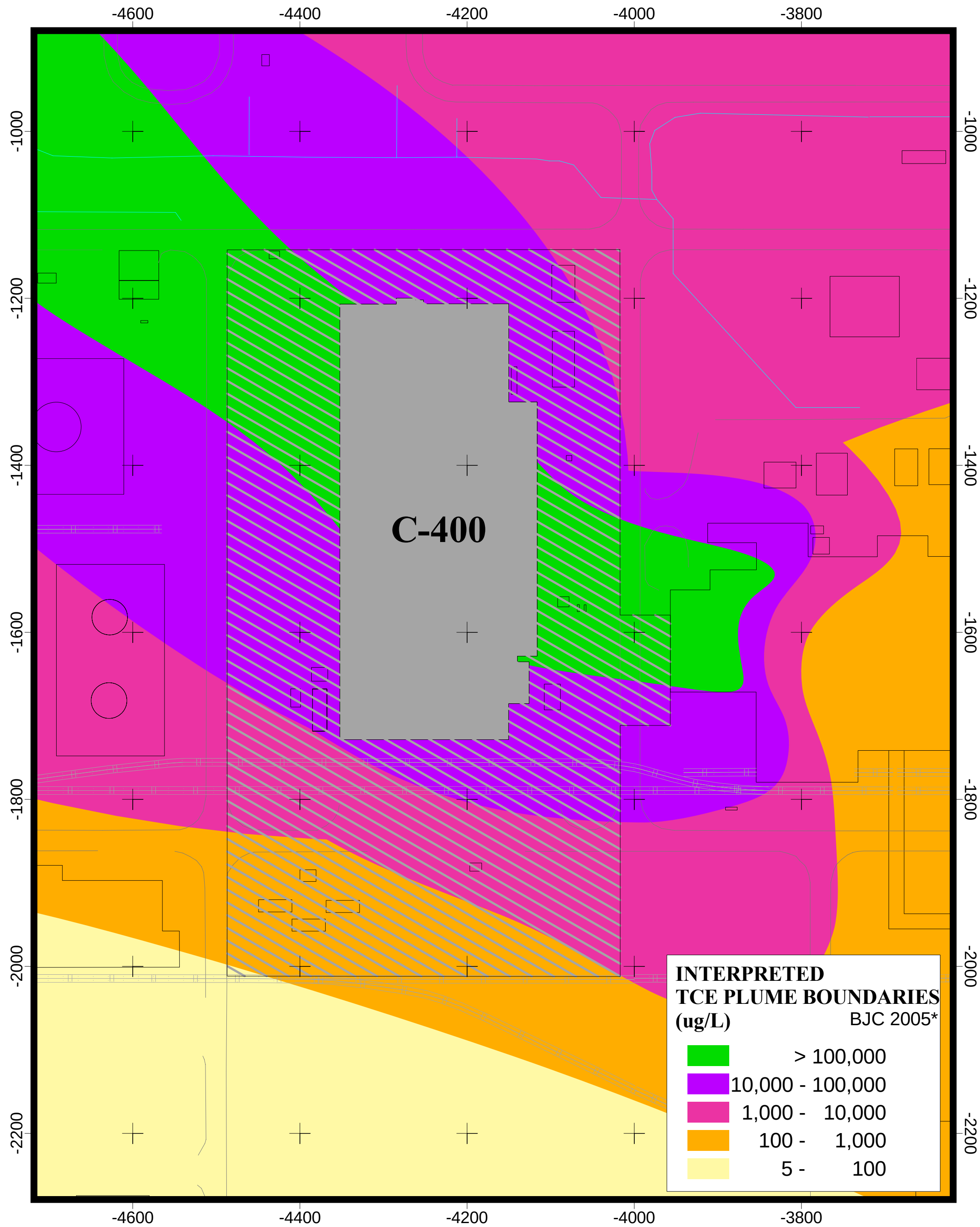
4. LAND USE CONTROLS

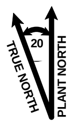
The selected remedy for the VOC contamination at C-400 Area includes five LUCs: Property Record Notice, Deed Restrictions, Environmental Covenant, Excavation/Penetration Permits Program, and Access Controls. Table 1 contains a summary of these LUCs, including the purpose, duration, implementation, and affected areas. Figure 1 shows the C-400 Area (the hatched area) that is addressed by Property Record Notice, Deed Restrictions, Environmental Covenant, Access Controls and the E/P Permits Program. Figure 1 also shows the interpreted TCE groundwater plume in the vicinity of the C-400 Building. Note that the groundwater plume outside of the C-400 Area (i.e., outside hatched area in Figure 1) is beyond the scope of the interim remedial action and will be addressed in a future response action. Each of the controls is discussed in more detail in the following subsections.

4.1 PROPERTY RECORD NOTICE

The term "Property Record Notice," as used in this LUCIP, refers to any nonenforceable, purely informational document recorded along with the original property acquisition records of DOE and its predecessor agencies that alerts anyone searching the records to important information about the contamination present at the C-400 Area, as depicted in Figure 1 (hatched area). A Property Record Notice (Notice) will be filed at the McCracken County Clerk's Office, in accordance with state and federal law, within 120 days of regulatory approval of the LUCIP and will remain in effect until DOE, the KEPPC, and EPA approve a request to modify or delete it. The Notice will include the purpose of the Notice, a brief summary of the main contaminants of concern, a description of the CERCLA remedial action including LUCs, a description of the land/groundwater use restrictions for the C-400 Area, and a DOE program contact. The Property Record Notice will contain information regarding the groundwater plume sitewide. The Notice will inform the reader that an Environmental Covenant is to be recorded prior to any other interest being created in the DOE property subject to the interim action or before any actual transfers of such property. The Notice also will inform the reader that, upon title transfer of the C-400 Area (Figure 1, hatched area), the deed will include applicable land use restrictions and information required by CERCLA Section 120 (h) (3). The Notice also will include a survey plat, accomplished by a registered land surveyor (under the direction and approval of a DOE official and consistent with applicable security requirements), that depicts the contamination and the area subject to LUCs and describes the use restrictions that correspond to the hatched area on Figure 1. DOE will file both the Notice and survey plat in the register of deeds records (e.g., Real Estate Office) of the McCracken County Clerk. A copy of the Property Record Notice to be filed is included as Appendix A.

DOCUMENT No. DOE/OR/07-2151&D2





Area of Property Record Notice, Deed Restrictions, Access Controls, and the Excavation/Penetration Permits Program.

Within this area:
Limit use of the property to industrial activities, prevent industrial worker exposure to groundwater contamination, and restrict use of the groundwater.

*Plume information shown in this figure is accurate as of May 2005.

200 0 200 Feet

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 1. LUC Boundary for the C-400 Area

PADUCAH Remediation Services
A Portage Shaw Joint Venture Company

Figure No. C5AC90005SK009r2.apr
DATE 03-30-07

Table 1. Summary of LUCs for the area of VOC contamination at C-400 at PGDP

Type of control	Purposes of control	Duration	Implementation	Affected areas
Property Record Notice [a]	Provide notice to anyone searching records about the existence and location of contaminated areas, the CERCLA remedy including LUCs, the land/groundwater use restrictions to be included in property transfer documents, and requirement to execute an Environmental Covenant.	LUCs will be maintained until the concentrations of hazardous substances in the soil and groundwater are at such levels to allow for unrestricted use and unlimited exposure. The LUC will remain in place until Kentucky/EPA approve a DOE request to modify/delete the LUCs.	Notice recorded by DOE in accordance with state law and federal law at the McCracken County Clerk's Office within 120 days of regulatory approval of the LUCIP.	C-400 Area (Located within the PGDP security fence.)
Deed Restrictions [b]	Limit use of the property to industrial activities, prevent industrial worker exposure to soil/groundwater contamination, and restrict use of the soil/groundwater to protect human health and the environment from the potential of inadvertent exposures to residual contamination.	LUCs will be maintained until the concentrations of hazardous substances in the soil and groundwater are at such levels to allow for unrestricted use and unlimited exposure. The LUC will remain in place until Kentucky/EPA approve a DOE request to modify/delete the LUCs.	The DOE will prepare and then record the deed with the McCracken County Clerk, in accordance with the laws of the Commonwealth of Kentucky and federal requirements. Concurrent with the transfer of fee title from DOE to the Grantee, information regarding the environmental use restrictions and land use controls will be communicated in writing to the property owners and to appropriate state and local agencies to ensure such agencies can factor such conditions into their oversight and decision-making activities regarding the property.	C-400 Area (Located within the PGDP security fence.)
Environmental Covenant [c]	Impose enforceable activity and use restrictions on contaminated property to protect human health and the environment from the potential of inadvertent exposures to residual contamination.	LUCs will be maintained until the concentrations of hazardous substances in the soil and groundwater are at such levels to allow for unrestricted use and unlimited exposure. The LUC will remain in place until Kentucky/EPA approve a DOE request to modify/delete the LUCs.	DOE is to record the Environmental Covenant prior to any other interest(s)[b] being created in the DOE property that is the subject of this interim action or before any actual transfer of such property. The Environmental Covenant is to be recorded at the McCracken County Clerk's Office in accordance with applicable federal and state law.	C-400 Area (Located within the PGDP security fence.)

[a] Property Record Notice – Refers to any nonenforceable, purely informational document recorded along with the original property acquisition records of DOE and its predecessor agencies that alerts anyone searching property records to important information about contamination/waste on the property.

[b] Deed Restrictions – Refers to conditions and/or covenants that restrict or prohibit certain uses of real property and to limitations on its use necessitated by residual contamination in accordance with federal and state law.

[c] Environmental Covenant – Refers to the document executed by the property owner (i.e., the United States) and approved by KEPPC pursuant to KRS 224.80-100 that includes activity and use restrictions for contaminated property (i.e., Impacted Area), which is recorded and enforceable by Kentucky, EPA, and interest holders against owners and subsequent owners.

Table 1. Summary of LUCs for the area of VOC contamination at C-400 at PGDP (continued)

Type of control	Purposes of control	Duration	Implementation	Affected areas
Excavation/Penetration Permits Program[d]	Requires review and approval of any proposed intrusive activities to protect workers and remedy integrity; process may prohibit or limit intrusive activities.	LUCs will be maintained until the concentrations of hazardous substances in the soil and groundwater are at such levels to allow for unrestricted use and unlimited exposure. The LUC will remain in place until Kentucky/EPA approve a DOE request to modify/delete the LUCs.	• Implemented by DOE and/or its contractors. • Provide permits program with contamination information as soon as practicable after signing the ROD and update information regularly while remediation proceeds. • Initiated by permit request.	C-400 Area (Located within the PGDP security fence.)
Access Controls[e] (e.g., signage, fences, gates, security measures, etc.)	Restrict access to workers and prevent public/uncontrolled access to contaminated areas.	LUCs will be maintained until the concentrations of hazardous substances in the soil and groundwater are at such levels to allow for unrestricted use and unlimited exposure. The LUC will remain in place until Kentucky/EPA approve a DOE request to modify/delete the LUCs.	Access controls will be implemented during installation and operation ERH systems at select areas within the C-400 Area. These access controls will include warning and informational signage, temporary fencing and/or barricades, and visitor sign-in controls. Upon completion of the remedial action, these interim controls will cease and long-term access controls may be selected as LUCs to be maintained in accordance with the requirements of this LUCIP.	C-400 Area (Located within the PGDP security fence.)

[d] Excavation/Penetration Permits Program – Refers to the internal DOE/DOE contractor administrative program(s) that requires the permit requestor to obtain authorization, usually in the form of a permit, before beginning any excavation/penetration activity (e.g., well drilling) for the purpose of ensuring that the proposed activity will not affect underground utilities/structures, or in the case of contaminated soil or groundwater, will not disturb the affected area without the appropriate precautions and safeguards.

[e] Access Controls – Physical barriers or restrictions to entry. (e.g., signage, fences, gates, security measures, etc.)

4.2 DEED RESTRICTIONS

The term “Deed Restriction,” as used in this LUCIP, refers to conditions and/or covenants that restrict or prohibit certain uses of real property and to limitations on its use necessitated by residual contamination in accordance with federal and state law.

DOE will provide notice to EPA and Kentucky at least 90 days prior to any transfer or sale of the C-400 Area (Figure 1, hatched area) so that EPA and Kentucky can be involved in discussions to ensure that appropriate provisions to maintain effective LUCs are included in the transfer terms or conveyance documents. In addition to the land transfer notice above, DOE will provide EPA and Kentucky with similar notice, within the same time frames, as to any federal-to-federal transfer of property. DOE will provide a copy of executed deed or transfer assembly to EPA and Kentucky.

Each transfer of fee title from DOE of any portion (i.e., parcel) of contaminated land in the C-400 Area will include a covenant as specified in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 120(h)(3), which will contain a description of the residual contamination on the property and the environmental use restrictions, expressly prohibiting activities inconsistent with the remedial action and LUC objectives. The environmental restrictions are included in a section of the CERCLA 120(h)(3) covenant that DOE is required to include in the deed for any property that has had hazardous substances stored for one year or more, or on which hazardous substances are known to have been released or disposed of on the property. Each deed also will contain a reservation of access to the property for DOE, EPA, and Kentucky and their respective officials, agents, employees, contractors, and subcontractors for purposes consistent with implementing remedial investigations/actions pursuant to the FFA.

In the event DOE plans to transfer fee title to any portion (i.e., parcel) of the contaminated land in the C-400 Area, DOE will comply with the transfer provisions of CERCLA Section 120(h)(3), the FFA, and the LUCAP, including any requirements pertaining to the imposition of restrictions on future land use (see Appendix B). The deed(s) (or other conveyance document) for such transfer will contain appropriate provisions to ensure that the use restrictions continue to run with the land and are enforceable by the DOE against the Grantee (including any successors and/or assigns). The deed(s) will provide that any lease or subsequent deed executed by the Grantee for the parcels within the C-400 Area property must include land/groundwater use restrictions that are no less restrictive than the use restrictions described in Appendix B of this LUCIP. The deed(s) also will include the requirement that any transferee lease contain the same use restrictions and conditions related to LUCs. Before executing the deed(s) for conveyance, the DOE will provide notice to EPA and Kentucky Department for Environmental Protection (KDEP) of the final draft deed language and provide an opportunity to review the restrictive covenants, use conditions, and other LUC provisions. The DOE will prepare and then record the deed with the Real Estate Office of the McCracken County Clerk, in accordance with the laws of the Commonwealth of Kentucky and federal law. Concurrent with the transfer of fee title from DOE to the Grantee, information regarding the environmental use restrictions and LUCs will be communicated in writing to the property owners and to appropriate state and local agencies to ensure such agencies can factor such conditions into their oversight and decision-making activities regarding the property. During the time between the adoption of the ROD for the C-400 Area and the deeding of the property, DOE shall ensure that any new lease contains land/groundwater use restrictions and controls no less restrictive than the use restrictions included in Appendix B of this LUCIP. These lease terms shall remain in place until the property is transferred by deed, at which time they will be superseded by the LUCs described in the ROD and this LUCIP.

4.3 ENVIRONMENTAL COVENANT

An Environmental Covenant will be created for the C-400 Area (Figure 1, hatched area) in accordance with federal and state law, including KRS 224.80-100 et seq., and recorded prior to any other interests being created in the DOE property (e.g., liens, mortgages, leases, easements, licenses, profits, servitudes, covenants, or life estates) or before any actual transfer of such property. The term "Environmental Covenant," as used in this LUCIP, refers to the document executed by the property owner (i.e., the United States) and approved by EPA and KEPPC pursuant to KRS 224.80-100 that includes activity and use restrictions for the Impacted Area (i.e., the contaminated property indicated by the hatched area on Figure 1), which is recorded and enforceable by Kentucky, EPA, and interest holders against owners and subsequent owners. The Environmental Covenant will include the information, restrictions, and requirements in accordance with the ROD, LUCIP, and KRS Chapter 224 Subchapter 80. Prior to recording the Environmental Covenant, DOE shall request modification to revise the final C-400 Remedial Design Report, Appendix H, (namely this LUCIP) in accordance with FFA Section XX.J *Subsequent Modifications of Final Documents*. DOE shall submit a draft revised LUCIP, including an executed copy of the Environmental Covenant, for review and approval by EPA and KEPPC. Following approval of the revised Appendix H of the Remedial Design Report, DOE shall record the Environmental Covenant at the McCracken County Clerk's Office, in accordance with applicable federal/state law, and send file stamped copies to the Kentucky Division of Waste Management and EPA. In addition, the DOE shall include a file-stamped copy of the Environmental Covenant in the revised copy of the LUCIP that must be attached to the LUCAP. The restrictions to be included in the Environmental Covenant are provided in Appendix B. The Environmental Covenant will be maintained until the concentrations of hazardous substances within the soil and groundwater are at such levels to allow for unrestricted use and unlimited exposure. The Environmental Covenant will remain in place until KEPPC and EPA approve a request by DOE to modify or delete it.

4.4 EXCAVATION/PENETRATION PERMITS PROGRAM

This LUC will apply to the C-400 Area, as depicted in Figure 1 (hatched area). The E/P Program will be the primary mechanism to control industrial worker exposure to waste, below-grade structures, or contaminated soil/groundwater left in place that could be encountered during excavation activities. The E/P Program refers to the existing program administered by DOE's contractors at PGDP and currently includes a specific permitting procedure (PA-2012 or equivalent) designed to provide a common site wide system to identify and control potential personnel hazards related to trenching, excavation, and penetration. The E/P permits are issued by the Paducah Site's DOE Prime Contractor. These permits currently are being issued by the Engineering Department of Paducah Remediation Services, LLC.[1] The primary objective of the E/P permits procedure is to provide notice to the organization requesting a permit of existing underground utility lines and/or other structures and to ensure that any E/P activity is conducted safely and in accordance with all environmental compliance requirements pertinent to the area.

The E/P permits procedure

- Requires formal authorization (i.e., internal permits/approvals) before beginning any intrusive activities at PGDP;
- Is reviewed annually; and

[1] The contractor and/or organization may change from time-to-time without need to modify this LUCIP.

- Is implemented by trained personnel knowledgeable in its requirements.

An initial draft of an E/P permit is reviewed by project support groups such as Environmental Compliance, Industrial Hygiene, Industrial Safety, Quality Assurance, and Nuclear and Facility Safety and approved by Nuclear and Facility Safety, the Facility Manager, the Issuing Authority/Engineering, and the work group Supervisor and Safety Representative. The reviews conducted by these sections ensure that the latest updates in engineering drawings, utility drawings, and solid waste management unit inventories are considered prior to the issuance of an E/P permit.

Within 30 days of regulatory approval of the LUCIP, the LUCIP and other CERCLA documents containing pertinent information regarding the extent of soil and groundwater contamination associated with the C-400 Area will be made available to the organizations responsible for implementing the E/P Permits Program, and this information will be utilized by these organizations in reviewing an E/P request. The information regarding extent of contamination in these documents will be utilized by these organizations and taken into account before authorizing any E/P. The DOE shall notify EPA and KDEP of any material changes (such as significant revisions, cancellation, etc.) to the E/P permits procedure that would affect implementation of this LUC and potentially affect the remedy effectiveness.

4.5 ACCESS CONTROLS

The PGDP is a federal facility with restricted access by the general public. Physical access to the PGDP is prohibited by security fencing, and armed guards patrol the DOE property 24 hours per day to restrict workers entry and prevent uncontrolled access by the public/site visitors. Figure 2 shows the PGDP Secured Area Boundary. These existing access controls are being maintained outside of the requirements of CERCLA and this LUCIP due to the nature and security needs of the facility. Access controls will be implemented during installation and operation of ERH systems at select locations within the C-400 Area. These interim access controls will include warning and informational signage, temporary fencing and/or barricades, and visitor sign-in controls. The designated locations for these interim access controls will be provided in the Remedial Action Work Plan and depicted in a figure of appropriate scale. Upon completion of the remedial action, these interim actions will cease and long-term access controls may be selected as LUCs to be maintained in accordance with the requirements of this LUCIP.

As interim controls, warning signs for the C-400 Area will be posted before beginning C-400 IRA field activities that involve worker exposure to contaminated groundwater and soils. The signs shall 1) include lettering that is legible from a distance of least 25 feet; 2) contain contact information for DOE and/or contractor personnel; 3) be visible from surrounding areas and at potential routes of entry into the C-400 Area. The warning signs shall contain language similar to the following:

WARNING: CONTAMINATED AREA
Hazardous Substances in Soil and Groundwater
Authorized Access Only
Contact: [Name and phone number]

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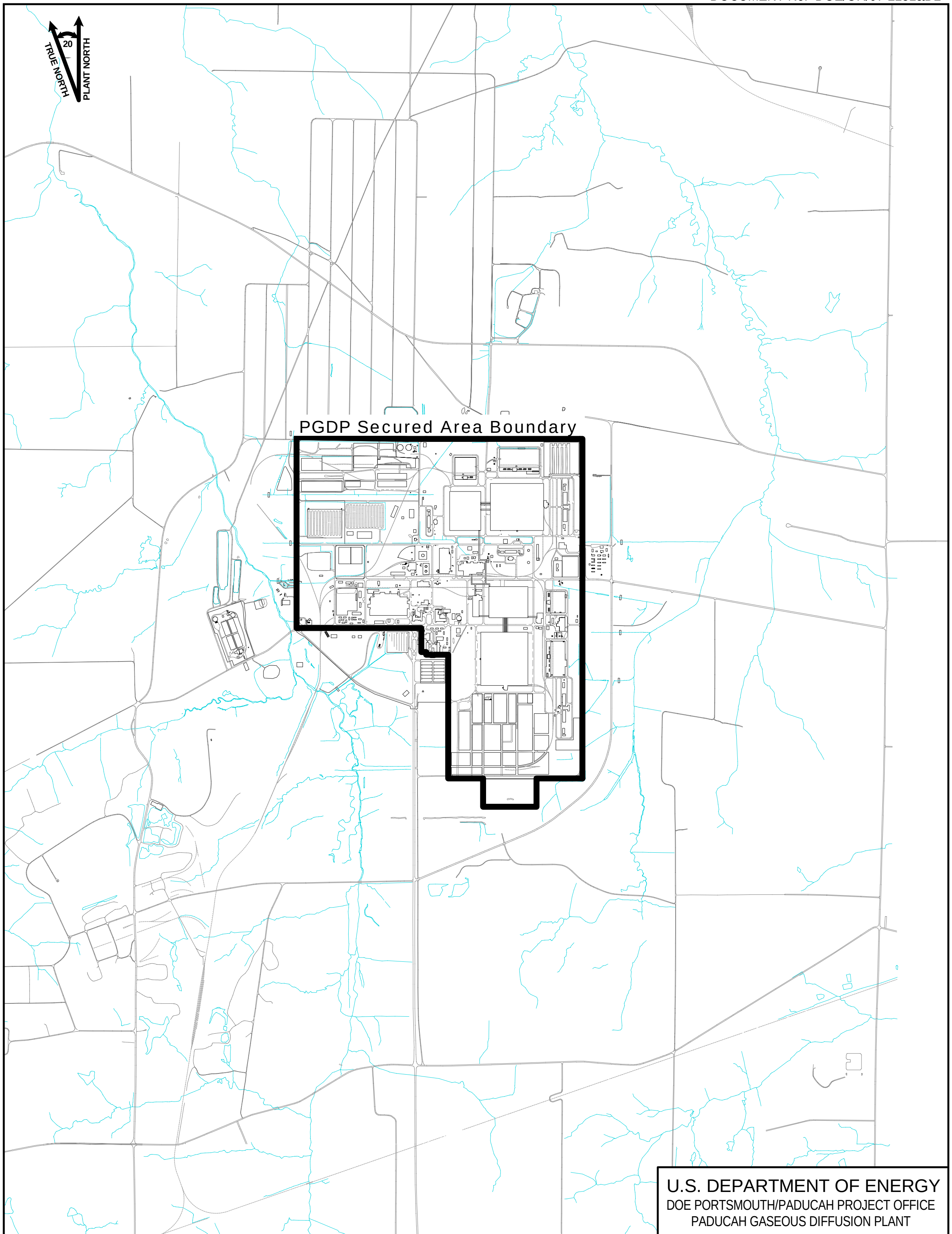

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 2. Paducah Gaseous Diffusion Plant (PGDP) Secured Area Boundary

PADUCAH Remediation Services
A Portage Shaw Joint Venture Company

Figure No. C5AC90005SK009r2.apr
DATE 03-30-07

5. MONITORING AND INSPECTING LUCS

LUCs at the C-400 Area (Figure 1, hatched area) will be maintained until the concentration of hazardous substances in the soil and groundwater are at levels to allow for unrestricted use and unlimited exposure. Records pertaining to the monitoring and field inspections will be maintained in accordance with the data and records management provisions of the FFA.

The frequency and implementation of the monitoring of the LUCs is specified herein. The DOE and/or its contractors will perform the monitoring and annual field inspections. Although DOE may transfer these procedural responsibilities to another party by contract, transfer agreement, or through other means, DOE will retain ultimate responsibility for the remedy integrity, including the LUCs, to the extent provided by applicable law. However, DOE's ultimate responsibility will not diminish the transferee's responsibility for conducting such activities in accordance with any agreement with DOE or applicable law. The DOE will notify EPA and KDEP as soon as practicable, but no longer than 10 days, after discovery of any activity that is inconsistent with the LUC objectives or use restrictions, or any other action that will interfere with the effectiveness of the LUCs. DOE will notify EPA and KDEP regarding how DOE has addressed or will address the breach within 10 days of sending EPA and KDEP notification of the breach.

The LUC monitoring results will be included in a separate annual report or as a section of another annual environmental report, if appropriate, and provided to the EPA and KDEP. The annual monitoring reports will be used in preparation of the Five Year Review to evaluate the effectiveness of the remedy. The annual monitoring report, submitted to the EPA and KDEP by the DOE, will evaluate the status of the LUCs and how any deficiencies or inconsistent land uses have been addressed. In the event DOE transfers the C-400 Area property, the annual evaluation will address whether 1) the use restrictions and controls referenced above were communicated in the deed(s) or transfer instrument(s); 2) the owners and state and local agencies were notified of the use restrictions and controls affecting the property; and 3) use of the property has conformed with such restrictions and controls.

A summary of the monitoring frequency and implementation actions is provided in Table 2.

5.1 MONITORING

The LUCAP requires monitoring of LUCs quarterly throughout the remediation period unless justification for a different monitoring frequency is provided in the LUCIP (DOE 2000). The Property Record Notice filed for the C-400 Area will be monitored one time within one year of filing and then once every five years in conjunction with the CERCLA Five-Year Review. Similarly, the Deed Restrictions and Environmental Covenant will be monitored within one year of filing and then once every five years in conjunction with the CERCLA Five-Year Review. These reviews will ensure that the Property Record Notice, Deed Restrictions, and Environmental Covenant have been filed properly.

Table 2. Summary of LUC monitoring requirements for the C-400 Area at PGDP

Type of control	Purpose of monitoring	Frequency and justification	Implementation
Property Record Notice	To ensure that Property Record Notice recorded at the McCracken County Clerk's Office is filed properly.	• Frequency: to be monitored (i.e., verified) one time within one year of filing, and then once every five years in conjunction with the CERCLA Five-Year Review. • Justification: Property Record Notice is not expected to change once it has been filed.	DOE will verify that Property Record Notice is recorded properly.
Deed Restrictions	To ensure that Deed Restrictions recorded at the McCracken County Clerk's Office are filed properly.	• Frequency: to be monitored (i.e., verified) one time within one year of filing, and once every five years in conjunction with the CERCLA Five-Year Review. • Justification: Deed Restriction is not expected to change once it has been filed.	DOE will verify that Deed Restrictions are recorded properly in accordance with applicable federal and state law.
Environmental Covenant	To ensure that Environmental Covenant recorded at the McCracken County Clerk's Office is filed properly.	• Frequency: to be monitored (i.e., verified) one time within one year of filing, and once every five years in conjunction with the CERCLA Five-Year Review. • Justification: Environmental Covenant is not expected to change once it has been filed.	DOE will verify that Environmental Covenant is recorded properly in accordance with applicable federal and state law.
Excavation/ Penetration Permits Program	To ensure that Excavation/Penetration Permits Program is functioning properly.	• Frequency: to be monitored annually. • Justification: permits program is part of an established procedure and is not expected to be discontinued.	DOE will verify that the contractor's permits program is functioning properly in accordance with that described in Section 4.3.
Access controls: • Implemented during installation and operation of ERH systems at the C-400 Area (warning and informational signage, temporary fencing and/or barricades, and visitor sign-in controls) • Long-term access controls may be selected upon completion of the remedial action	To ensure that access controls are functioning properly.	• Frequency: to be monitored quarterly during installation and operations of the IRA systems • Justification: sufficient to verify condition and adequacy of controls during changing conditions resulting from installation and operations activities • Frequency: monitoring frequency for long-term access controls to be determined upon selection	DOE will verify access controls are functioning properly and located in the designated locations.

The E/P Program identified in this LUCIP will be monitored annually to verify that the program is functioning properly. Annual monitoring, initiated by the DOE contractor's Project Assessment Schedule, will be completed by June 30 of each year. Annual monitoring is appropriate for this LUC, since the E/P Program is part of an established procedure and is not expected to be discontinued.

Access controls implemented during installation and operation of ERH systems will be monitored quarterly to verify condition and adequacy during the remedial action; other required access controls will be monitored at the frequency identified when the access controls are selected (i.e., upon completion of the remedial action) to verify that access controls are functioning properly.

5.2 FIELD INSPECTIONS

Field inspections of the C-400 Area will be conducted annually to verify the following:

- The land use remains industrial (i.e., no recreational or residential land uses);
- Groundwater wells have not been installed and groundwater is not being used for any purpose;
- Unpermitted excavation/penetration activities have not occurred;
- Disruption of remedial/monitoring system has not occurred; and
- Access controls remain intact and located in designated areas.

These inspections will be documented and recorded using a checklist similar to the one provided in Appendix C. These records will be maintained in accordance with applicable sections of the LUCAP.

6. MODIFICATION OF LUCS

The aforementioned LUCs are expected to remain in place until the concentration of hazardous substances in the soil and groundwater is at such levels to allow for unrestricted use and unlimited exposure. However, if conditions at the site improve, land use objectives change, and the remedial goals are met, then the parties may agree to modify or discontinue a particular LUC.

DOE will not modify or terminate the aforementioned LUCs or implementation actions, or modify land use without approval by EPA and Kentucky. DOE shall seek prior EPA concurrence before taking any anticipated action that DOE anticipates would disrupt the effectiveness of the LUCs or any action that would alter or negate the need for LUCs. The request by DOE to modify/discontinue a LUC will include an adequate justification and must be in writing. The determination to modify or discontinue a particular LUC will be made by the EPA and Kentucky. The approval to modify or discontinue a LUC will be documented in writing and placed in the Administrative Record file. If changes to the LUCs are deemed significant and affect the scope of the remedy, then an Explanation of Significant Differences or Amendment to the C-400 Cleaning Building ROD may be required.

DOE will in writing notify EPA and KDEP 60 days in advance of any proposed land use changes that are inconsistent with LUC objectives or the selected remedy.

7. ENFORCEMENT OF LUCS

DOE is responsible for implementing, maintaining, monitoring, reporting on, and enforcing the LUCs. Some of the LUCs, such as the Access Controls and the E/P Permit Program, are being implemented by DOE and/or its contractors at PGDP.

Although DOE may transfer these procedural responsibilities to another party by contract, transfer agreement, or through other means, DOE will retain ultimate responsibility for the remedy integrity, including the LUCs, to the extent provided by applicable law. However, DOE's ultimate responsibility will not diminish the transferee's responsibility for conducting such activities in accordance with any agreement with DOE

Any activity that is inconsistent with the LUC Objectives or use restrictions or any other action that may interfere with the effectiveness of the LUCs will be addressed by DOE as soon as practicable, but, in no case, will the process be initiated later than 10 days after DOE becomes aware of the breach.

8. REFERENCES

DOE (U.S. Department of Energy) 2000. *Land Use Control Assurance Plan for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1799&D2, January.

DOE 2005. *Record of Decision for Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2150&D2/R2, July.

EPA (U.S. Environmental Protection Agency) 2000. *Memorandum of Agreement for Implementation of a Land Use Control Assurance Plan for the United States Department of Energy Paducah Gaseous Diffusion Plant*, Signed March 30.

APPENDIX A

PROPERTY RECORD NOTICE

NOTICE OF ENVIRONMENTAL CONTAMINATION AND LAND USE RESTRICTIONS

PURPOSE

The purposes of this document are to 1) provide notice of the environmental contamination in the C-400 Cleaning Building area property at the Paducah Gaseous Diffusion Plant (PGDP) owned by the U.S. Department of Energy (DOE) and located in McCracken County in the Commonwealth of Kentucky; 2) summarize the CERCLA remedial action to be undertaken by DOE in order to protect human health and the environment; and 3) describe the land use restrictions that apply to the C-400 Cleaning Building area.

NOTICE OF ENVIRONMENTAL CONTAMINATION

The C-400 Cleaning Building area subsurface soil and groundwater are contaminated with volatile organic compounds (VOCs) such as TCE and its breakdown products (trans-1,2-dichloroethene, cis-1,2-dichloroethene, and vinyl chloride) and 1,1-dichloroethene, as well as tetrachloroethene, carbon tetrachloride, chloroform, 1,1,1-trichloroethane, 1,1,2-trichloroethane, and toluene. The primary contaminant of concern for the C-400 Cleaning Building area is the TCE contamination in subsurface soil and groundwater. Both the Upper Continental Recharge System (UCRS) and the Regional Gravel Aquifer (RGA) contain high VOC concentrations. Three groundwater plumes of dissolved contaminants have migrated beyond the secured fenced area (see Figure A-1). Groundwater from the C-400 Cleaning Building area flows primarily with the PGDP's Northwest Plume, but also contributes to the Northeast Plume. The PGDP's Northwest Plume reaches approximately 4.6 km (2.8 miles) beyond the PGDP security-fenced area to Little Bayou Creek in the Ohio River floodplain. The Northeast Plume extends approximately 3.5 km (2.2 miles) from the east side of PGDP northward to Metropolis Lake Road. TCE and other VOCs from the C-400 Cleaning Building area also may contribute to the Southwest Plume. The Southwest Plume extends approximately 0.2 km (0.1 miles) west of the PGDP security fence and is contained within PGDP property.

Attachment 1 to this Notice is a survey plat showing the major areas of concern as depicted in Figure 8 of the *Record of Decision for Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2150&D2/R2, July 2005, which corresponds to the hatched area in Figure A-2.

CERCLA INTERIM REMEDIAL ACTION

A Record of Decision (ROD) issued by DOE and the U.S. Environmental Protection Agency (EPA) with concurrence from the Kentucky Environmental and Public Protection Cabinet (KEPPC), specifies the selected interim remedial action that DOE must implement to remediate the VOC contamination within the C-400 Cleaning Building area in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended, 42 USC Section 9601 et seq. The selected remedy consists of the following actions:

- A remedial design investigation to further determine areal and vertical extent of the contamination in the C-400 Cleaning Building area to determine optimum placement of the remediation system.

- Removal and treatment of TCE and other VOCs from the contaminant source zone in the UCRS and RGA at the C-400 Cleaning Building area using an Electrical Resistance Heating remediation system.

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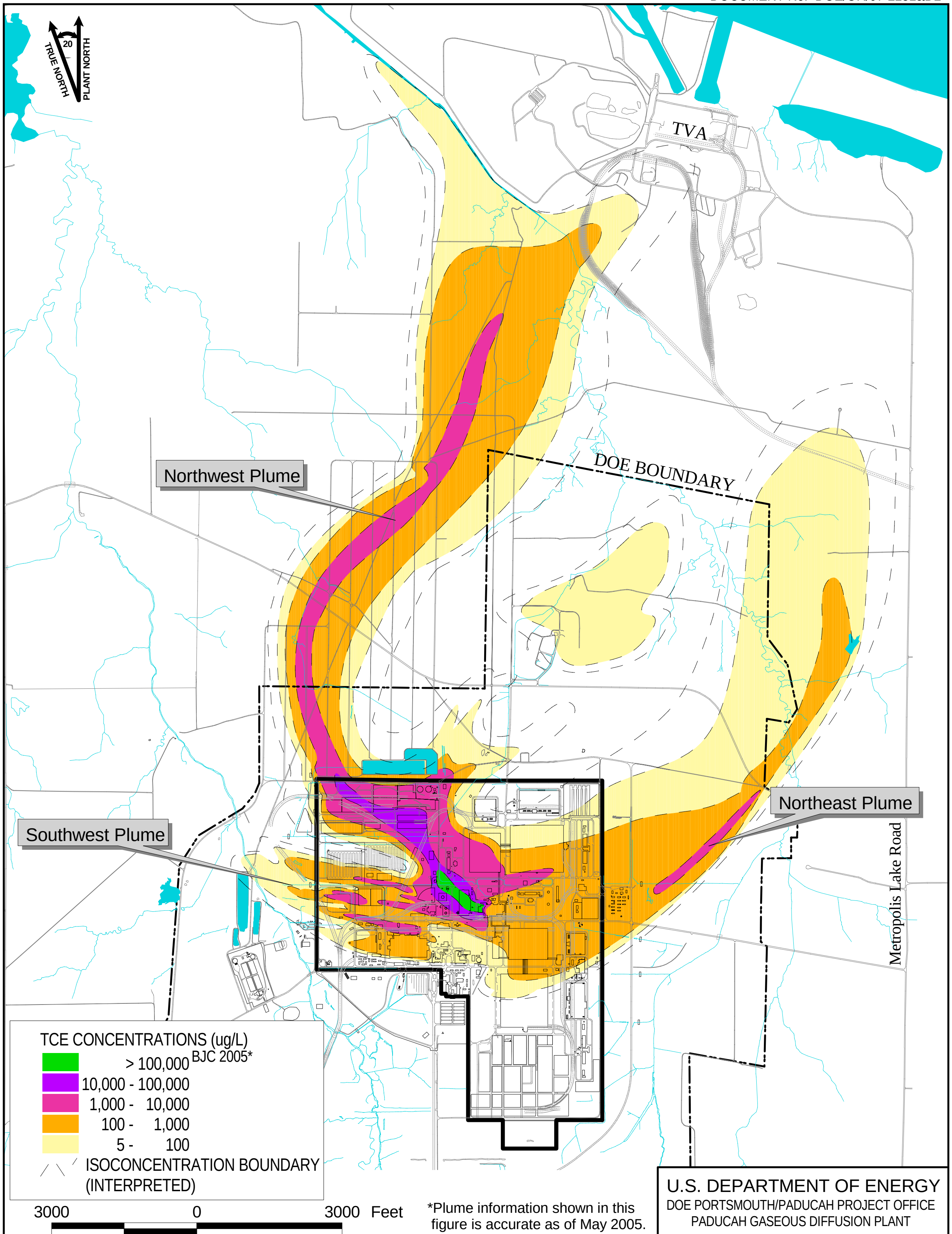

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure A.1. Trichloroethene Plume Locations

PADUCAH Remediation Services
A Portage Shaw Joint Venture Company

Figure No. C5AC90005SK009r2.apr
DATE 03-30-07

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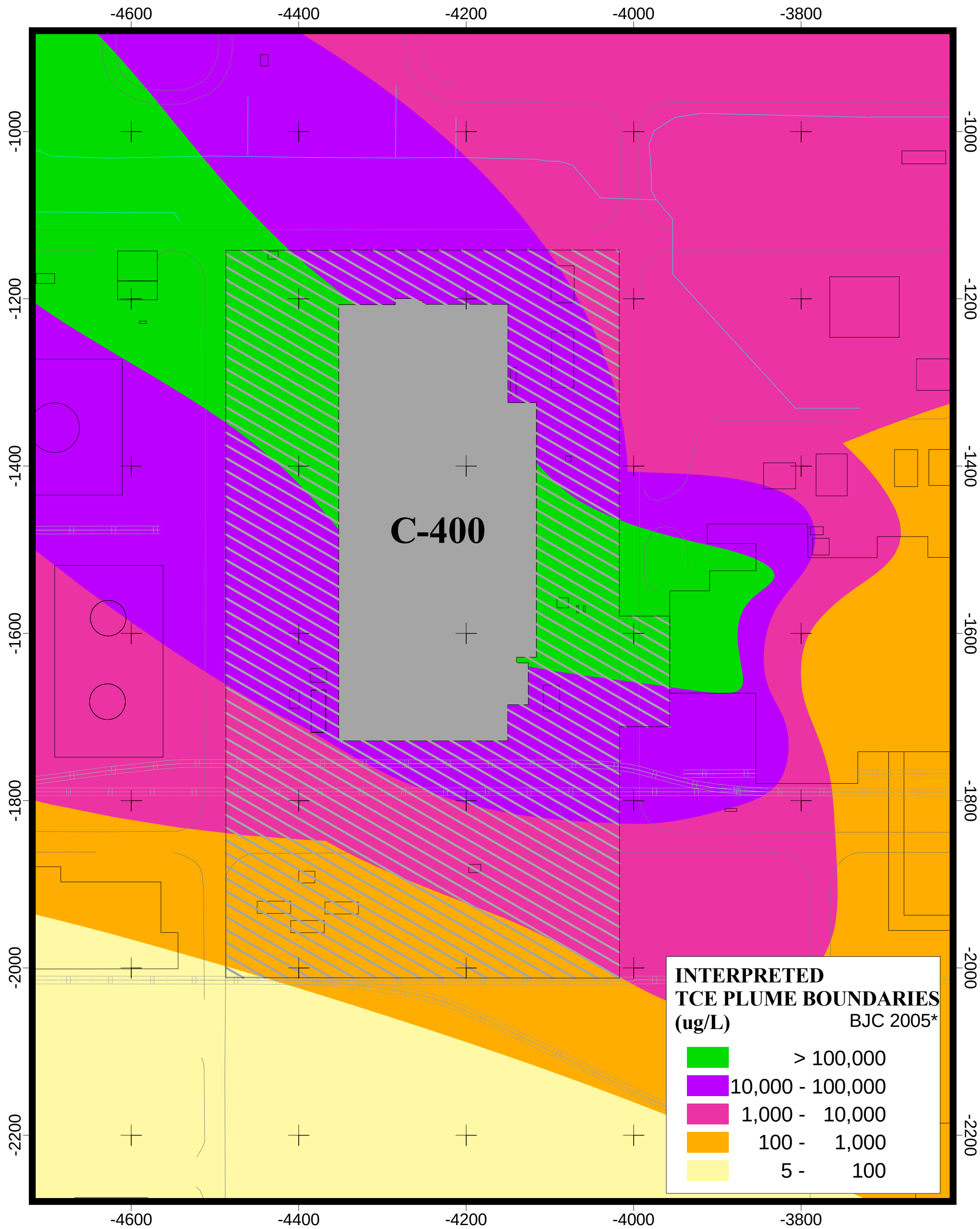

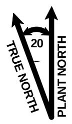

Area of Property Record Notice, Deed Restrictions, Access Controls, and the Excavation/Penetration Permits Program.

Within this area:
Limit use of the property to industrial activities, prevent industrial worker exposure to groundwater contamination, and restrict use of the groundwater.

*Plume information shown in this figure is accurate as of May 2005.

200 0 200 Feet

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure A.2. LUC Boundary for the C-400 Area

PADUCAH Remediation Services
A Portage Shaw Joint Venture Company

Figure No. C5AC90005SK009r2.apr
DATE 03-30-07

- Implementation, maintenance, and reporting of Land Use Controls (LUCs) to prevent unacceptable exposure to contamination in the C-400 Cleaning Building area.

- Continuation of groundwater monitoring of the source and dissolved-phase plumes, since contamination would remain in place following the interim remedial actions.

More detailed information about the contamination at the C-400 Cleaning Building area of PGDP and the interim remedial action may be found in the CERCLA documents that are part of the Administrative Record File relating to selection, design, and implementation of the actions specified in the ROD. These documents are available for public inspection during regular business hours at the Environmental Information Center in the Barkley Centre, Paducah, Kentucky, and at the Paducah Public Library.

LAND USE RESTRICTIONS

The selected remedy for C-400 Cleaning Building Area includes the following LUCs: Property Record Notice, Deed Restrictions, Environmental Covenant, an Excavation/Penetration Permits Program, and Access Controls that are applicable to the area depicted in Figure A-2 (hatched area). Attachment 1 is a survey plat of the C-400 Area that depicts the groundwater contamination (so-called Impacted Area) that is subject to the land use restrictions described below that will be included in an Environmental Covenant and property transfer documents. Any person who is unsure whether DOE has authorized a proposed use in the areas covered by the ROD should contact the U.S. Department of Energy, Paducah Site Office, P.O. Box 1410, Paducah, Kentucky 42001, (270) 441-6800, prior to proceeding with such use.

An Environmental Covenant will be created for this area in accordance with federal and state law, including KRS 224.80-110, and recorded prior to any other interests (e.g., liens, mortgages, leases, easements, licenses, profits, servitudes, covenants, or life estates) being created in the DOE property described above (Figure A-2 hatched area and Attachment 1) or before any actual transfer of such property. Additionally, in the event DOE transfers fee title to any portion (i.e., parcel) of this area, DOE will comply with applicable requirements, including the transfer provisions of CERCLA Section 120(h)(3) and the Paducah Federal Facility Agreement. Both the Environmental Covenant and any deed(s) of fee title transfer will include restrictions on groundwater and land use consistent with the following:

A. Prohibited Uses:

i.) No residential use of the Impacted Area shall be permitted, including any residence or dwelling, house, apartment, or condominium, or other purposes with a similar potential for human exposure such as elementary and secondary schools, child care facilities, and playgrounds.

ii.) No recreational use of the Impacted Area shall be permitted.

B. Prohibited Activities:

i.) Groundwater at the Impacted Area shall not be used except to the extent that such use has been approved by the U.S. Department of Energy, U.S. Environmental Protection Agency, and the Kentucky Environmental and Public Protection Cabinet.

ii.) No soil at the Impacted Area shall be disturbed unless in accordance with the DOE Excavation/Penetration Permits Program or by obtaining the written approval of the Director, Division of Waste Management, Kentucky Environmental and Public Protection Cabinet.

iii.) Except as necessary to protect human health, safety or the environment, no action shall be taken, allowed, suffered, or omitted on the Impacted Area if such action or omission is reasonably likely to:

a. Create a risk of migration of hazardous substances, pollutants or contaminants or a potential hazard to human health or the environment; or

b. Result in a disturbance of the structural integrity of any engineering controls designed or utilized at the Impacted Area to contain hazardous substances, pollutants or contaminants or limit human exposure to hazardous substances, pollutants or contaminants.

Additional facts may be contained in the DOE Realty Office's Land Notation. The DOE Realty Officer can be contacted in the Real Property Management Office of the Environmental Management Consolidated Business Center, Office of Logistics Management at 250 E. 5th Street, Suite 500, Cincinnati, OH 45202, (513) 246-0500.

Attachment 1

(This attachment will contain the survey plat to be prepared by a registered land surveyor.)

APPENDIX B

RESTRICTIONS TO BE INCORPORATED INTO ENVIRONMENTAL COVENANT

RESTRICTIONS TO BE INCORPORATED INTO ENVIRONMENTAL COVENANT

A. Prohibited Uses:

i. No residential use of the Impacted Area shall be permitted, including any residence or dwelling, house, apartment, or condominium, or other purposes with a similar potential for human exposure such as elementary and secondary schools, child care facilities, and playgrounds.

ii. No recreational use of the Impacted Area shall be permitted

B. Prohibited Activities:

i. Groundwater at the Impacted Area shall not be used except to the extent that such use has been approved by the U.S. Department of Energy, U.S. Environmental Protection Agency, and the Kentucky Environmental and Public Protection Cabinet.

ii. No soil at the Impacted Area shall be disturbed unless in accordance with the DOE Excavation/Penetration Permits Program or by obtaining the written approval of the Director, Division of Waste Management, Kentucky Environmental and Public Protection Cabinet.

iii. Except as necessary to protect human health, safety or the environment, no action shall be taken, allowed, suffered, or omitted on the Impacted Area if such action or omission is reasonably likely to:

   a. Create a risk of migration of hazardous substances, pollutants or contaminants or a potential hazard to human health or the environment; or

   b. Result in a disturbance of the structural integrity of any engineering controls designed or utilized at the Impacted Area to contain hazardous substances, pollutants or contaminants or limit human exposure to hazardous substances, pollutants or contaminants.

APPENDIX C
EXAMPLE LAND USE CONTROLS CHECKLIST

EXAMPLE

C-400 AREA
LAND USE CONTROLS CHECKLIST

Inspector(s): ______________________________ **Date:**____________________

____

____

Inspector: For unsatisfactory conditions list any deficiencies under the "Deficient Condition or Comment" column.

LAND USE CHANGES (Industrial Land Use Assumed)	NA	Yes	No	Deficient Condition or Comment
Is there evidence (visual, physical, or otherwise) to indicate that there have been changes to land use (e.g., bike trails or hunting grounds)?				
Is there evidence (visual, physical, or otherwise) to indicate that there has been residential use of the Impacted Area (including any residence or dwelling, house, apartment, or condominium, or other purposes with a similar potential for human exposure such as elementary schools, child care facilities, and playgrounds)?				
Is there evidence (visual, physical, or otherwise) to indicate that there has been recreational use of the Impacted Area?				
ACTIVITIES	NA	Yes	No	Deficient Condition or Comment
Have any groundwater wells (for consumption of water) been installed?				
Is there evidence of trenching or excavation other than that specifically addressed by an Excavation/Penetration Permit?				
Are Access Controls intact and located in designated spots with the C-400 Area?				
Is there evidence that remedial or monitoring systems have been tampered with, disrupted, or destroyed?				
Has an unauthorized groundwater well(s) been installed within the C-400 Area?				
Is there evidence of any prohibited uses of the groundwater (including consumptive, irrigation, industrial uses, etc.)?				
REVIEWS	NA	Yes	No	Deficient Condition or Comment
Has the recording of Property Record Notice and Deed Restrictions been verified at the County Court Clerk's office?				
Are the Property Record Notice and Deed Restrictions up to date?				

APPENDIX E

ELECTRO-THERMAL DYNAMIC STRIPPING PROCESS SIMULATION REPORT

(The following is a historical document reprinted in its original format. Pagination and formatting from original document retained.)

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ET-DSP™

Electro-Thermal Dynamic Stripping Process

Prepared for:

Paducah Remediation Services

Numerical Simulation Study of the Paducah C-400 Project

Paducah, Kentucky

CERTIFIED FOR CONSTRUCTION VERSION

McMILLAN-McGEE CORP.

CREATORS OF ET-DSP™

Numerical Simulation Study of the Paducah C-400 Project

Paducah, Kentucky

CERTIFIED FOR CONSTRUCTION VERSION

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McMillan-McGee Corp.

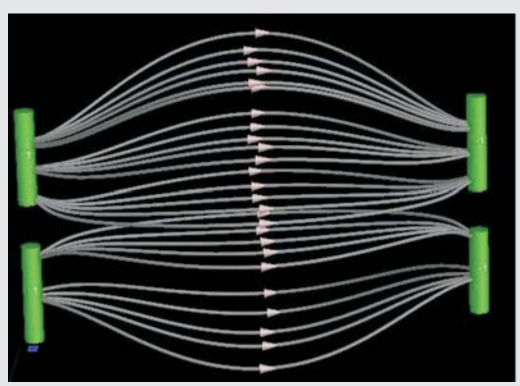
Electromagnetic Systems and Services for the Energy and Environmental Industries

Prepared For:

Paducah Remediation Services

PRS, LLC
761 Veterans Ave.
Kevil, KY 42053

December 27, 2007



Computer simulation showing current distribution between two layers of ET-DSP™ electrodes

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Nomenclature

Symbol	Description
Ω•m	Ohm meters, electrical resistivity unit
°C	Degrees Celsius, temperature unit
BGS	Below ground surface – site depth reference
BTU	British thermal unit – energy unit
cfm	Cubic feet per minute – vapor flow rate unit
CWE	Cold water equivalent
digiTAM™	Digital Temperature Acquisition Module
digiPAM™	Digital Pressure Acquisition Module
DOE	United States Department of Energy
DNAPL	Dense non-aqueous phase liquids
ET-DSP™	Electro Thermal Dynamic Stripping Process
Gpm	Gallons per minute – liquid flow rate
GW	Groundwater
kW	Kilowatt – electrical power unit (1,000 watts)
kWh	Kilowatt hour – electrical energy unit (1,000 watts in 1 hour)
kWh/m^3	Kilowatt hour per m^3 – electrical energy density unit
m	Meters – geometric distance unit
m^2	Square meters – geometric area unit
m^3	Cubic meters – geometric volume unit
mD	milliDarcies – hydraulic permeability unit (0.001 Darcies)
MWh	Megawatt hour – electrical energy unit (1,000,000 watts for 1 hour)
Mc^2	McMillan-McGee Corp.
MM	million
MPE	Multi-Phase Extraction
MSL	Mean sea level – site depth reference
NAPL	Non-Aqueous Phase Liquid

Symbol	Description
PDS	Power Delivery System
ppm	Parts per million – chemical concentration unit
PGDP	Paducah Gaseous Diffusion Plant
PRS	Paducah Remediation Services, LLC
RGA	Regional Gravel Aquifer – hydrogeologic region
Scfm	Standard cubic feet per minute – vapor flow rate, ambient
SVE	Soil vapor extraction
SWMU	Solid Waste Management Unit
TBD	To be determined
TCE	Trichloroethylene
UCRS	Upper Continental Recharge System – hydrogeologic region
VOC	Volatile organic compound
VX	Vapor extraction
WCS	Water Circulation System

1. Summary

An ET-DSP™ system consisting of 369 electrodes, 80 extraction wells, 17 PDS units, and MPE treatment system

The objective of the numerical simulation study is to develop a subsurface model of the Paducah Gaseous Diffusion Plant (PGDP) C-400 site to determine the optimal system design and operating strategy for application of ET-DSP™ in conjunction with a multi-phase extraction (MPE) and above-ground treatment system. The site consists of three distinct treatment volumes designated as the Southeast, Southwest and East areas. Of these areas the Southeast contaminant zone is the largest and represents 62% of the total treatment volume. Simulation of the Southeast area is based on a two-part model of the Upper Continental Recharge System (UCRS) and Regional Gravel Aquifer (RGA) geological units.

For the RGA a groundwater flow velocity of 1 ft/day is represented in the model based on site-specific parameters. A flow velocity of 1 ft/day is the expected condition but a flow velocity of 3 ft/day also was modeled as a contingency. Calculated representative groundwater flow rates for the RGA at C-400 are 0.65 ft/day in the upper RGA and 1.7 ft/day in the lower RGA[1]. In addition, a flow velocity of 6 ft/day was modeled to evaluate how a much higher than expected flow velocity will affect heating. The groundwater is largely stagnant in the UCRS, where the vertical hydraulic conductivity is 3 orders of magnitude less (direction of groundwater flow), so that the treatment volume above 19.8 m (65 ft) is modeled with no groundwater flow.

The study resulted in a technical approach for the PGDP C-400 Complex similar to other Electro-thermal Dynamic

[1] Calculated flow rates assume the RGA hydraulic conductivity is 425 ft/day (the value assigned to the C-400 area in the PGDP groundwater flow model), the porosity is 0.25 (value commonly used in site contaminant transport modeling) and the gradient in the upper RGA is 3.8E-04 and the gradient in the lower RGA is 1.0E-03. (Gradients are documented by comparison of monitoring wells at the southeast corner of C-400 and northwest of C-400, along the pathway of the Northwest Plume.) These compare to flow rates of 2.7 to 2.8 ft/day in the off-site Northwest Plume, as determined by definitive TCE trends related to startup of the Northwest Plume Extraction Well Field, where the hydraulic conductivity is very high.

Stripping Process (ET-DSP™) DNAPL projects with specific regard to the following design issues:

1. Treatment using ET-DSP™ and extraction systems is confined to three areas of the site defined by the Dense Non-aqueous Phase Liquid (DNAPL) distributions. Remediation is to occur along existing infrastructure with minor impact on ongoing operations at PGDP.

2. The ET-DSP™ treatment volumes extend below surface from 5.5 m (18 ft) to a maximum depth of 30.5 m (100 ft) below ground surface (BGS)[2]. Due to the presence of buried utility lines at 3.0 m (10 ft) BGS, only Soil Vapor Extraction (SVE) operations will be permitted for treating impacted areas above the 5.5 m depth.

3. Electrical and hydraulic properties of the soil are variable through several layers in the treatment volume. The upper portion of the treatment volume consists of Upper Continental Recharge System (UCRS) deposits of clay, silty sand and gravel. The lower portion includes the sand and gravel layers of the Regional Gravel Aquifer (RGA) and silty sand in the upper 1.0-2.5 m (3.3-8.2 ft) of the McNairy formation.

4. There is significant groundwater flow in the RGA that may affect electrical heating performance. This will require additional thermal energy to heat the soil where this flow enters the treatment volumes.

5. Hydraulic control will be maintained at all times during remedial operations, and

6. The heating strategy and treatment operations must minimize the overall energy consumption of the project.

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[2] The maximum depth of the Continental Deposits above the McNairy Formation.

The results of this study indicate that an ET-DSP™ configuration of 369[3] electrodes and 80 extraction locations including 28 MPE wells with groundwater extraction capability[4] will provide the capability to adequately heat the treatment volume and achieve criteria for ceasing operations in 240 days or less.

The layout of the electrodes and extraction wells is an optimal configuration to meet the remediation goals as previously defined in Section 3 of the Remedial Design Report. This report provides the results of a numerical simulation study for the PGDP C-400 Complex to support design recommendations for the technical approach.

[3] The electrode locations are configured in layers with one to five electrodes per well to target the three treatment volumes.

[4] The extraction system consists of 28 dedicated extraction well borings and 52 extractors placed above the top electrode at electrode wells within the treatment areas.

Table 1-1 presents a summary of the project details and physical site parameters that were used in the numerical simulation. Note that the calculations used to determine the volumes are presented in Appendix B. The calculation of areas was determined by overlaying the different plumes on top of each other and determining the overall footprint. The temperature response is measured in the laboratory; this multiplying factor represents the decrease in electrical resistivity as the soil is heated from ambient conditions to the boiling point of water. Other values such as hydraulic conductivity, permeability, and porosity were provided by PRS. Values for heat capacity and thermal conductivity were obtained from the public domain.

Additional data were obtained from professionals at PRS and laboratory tests performed by McMillan-McGee. The soil properties are fully represented in the figures of Section 2, but are summarized for the treatment volume as follows (all depth measurements are approximate):

Table 1-1: Paducah C-400 Project and Site Characteristics

Item	SE Area	SW Area	East Area	Comments
Treatment Area	1,490 m^2	649 m^2	661 m^2	Composite of plume areas Total area – 2,800 m^2
Heated Volume	10,398 m^3 12,973 m^3 23,371 m^3	5,564 m^3 3,254 m^3 8,818 m^3	4,519 m^3 1,007 m^3 5,526 m^3	Total Vadose – 20,481 m^3 Total Saturated – 17,234 m^3 Total Heated – 37,715 m^3
Deep Extent	30.5 m	24.4 m	18.3 m	Maximum
Shallow Extent	5.5 m BGS			Utilities at 3.0 m BGS
Groundwater	16.8 m BGS			Client data
Contaminants of Concern	TCE and breakdown products			Client data
Soil Resistivity	38 to 108 Ω•m			Measured data[5]
Temperature Response	3.15 (Initial Ω•m /Minimum Ω•m)			Decrease in resistivity
Hydraulic Conductivity (cm/s) Vertical/Lateral	Silt/Sand/Gravel, 5.8-11.6 m BGS: 3.0E-5 / 3.0E-3 Clay, 11.6-20.4 m BGS: 5.0E-7 / 3.0E-5 Gravel, 20.4-26.8 m BGS: 7.5E-2 / 1.5E-1 Sand/Silt, 26.8-30.5m BGS: 1.6E-7 / 6.3E-6			
GW Flow Velocity	2.1E10-2 cm/s (1 ft/day) – expected RGA flow velocity 6.4E10-2 cm/s (3 ft/day) – upper limit for RGA flow velocity			
UCRS Permeability	300 mD to 30,000 mD			
RGA Permeability	150,000 mD			
Porosity	0.30 to 0.35			
Saturation	Saturated zone – 100% Unsaturated zone – 40%			
Heat Capacity	Hydrocarbon – 1.40 kJ/kg/°C Water – 4.19 kJ/kg/°K Rock – 0.84 kJ/kg/°C			
Thermal Conductivity	Water – 67.96 kJ/m/°C/day Rock – 466.3 kJ/m/°C/day			

1. The UCRS extends from surface to 19.8 m (65 ft) BGS and consists of up to three layers of Upper Continental Deposits in the treatment volume:

    a. An upper gravel layer may appear from 5.8 m to 8.8 m (19 to 29 ft) BGS, with a high electrical resistivity of 108 Ω•m,

[5] Data provided in an attachment to this Numerical Simulation Report.

   b. Mixed sand and silt from 8.8 m to 11.6 m (29 to 38 ft) BGS, with a resistivity averaging 58 Ω•m, and

   c. Clayey-silt from 11.6 m to 19.8 m (38 to 65 ft) BGS, with a resistivity of 38 Ω•m

2. In the UCRS, the lateral hydraulic conductivity for the gravel, sand and silt is estimated at 3.0E-3 cm/s, while the clay layer has a lower hydraulic conductivity of 3.0E-5 cm/s. The simulation accounts for the decrease in viscosity of the water with temperature (there is a three-fold decrease in viscosity from 20 ˚C to 90˚C).

3. The RGA extends from 18.3 m to 29.0 m (60 to 95 ft) BGS, consisting of gravel of the Lower Continental Deposits. This zone has a high resistivity of 103 Ω•m with a hydraulic conductivity about 1.5E-1 cm/s.

4. The section of the McNairy Formation specified for treatment covers a maximum depth range of 29.0 m to 30.5 m (95 to 100 ft) BGS and contains a sand and silt mixture with a resistivity of 58 Ω•m and a low hydraulic conductivity of 6.3E-6 cm/s.

5. As the site is heated, the electrical resistivity decreases by a minimum factor of three and the permeability of clay layers increases. At some sites the permeability increases by a factor of ten[6] due to heating. This magnitude of permeability increase is not predicted for the RGA because the flow occurs in a gravel zone. However, permeability of the UCRS may increase, although, the simulation did not assume any increase.

Table 1-2 summarizes the design components for the technical approach.

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[6] Decreases in electrical resistivity measured in the Mc2 Electro-thermal Lab and increases in permeability based on field experience at other sites.

Table 1-2: Summary of the Technical Approach

Item	SE Area	SW Area	East Area	Comments
ET-DSP™ Electrodes	245	85	39	1-5 electrodes stacked, 369 total
ET-DSP™ PDS Units	11	4	2	660 kW, 17 total
Electrode Spacing	6.1 m			spacing varies
Electrode Vertical Placement – BGS Depths of Electrodes				
Deep RGA Electrode	27.5 to 30.5 m		-	Will provide heating influence 2 to 3 ft into McNairy Formation
Shallow RGA Electrode	21.5 to 24.5 m		-	
Deep UCRS Electrode	16.0 to 19.0 m			
Middle UCRS Electrode	11.0 to 14.0 m			
Shallow UCRS Electrode	5.5 to 8.5 m			No heating above 5.5 m BGS
Target Temperature	90 °C - vadose zone 87 °C -115 °C - saturated			varies with zone and with depth below water table
MPE Wells	19	6	3	Depths vary, 28 total
Vacuum Piezometers (Contingency vapor recovery wells)	7	2	1	Limited to vadose zone, 10 total
Electrode XE-Wells	34	13	5	Above upper electrode, 52 total
Water Injection Temp.	20°C			Water injected to electrodes
Water Injection (GPM)	40.0	15.8	7.8	Delivered via WCS
Liquid Extraction (GPM)	51.0	20.3	8.2	Extraction based on 5% more than injection plus 9 gpm in SE and 3,7 gpm in SW (1 ft/day groundwater flow)
Vapor Recovery Rate (SCFM)	460 732	216 320	108 148	~ 800 scfm total, XE-Wells off ~1,200 scfm total, XE-Wells on
Time to Reach Average Temperature	~ 90 days			Estimate from simulation

1.1. Numerical Simulation Results

The results of the numerical simulation are summarized in Tables 1.3 and 1.4. Table 1.3 provides the energy required to heat the zones, assuming stagnant groundwater flow conditions.

Table 1-4 lists the energy required to heat the subsurface for groundwater flow conditions of 1 ft/day (expected condition), 3 ft/day, and 6 ft/day. Note that the 2-D simulation runs showed the design would not adequately heat the RGA under conditions of 6 ft/day flow velocity. The power per electrode shown in Table 1-4 reflects the power levels that would be needed to heat the RGA, although, the design could not deliver the power levels required for a 6 ft/day flow velocity.

Simulation of the Southeast area is based on a two-part model of the UCRS and RGA geological units. Simulation results for the UCRS and RGA in the Southeast area are extrapolated to the Southwest and East areas. Based on past experience and given the relatively uniform soil properties at the C-400 site, direct volumetric scaling of the Southeast area model will provide sufficiently accurate results for determining operational parameters of the other two areas.

Table 1-3: Summary of numerical simulation results for the Paducah C-400 Project

Treatment Area	SE Area	SW Area	East Area	Units
Electrical				
Electrical Energy	6,594	2,288	1,049	mW-h
Average Power	1.526	530	243	kW
Energy Density	~290	~260	~190	kW-h/m³
Peak Power	1,980	689	315	kW
Operations				
Total Liquids Injected	39,247	15,503	7,653	m³
Total Liquids Produced	50,040	19,917	8,035	m³
Electrode Injection Rate	0.1 to 0.2	0.1 to 0.2	0.1 to 0.2	gpm
Extraction Well Rate	2.7	3.4	2.7	gpm
X-Well Vapor Flow Rate	20.0	36.0	36.0	scfm/well
XE-Well Vapor Flow Rate	8.0	8.0	8.0	scfm/well
Produced Energy (energy from vapor and groundwater extraction)	2,641.8	761.9	346.5	mW-h

Note: Energy values assume stagnant groundwater conditions

Table 1-4: Energy Required for RGA Groundwater Flow Scenarios

Southeast Area					
	Stagnant	**1 ft/day**	**3 ft/day**	**6 ft/day**	**Units**
Average total power level	1,526	1,716	2,094	2,851	kW
Power level per RGA electrode	6.2	8.1	12.8	18.8	kW
Power level per UCRS electrode	6.2	6.2	6.2	6.2	kW
Total energy	6,594	7,411	9,046	11,499	mW-h
Total energy in UCRS	3,832	3,832	3,832	3,832	mW-h
Total energy in RGA	2,762	3,579	5,214	7,667	mW-h
Southwest Area					
	Stagnant	**1 ft/day**	**3 ft/day**	**6 ft/day**	**Units**
Average total power level	530	608	766	1,003	kW
Power level per RGA electrode	6.2	9.8	17.0	27.7	kW
Power level per UCRS electrode	6.2	6.2	6.2	6.2	kW
Total energy	2,288	2,628	3,310	4,332	mW-h
Total energy in UCRS	1,619	1,619	1,619	1,619	mW-h
Total energy in RGA	668	1,009	1,690	2,712	mW-h

1.2. Recommendations

In summary, based on the results of the numerical simulation study, the following recommendations are put forward for the design of an ET-DSP™ system for the Paducah C-400 Project (refer to drawings in Appendix C for details on subsurface layout):

1. Three arrays of 3.0 m (10 ft)-long electrodes will be configured to remediate the full treatment areas defined by the NAPL distribution. One to five electrodes will be stacked to cover the vertical extents of the treatment volume at each well location. For effective remediation, the Southeast, Southwest, and Eastern treatment areas of the site require a total of 369 electrodes in 110 boreholes.

2. The results of the numerical simulation calculations indicate that for optimum heating, the perimeter electrodes need to be operated at 20 to 30 % greater power per electrode than the interior electrodes. This was a result of the high hydraulic conductivity of the soil and associated water inflow while maintaining hydraulic control.

3. The number of electrodes relative to the total treatment volume is increased to ensure the capture of rising vapors from above the saturated zone in the Southeast area. As well, relatively more electrodes are needed to compensate for the proportionally large surface area of three separate treatment areas with varied volumetric shapes (resulting in greater exposure to cooling effects from the surrounding unheated soil). However, delineating the treatment volume according to the known contaminant distribution at each depth results in more efficient use of these electrodes.

4. Due to extensive utility lines present down to 3.0 m (10 ft) BGS, the uppermost electrodes will be placed to limit the heating influence to below this depth and minimize interference with existing electrical systems. Step potential tests during commissioning and operation of the ET-DSP™ system will verify surface voltages are limited to safe levels (less than 15 V).

5. Seventeen 660 kVA Power Delivery System (PDS) units will provide power to the electrodes. Each PDS is capable of independent power control to each electrode via internet control.

6. Electrical conductivity of the soil and heat transfer by convection will be maintained at all electrodes using fifteen Water Circulation System (WCS) units. Water injection to each electrode will vary between 0.1 and 0.2 gpm. Injection rates in the saturated zone are lower than in the unsaturated zone. Rates are generally 0.1 gpm in the saturated zone and 0.2 gpm in the unsaturated zone. Actual injection and extraction rates during operations will be adjusted to maintain hydraulic control.

7. The Multi-Phase Extraction (MPE) system will consist of vertical wells installed within the electrode arrays at depths corresponding to the defined contaminant distributions. The Southeast area requires 53 extraction points, including 19 MPE wells and 34 vapor extractors installed at 4.0 m (13.1 ft) BGS in the electrode wells. The Southwest area requires 6 MPE wells and 13 electrode well vapor extractors. The East area is a shallow contaminated soil zone that requires 3 MPE wells and 5 electrode well vapor extractors. The extraction system will remove volatilized contaminants from the heated zone.

8. The average vapor extraction rate for each deep extraction wells in the Southwest and East areas is 36 standard cubic feet per minute (scfm) and 8 scfm for each shallow extraction well co-located with an interior electrode. This rate was used in the numerical modeling. Due to an increased number of vapor extraction points in the Southeast, the average vapor extraction rate for wells screened over the entire UCRS was estimated at 30 scfm. Five wells only have vapor screens at the bottom of the UCRS (X07 – X11) and a flow rate of 8 scfm was assumed for these wells. Total vapor extraction rates will not exceed 1,200 scfm.

9. The total liquid flow rate from all the MPE wells is estimated at 79.5 gpm during treatment. However, because the remediation will occur in phases, i.e., first the Southwest and East and then the Southeast, the maximum extraction rate at any one time will be 51 gpm. The extraction rate from the Southeast and Southwest areas includes the RGA groundwater flow, assumed to have a flow velocity of 1 ft/day. These extraction rates will ensure that all volatilized contaminants are captured and hydraulic control is maintained during ET-DSP™ operations.

10. Vapor extraction from the shallow extraction wells co-located with interior electrodes are not operated until after 60 days of ET-DSP™ operations are completed. This approach will ensure that target temperatures are achieved in the upper strata of the UCRS. Operating these shallow extractors before the UCRS achieved target temperatures would remove too much energy from the subsurface and make it harder to reach target temperatures. As a contingency, if monitoring at the surface and in the vicinity of site workers indicates that VOC vapors are migrating to the surface and are becoming a safety concern, the shallow vapor extractors will be put into service.

11. Within the heated areas, Digital Temperature Acquisition Module (digiTAM™) strings will be installed in at least 47 sensor wells. Each digiTAM™ will be constructed to monitor temperatures for the full treatment depth at each sensor well location. This data will be used to ensure target temperatures are achieved and maintained in the soil and that heat transfer to surface is safely controlled.

12. The simulation study assumed ET-DSP™ operations for 180 days, including the initial period of heating to target temperatures. Due to the potential for Dense Non-Aqueous Phase Liquid (DNAPL) mass removal rates exceeding the capacity of surface facilities, an additional two months of operations may be necessary to achieve the cleanup goals.

2. Discussion

The ET-DSP™ system is:

1. *Designed to vaporize the TCE*
2. *Installed along existing infrastructure*
3. *Controlled remotely, and*
4. *Monitored via the internet.*

The C-400 Complex is located at the Paducah Gaseous Diffusion Plant west of Paducah, Kentucky. Trichloroethylene (TCE) is the primary contaminant of concern for the areas to be remediated. The three treatment areas of the site vary in contaminant distribution, but all areas are impacted from surface to 18.3 m (60 ft) BGS or deeper. High TCE concentrations are spread over a wide area of the Southeast corner of C-400 and extend to the McNairy Formation at 30.5 m (100 ft). The Southwest corner covers a smaller area and the NAPL distribution is confined above 24.4 m (80 ft) in the RGA. The East contaminant zone from Solid Waste Management Unit 11 (SWMU-11) includes NAPL migration over a significant area of the UCRS clay layer at 12.2 to 18.3 m (40 to 60 ft) BGS and extends from surface to the 18.3 m depth directly under the SWMU-11 location. The electrical resistivity varies from 38 Ω•m for the clay to 108 Ω•m for the UCRS gravel. The various soil layers for the three treatment volumes are represented in Figure 2-1 through Figure 2-3. Figure 2-4 shows a north-south cross section to a depth of approximately 230 ft bgs.

ET-DSP™ is the enhanced electro-thermal soil remediation process selected for this project. This technology makes use of custom constructed electrodes installed in the subsurface with a standard drill rig. Applying a voltage between electrodes induces electrical current in the soil, which generates heat in-situ to mobilize contaminants for recovery by an extraction system. ET-DSP™ makes use of standard three-phase electrical power from the utility. Each electrode is assigned as an A-, B-, C-phase such that optimal electrical and heating performance is achieved.

The remediation goal for the Paducah C-400 Project as well as the criteria for ceasing operations is presented in Section 3 of the Remedial Design Report.

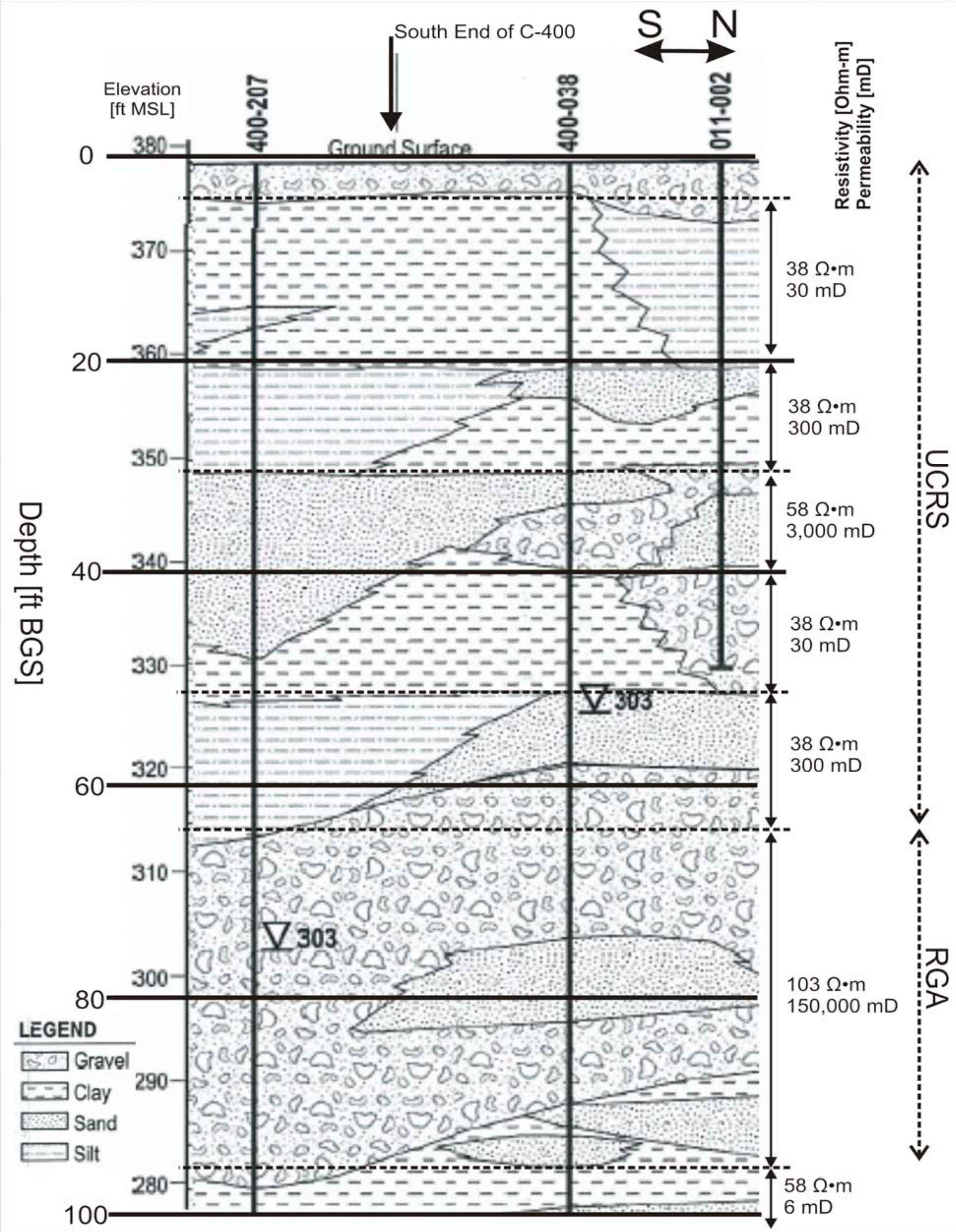

Figure 2-1: Soil profile of the C-400 Southeast corner

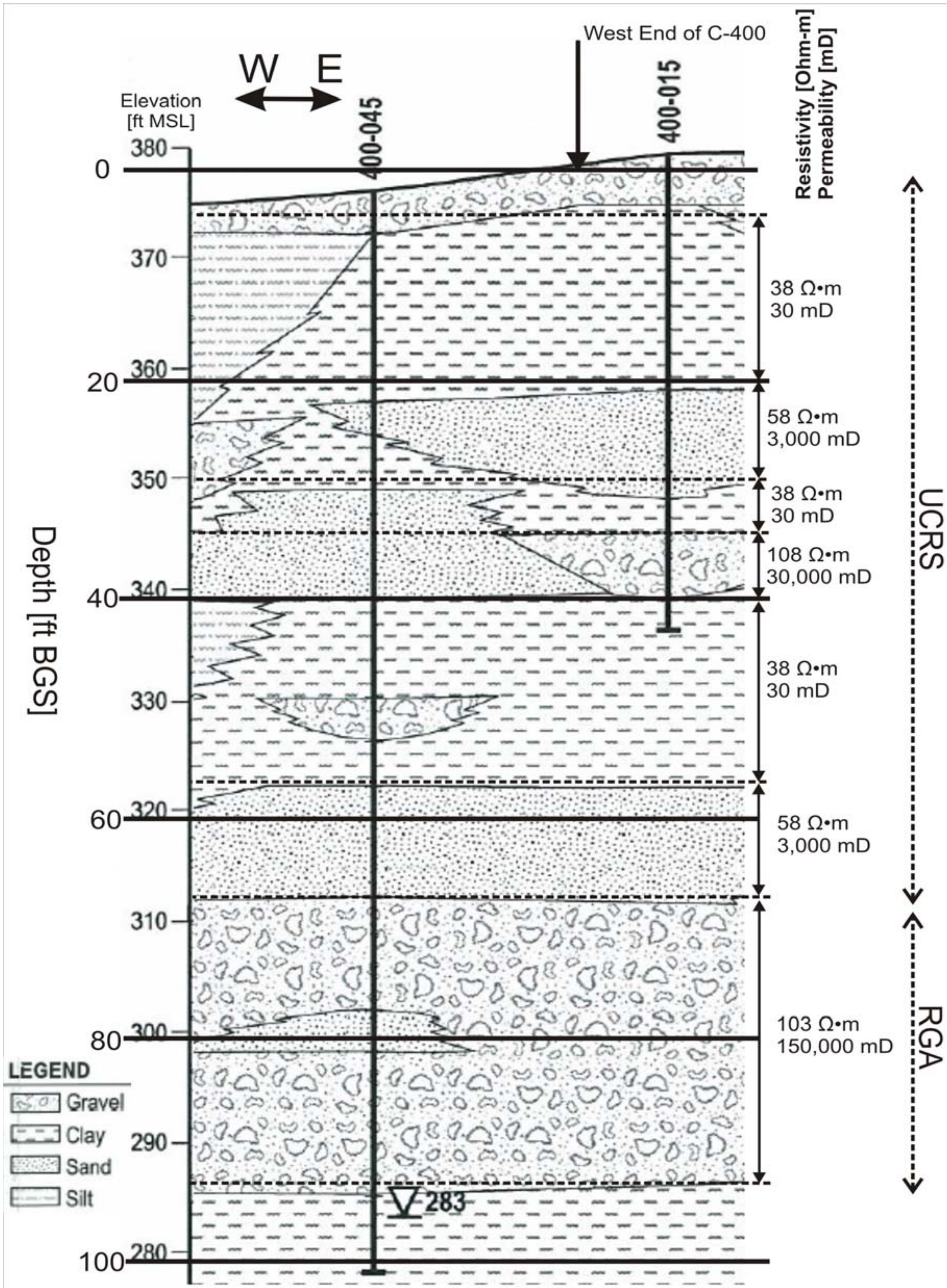

Figure 2-2: Soil profile of the C-400 Southwest corner.

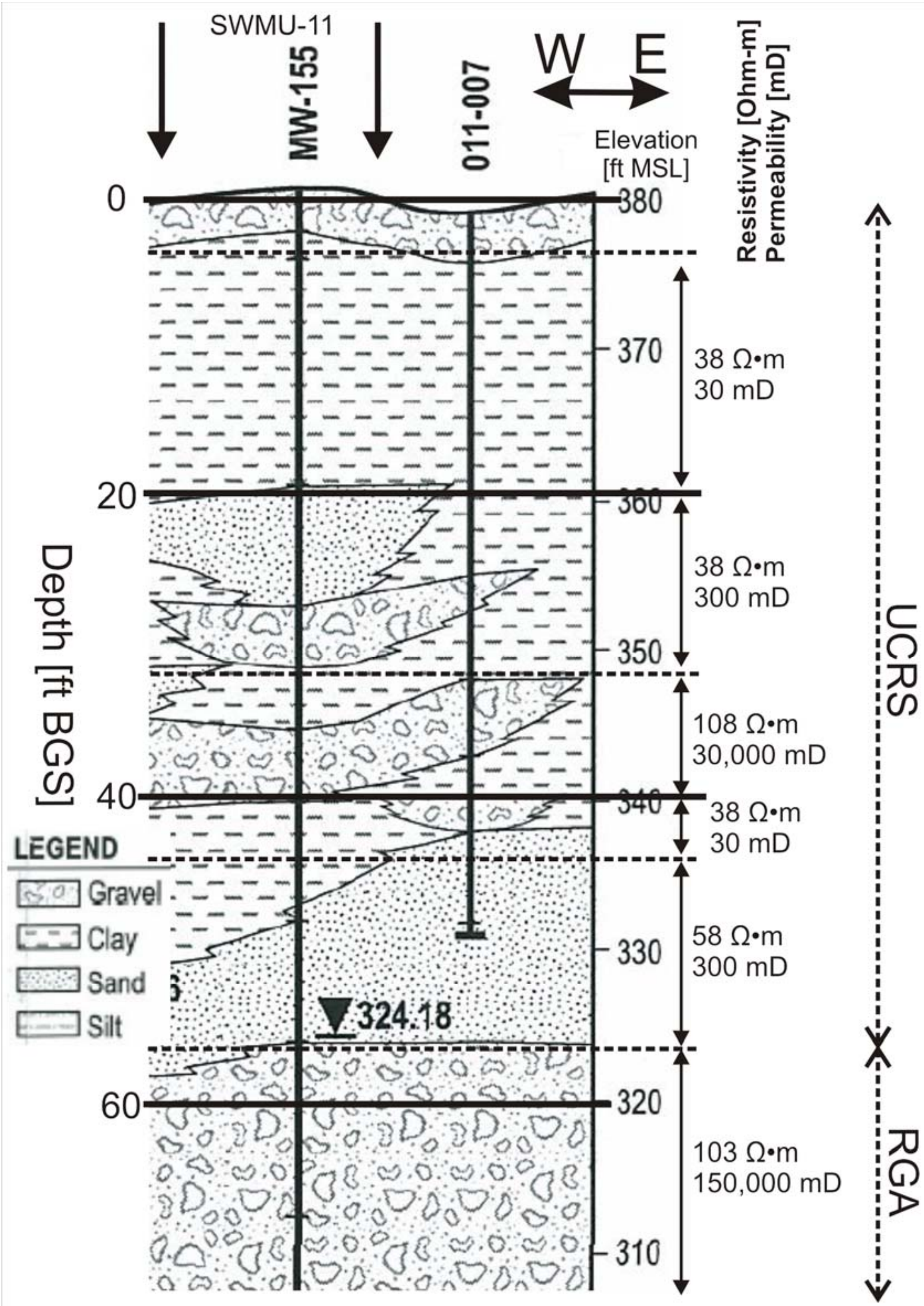

Figure 2-3: Soil profile of the SWMU-11 East area

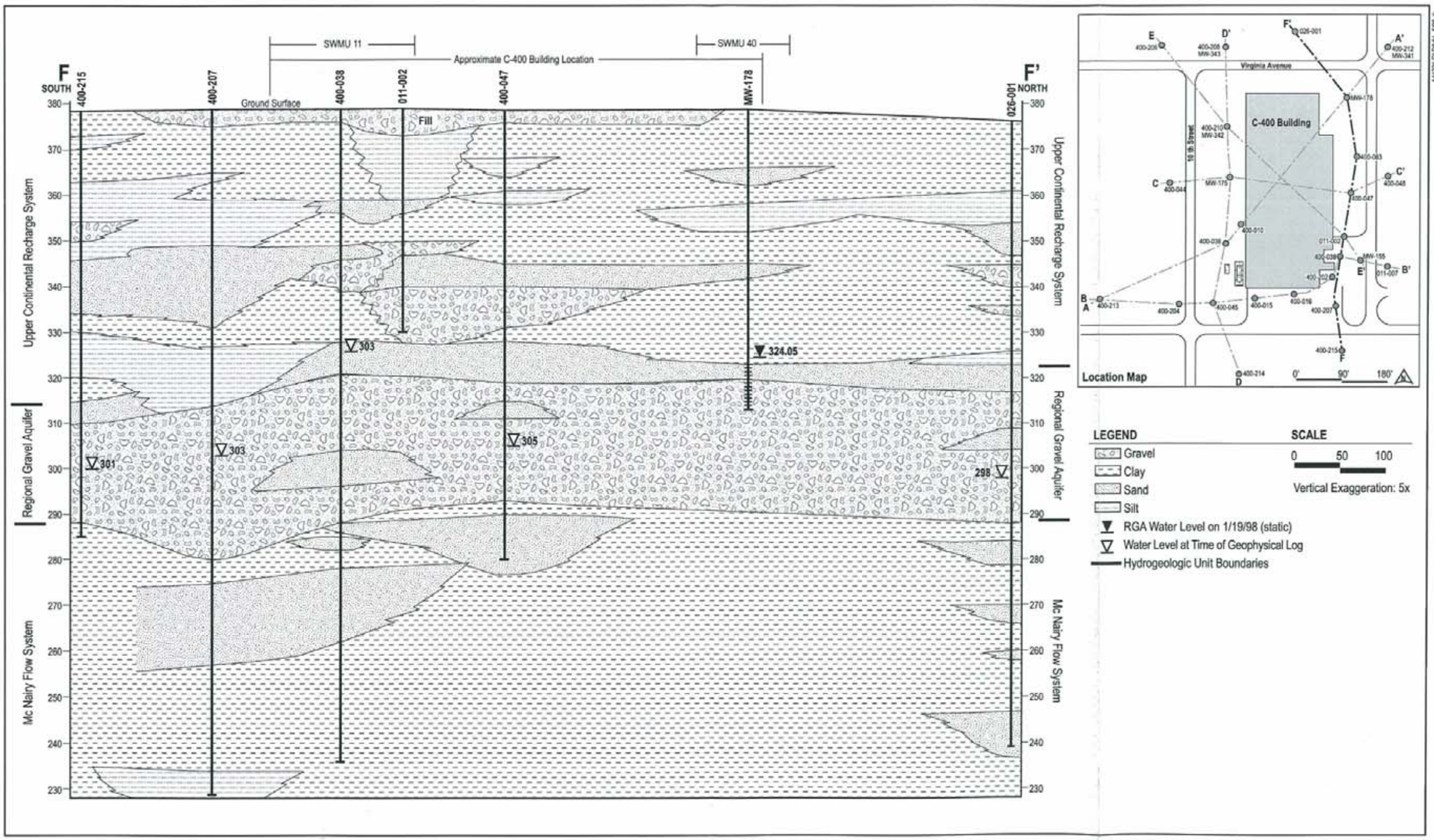

Figure 2-4 North-South Cross Section

Figure 2-5 through Figure 2-8 show the plan view layouts of extraction wells (blue) and electrodes (red) for thermal treatment at the PGDP C-400 Complex. The contour lines in the figures define the treatment zones at the four 6.1 m (20 ft) depth intervals defined for treatment. The detailed plan view drawings are provided in Appendix C. The application of ET-DSP™ for the site is designed to ensure sufficient heating to volatilize TCE in the soil. Detailed information with respect to the geology and hydro-geology of the site and history of operations are documented by PRS. The radius of capture for the extraction wells was calculated at 7.9 m (25.9 ft) is shown for one of the extraction wells.

The precise well field layout is provided in the site drawings, which also include the subsurface and above ground obstructions that have been considered in the design. Modifications to the well field layout during later stages of the project should be made according to Mc^2 guidelines to maintain safe and effective operation of the overall system.

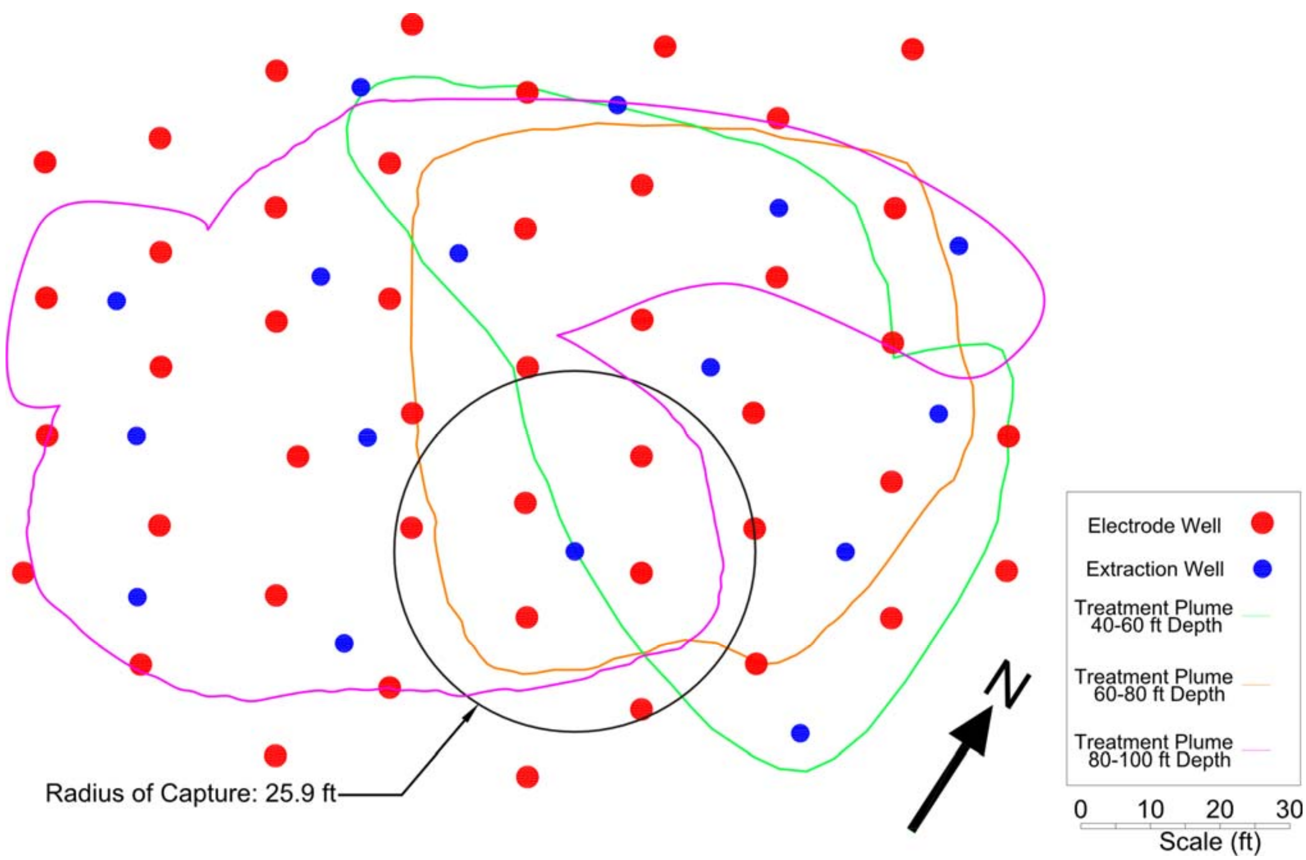

Figure 2-5: Layout of electrodes and extraction wells in the RGA for the Southeast Treatment Area.

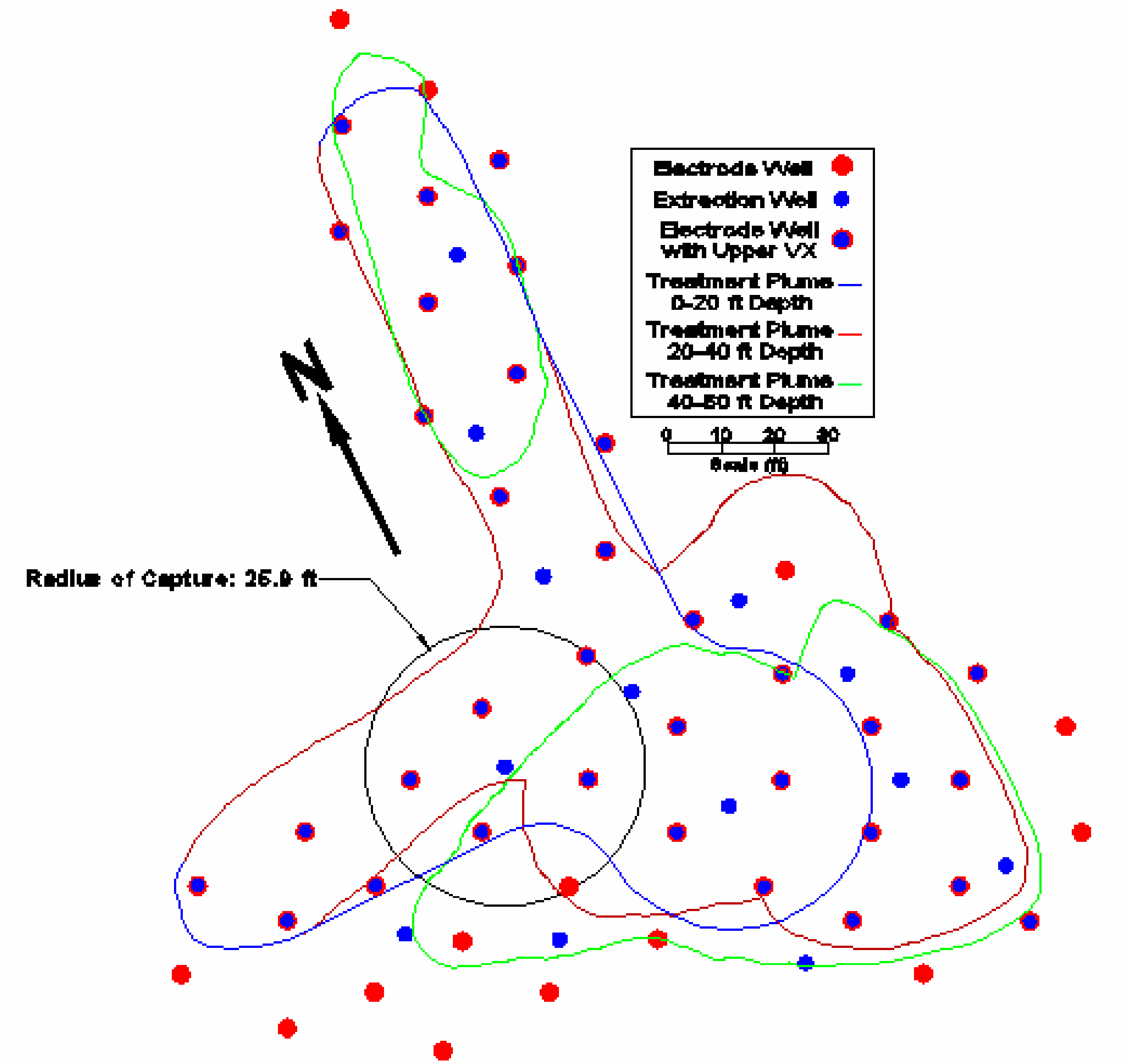

Figure 2-6: Layout of electrodes and extraction wells in the UCRS for the Southeast Treatment Area.

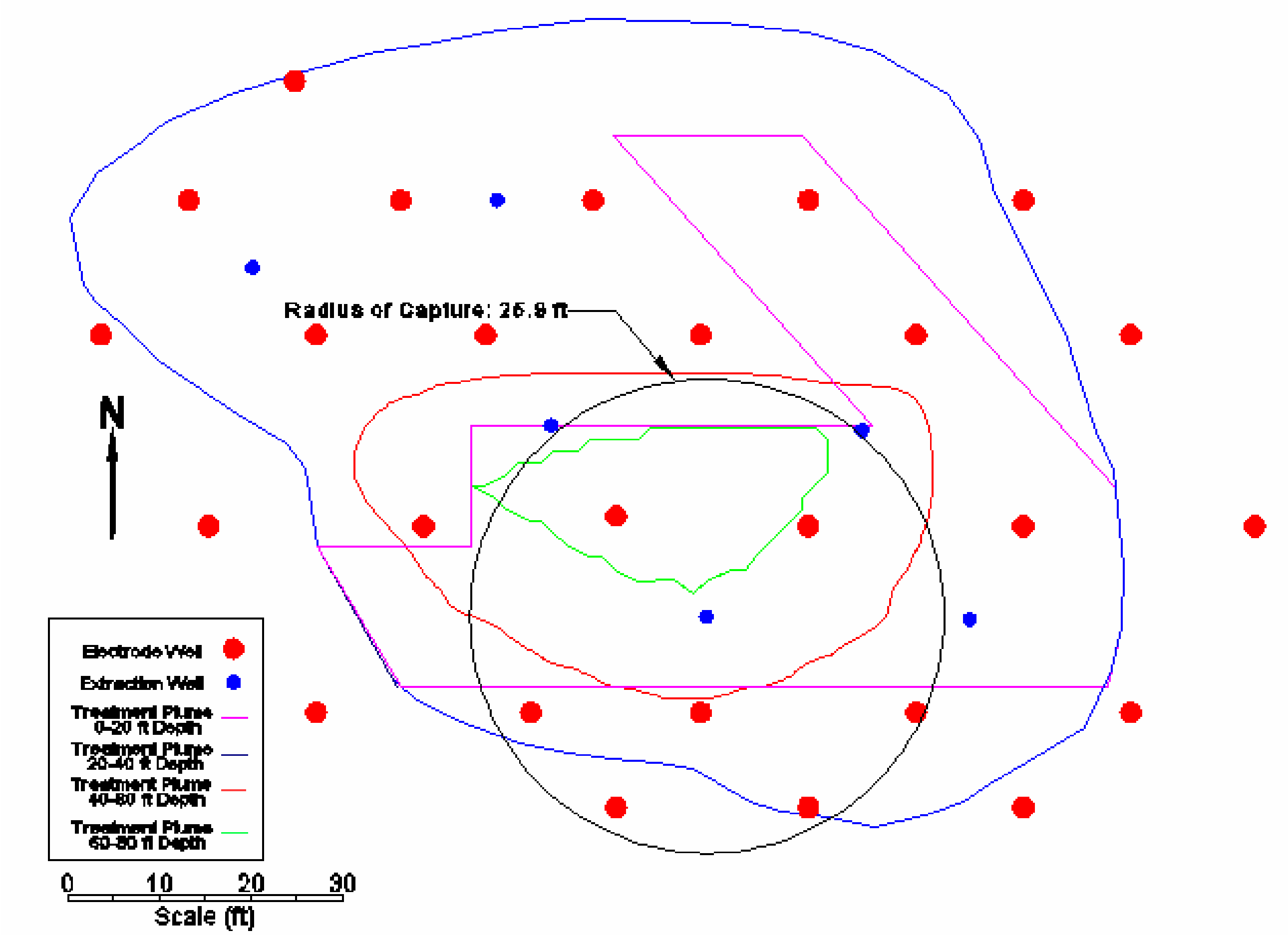

Figure 2-7: Layout of electrodes and extraction wells for the Southwest Treatment Area.

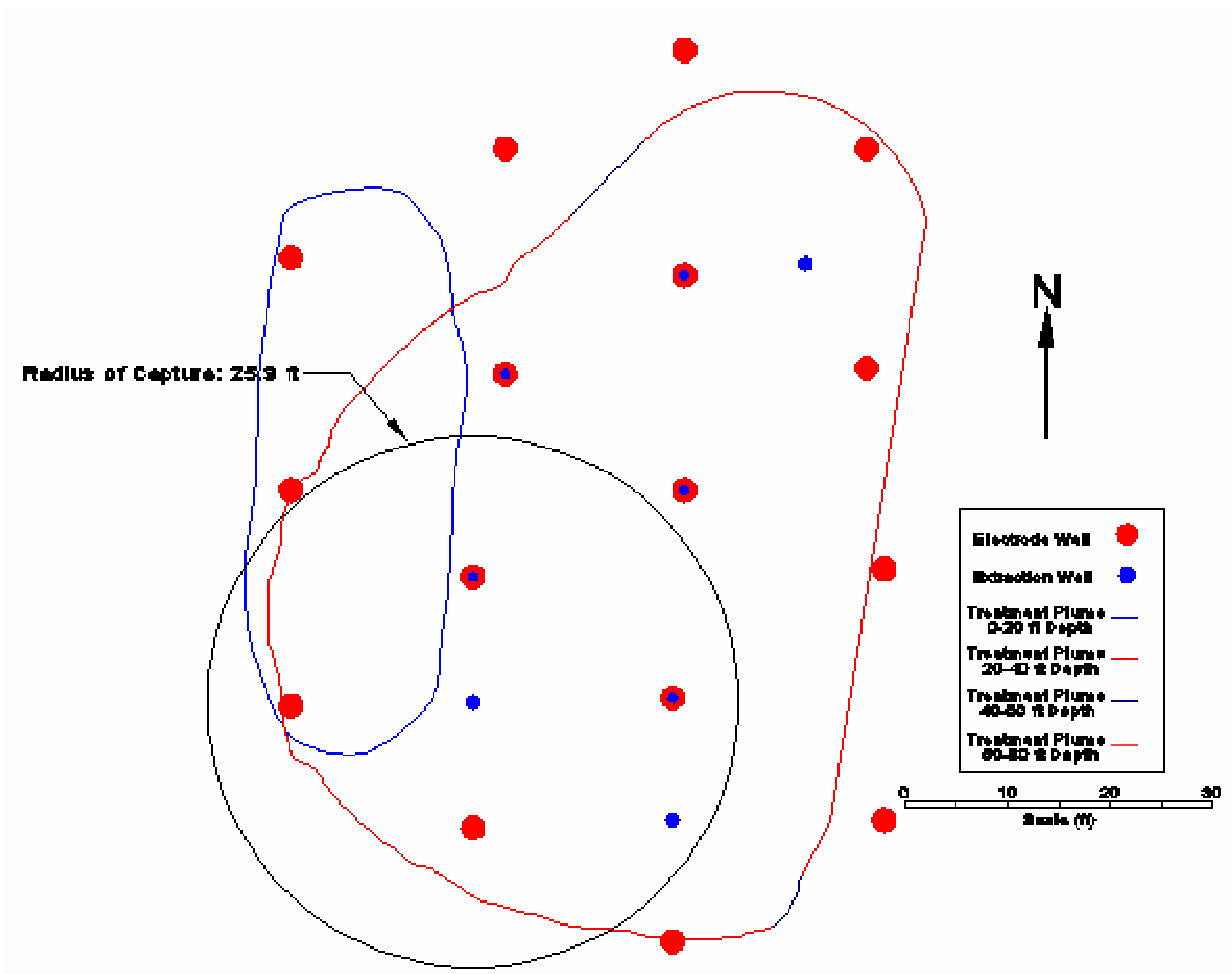

Figure 2-8: Layout of electrodes and extraction wells for the East Treatment Area.

The electrode wells are configured as shown for the following reasons:

1. The electrode arrays are configured for heating of the full treatment volume. The outermost electrodes have large enough radius of influence to effectively treat the remediation boundary.
2. The spacing between electrodes is determined by simulation results for given soil properties, and
3. Although the soil varies greatly among layers, the properties are well defined in the three treatment areas and full power and moisture control at each electrode will compensate for these variations.

The extraction wells are located as shown for the following reasons:

1. The extraction wells are distributed within the electrode array for targeted extraction rates as needed, and
2. The well spacing is designed for rapid removal of contaminants from the soil and therefore prevents redistribution of the chemicals outside of the heated volume.

Figure 2-9 and Figure 2-10 show the vertical placement of electrodes and extraction wells in the RGA and UCRS for the Southeast treatment area. Electrodes are placed at given depths according to the heating requirements of the NAPL distribution at each well location. Similarly, the extraction wells are constructed to recover contaminants according to the contaminant depth at each extraction location. Extraction wells extending into the RGA will require liquid extraction capability. Most electrode wells internal to the treatment plumes at the UCRS, vapor extractors are placed in the well above the uppermost electrode.

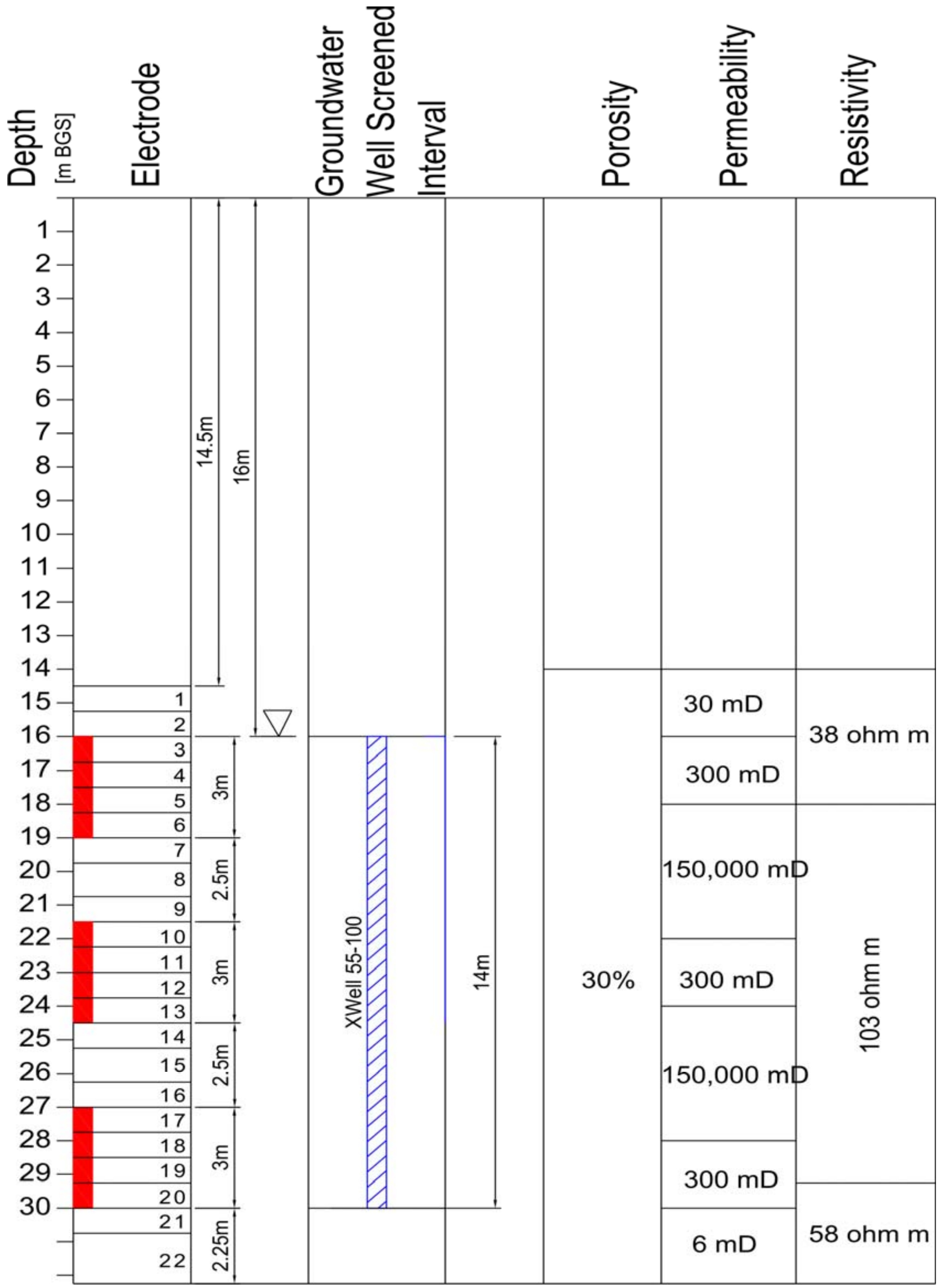

Figure 2-9: Southeast Treatment Area - Downhole Placement of Electrodes and Extraction Wells in the RGA and Saturated Portions of the UCRS.

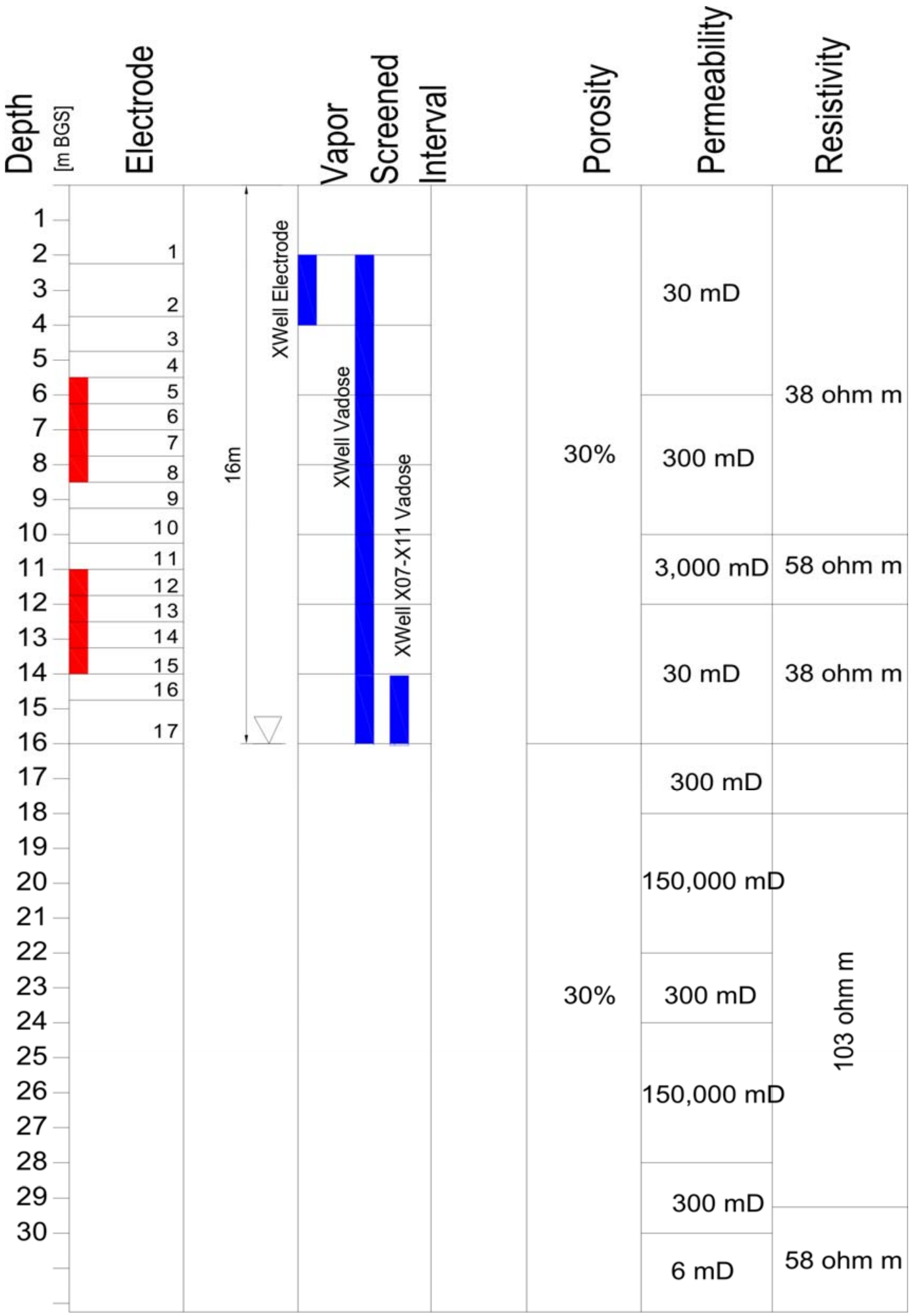

Figure 2-10: Southeast Treatment Area - Downhole Placement of Electrodes and Extraction Wells in Unsaturated Portion of the UCRS.

The electrodes and extraction wells are placed vertically as shown for the following reasons:

1. For all areas, the principal contaminant migration path has been downward with the chemicals largely contained above a certain depth. For the Southeast Corner the contaminants are concentrated above the McNairy Formation, for the Southwest corner contaminants reach the RGA in the center region of the treatment zone, and for the SWMU-11 East Treatment Area contaminants are contained within the UCRS.

2. Placement of the stacked 3.0 m (10 ft) electrodes in five layers results in heating from 6.1 to 30.5 m (20 to 100 ft) where required. Treatment of the RGA and upper McNairy formations requires electrical heating from the water table to the bottom of the NAPL distribution to prevent condensation and re-distribution of contaminants in the groundwater prior to capture by the MPE system.

3. The stacked electrode arrangement allows each layer of electrodes to be operated separately for the various soil types through the treatment depths. ET-DSP™ controls are designed to respond to variable soil properties across the site.

4. The vertical placement of the extraction wells provides a mechanism to ensure the capture of volatilized chemicals as contaminants are mobilized from each layer of the treatment volume.

Real time subsurface monitoring of the remediation process will consist of:

1. A minimum of 47 digiTAM™ temperature sensor strings, and

2. Ten Digital Pressure Acquisition Module (digiPAM™) pressure sensors to monitor hydraulic control.

2.1. Numerical Study

Design Issues:

1. *Electrode Well Spacing*
2. *Energy & Power*
3. *Extraction Strategy*
4. *Temperature Control*

In designing this system, McMillan-McGee has used all relevant information available, including results from recent electrical resistivity testing and soil analysis work (Mc², October 2006) and communications with PRS professionals. The following are addressed in the electro-thermal treatment design:

1. Operating strategy for the safe and effective deployment of thermal energy to the soil, contaminants, and groundwater.
2. Optimal well-field layout and specifications for down hole components (electrodes, extraction wells, and sensors inside the treatment volume).
3. Determination of operating parameters such as water usage and energy consumption, and other electrode, extraction and steam requirements.

The placement of the extraction and electrode wells is described in Section 2. Electrodes are placed to ensure complete vertical heating of the treatment volumes in accordance with the remediation objectives. Water and contaminants are known to occupy the pore volume of soil in varying concentrations (saturations) and reside at depths limited in vertical extent according to data provided by PRS. The numerical simulation will characterize heat transfer in the soil for the in-situ thermal remediation process. The scope of the ET-DSP™ numerical simulation is as follows:

1. Using measured soil properties, determine the configuration of electrodes and extraction wells to heat the remediation areas described in Section 2, through the extent of the specified treatment depths, from approximately 5.5 m BGS to the bottom of each of the three contaminant volumes.
2. Estimate and provide recommendations for site operating parameters:
   a. ET-DSP™ water injection rates,
   b. Water extraction rates,
   c. Duration of heating,
   d. Energy requirements,

e. Power requirements, and

3. Engineering and operational data for implementation of ET-DSP™.

Simulation results for the UCRS in the Southeast area are used to establish these parameters for the Southwest and East areas. The soil properties are relatively uniform across the site such that direct volumetric scaling of the Southeast area model will determine the preceding design parameters for the other two areas.

The model also included the layout of the SVE wells and operating strategy to recover contaminants from the region from surface to 5.5 m (18 ft) BGS.

The simulation study was performed using TETRAD, a commercial numerical simulation program mathematically modified to model electro-thermal processes. Attachment A of this appendix presents a more detailed discussion of the TETRAD model. Average water saturation, hydraulic conductivity, contaminant concentration, and porosity data provided in various client reports were used in the input data set. Other soil properties, including electrical resistivity as a function of temperature, were measured in the Mc^2 laboratory. The laboratory report for the soil resistivity is included as an attachment. Other data (relative permeability, coefficient of thermal expansion, etc.) were obtained from the public domain or the McMillan-McGee database.

3. Results

3.1. Simulation Results Summary

Numerical simulation of the C-400 project consisted of a two-part model of the Southeast area. For the RGA a groundwater flow velocity of 1 ft/day is appropriately represented in the model. The groundwater is largely stagnant in the UCRS so that the upper 60 ft of the treatment volume is modeled with no groundwater flow. A more in-depth discussion of the 2-D modeling conducted for the RGA in the Southeast area is included as an appendix to this report.

As the soil properties are relatively uniform across the site, design parameters for the Southwest and East areas were extrapolated from the UCRS model of the Southeast area. Installation and operational parameters for individual subsurface components determined for the Southeast area of the UCRS from the model are adapted to the contaminant distributions for the other two treatment areas. Based on past experience with numerical models in field applications, direct volumetric scaling of the model will provide accurate representation of heating trends and operational parameters for the entire site.

The study resulted in the following technical approach for the remediation of TCE and other hydrocarbons at the PGDP C-400 Complex:

1. 369 electrodes in 110 boreholes are required to provide thermal remediation of the three impacted areas in the vicinity of C-400. Up to five 3.0 m (10 ft) electrodes will be stacked at each of the well locations to heat from 5.5 m (18 ft) BGS to the bottom of each NAPL distribution.

2. The electrodes will be connected to 17 PDS units. Note that the number of PDS units in use at any one time will vary depending on the phasing of the project, i.e., which areas are remediated concurrently. The peak input power to each electrode is about 14 kW for the three treatment areas.

3. The total electrical energy consumed over 180 days of operations will 10,900 mW-h (based on 1 ft/day flow velocity in RGA).

4. The peak power is calculated to be about 2,984 kW with a project average power of 2,299 kW.

5. The cumulative water injected during ET-DSP™ operations in all three areas is 62,403 m^3 at an injection rate that varies between 0.1 to 0.2 gpm per electrode.

6. The average liquid phase extraction rate from each extraction well varies depending on location, 2.7 to 3.4 gpm. Total produced (extracted) water is estimated at 77,992 m^3. This volume assumes the expected groundwater flow of 1 ft/day will be extracted to maintain hydraulic control.

7. Twenty-nine extraction well borings have been included for capturing contaminants as they are vaporized from the soil and groundwater into a bubble or free vapor phase. 19 extraction borings are placed in the Southeast Corner, 6 extractors will operate in the Southwest Corner, and 3 extractors are planned for the East source area. Vapor recovery will be supplemented with 52 electrode well vapor extractors installed near the surface for all electrode wells internal to the UCRS treatment zones. The expected vapor extraction rate from each well is 36 scfm (absolute conditions) from the deep extraction wells during operations and 8 scfm from the electrode well vapor extractors after target temperatures are achieved.

8. Forty-seven digiTAM™ strings are proposed for subsurface temperature monitoring throughout the remediation areas. Ten digiPAM™ pressure sensors will be used to verify hydraulic control in the Southeast area.

3.1.1. Chemical Recovery Curve

Figure 3-1 shows the total rate of TCE mass recovery from the target volume. This is the total mass recovery curve for all of the areas combined. Simulation results predict that after 180 days of operation, more than 99% of the volatile organic compound (VOC) mass will be removed from the soil. Temperatures greater than 100 ºC will be achieved within 90 days, resulting in peak recovery rates during the 80 to 100 day operating period.

The mass recovery curve is the result of multi-function calculations in the thermodynamic model. These calculations account for the concentrations of the chemicals and water in the liquid and vapor phases as a function of temperature and pressure. The initial increase in mass recovery shown in the curve is the result of increasing vapor phase saturations as the soil approaches target temperature. As this mass is then extracted from the pore space, the relative concentrations of mass in the vapor phase decreases exponentially.

The numerical model does not account for bubble flow, which is the most likely mechanism of transporting mobilized DNAPL. Therefore, the curve calculated by the simulation is used to provide an estimate of the expected duration of treatment to achieve the remediation goals. The rate limitation of 500 lbs/hour imposed by the surface facilities increases the treatment duration from 180 to 240 days.

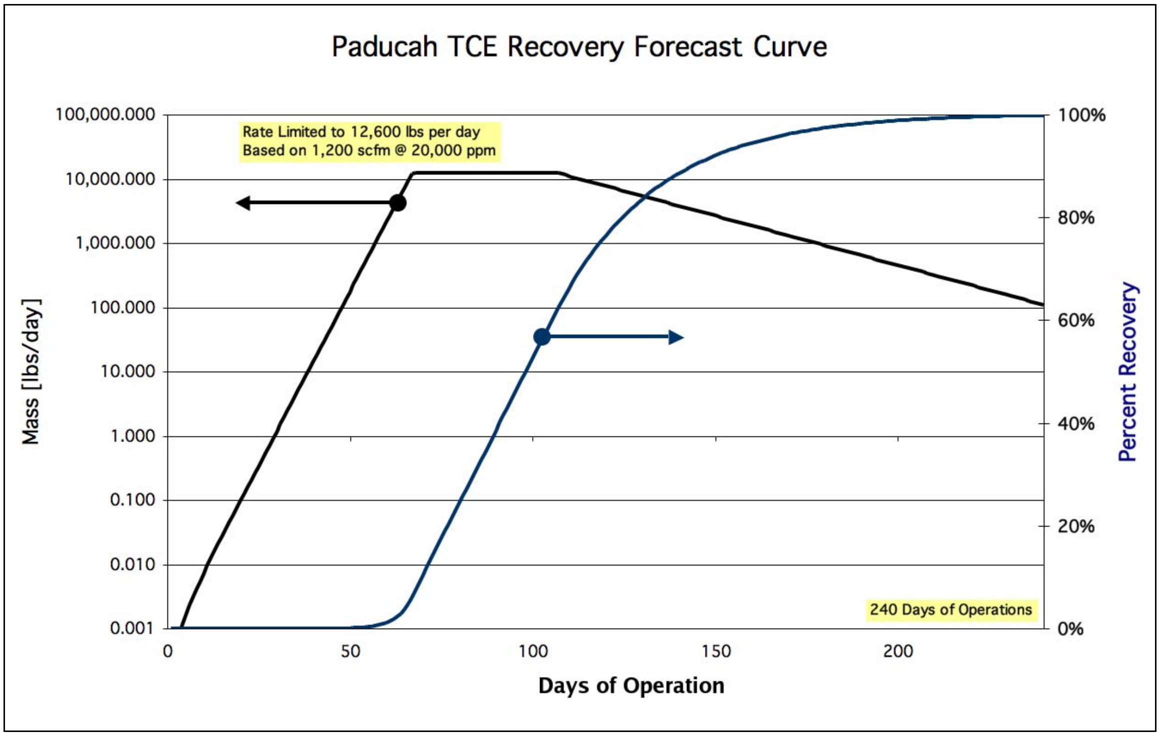

Figure 3-1: TCE chemical mass extraction rate from all extraction wells

3.1.2. Simulation Results with Groundwater Flow

Figure 3-2 to Figure 3-7 show the development of the temperature distribution in the SE Area of the RGA at a depth of 24.4 m (80 ft) bgs with a groundwater flow of 1 ft/day and in time increments of 30 days. A groundwater flow velocity of 1 ft/day is the expected condition and the design has been optimized for this flow condition. During operations, the power to individual electrodes will be adjusted to maximize heating and extraction from individual wells also will be adjusted to ensure hydraulic control is maintained.

Under these conditions (1 ft/day flow velocity) the average temperature in the treatment volume reaches target temperature of 105 ˚C (boiling point of TCE at a depth of 7.6 m (25 ft) below the top of the water table) within 90 days. The target temperature of TCE in the saturated zone is the boiling point of free-phase TCE adjusted for depth below the water table.

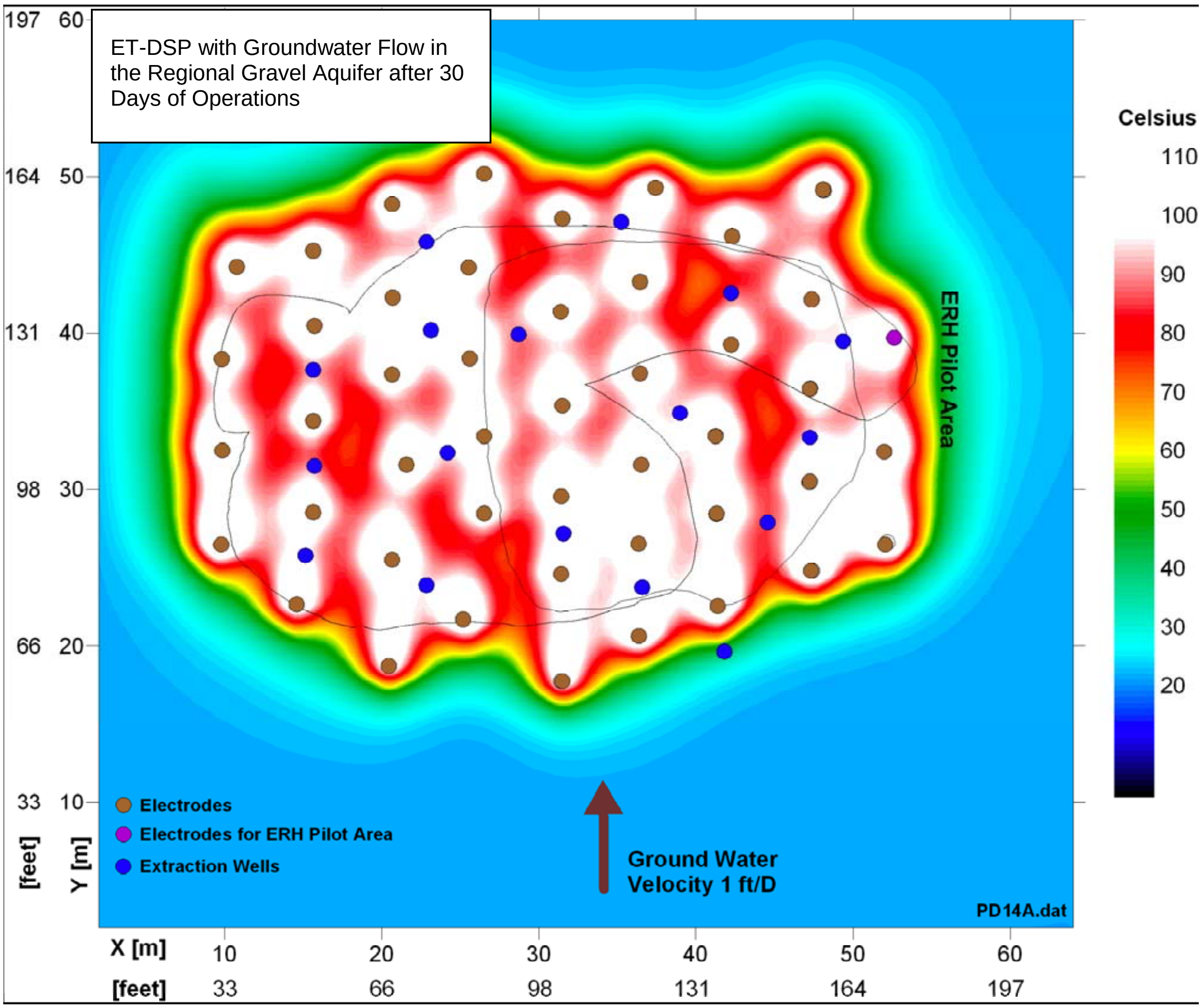

Figure 3-2: Temperature Distribution in the SE Area RGA After 30 Days at 24.8 m (80 ft) BGS with Groundwater Velocity of 1 ft/day.

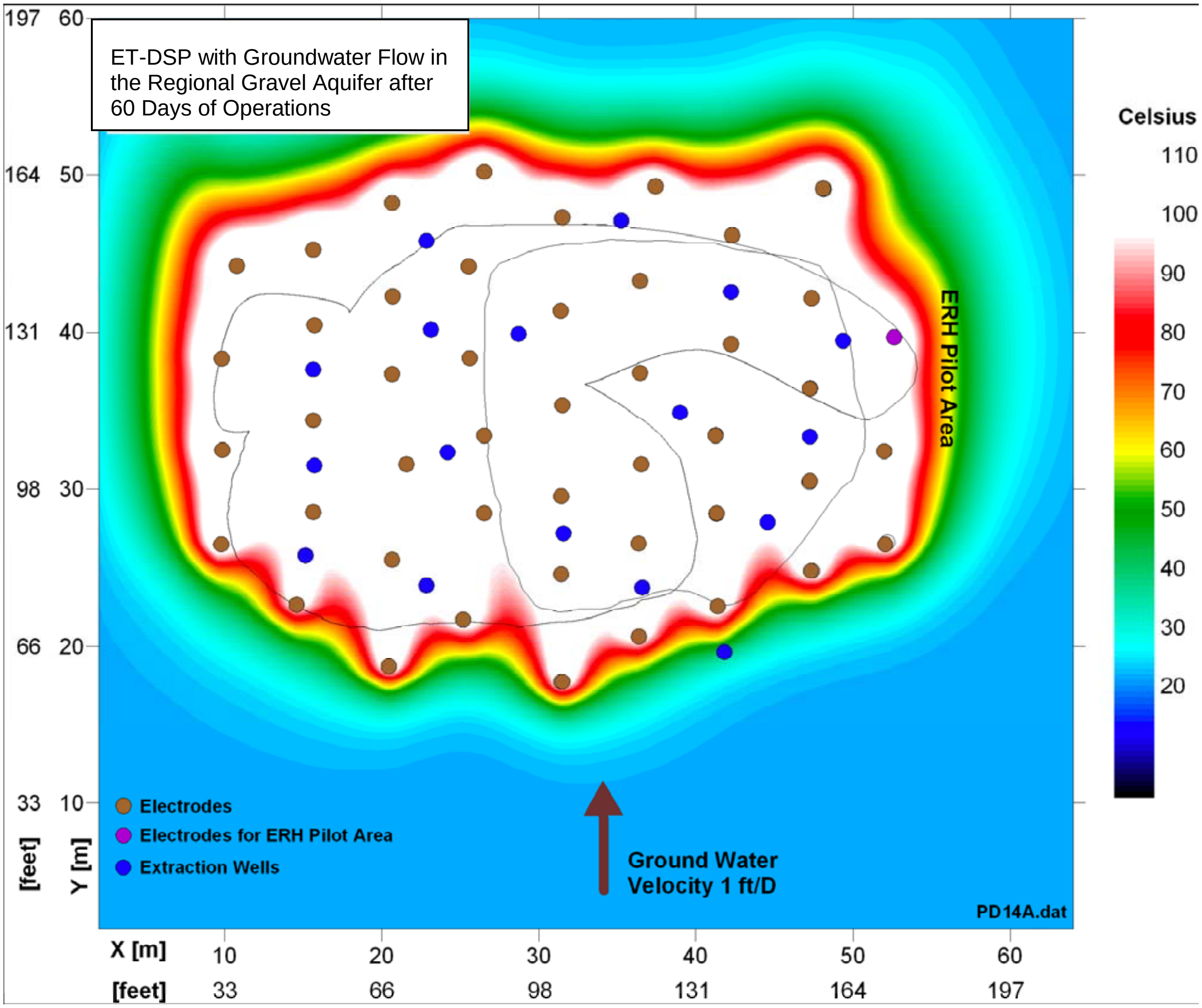

Figure 3-3: Temperature Distribution in the SE Area RGA After 60 Days at 24.8 m (80 ft) BGS with Groundwater Velocity of 1 ft/day.

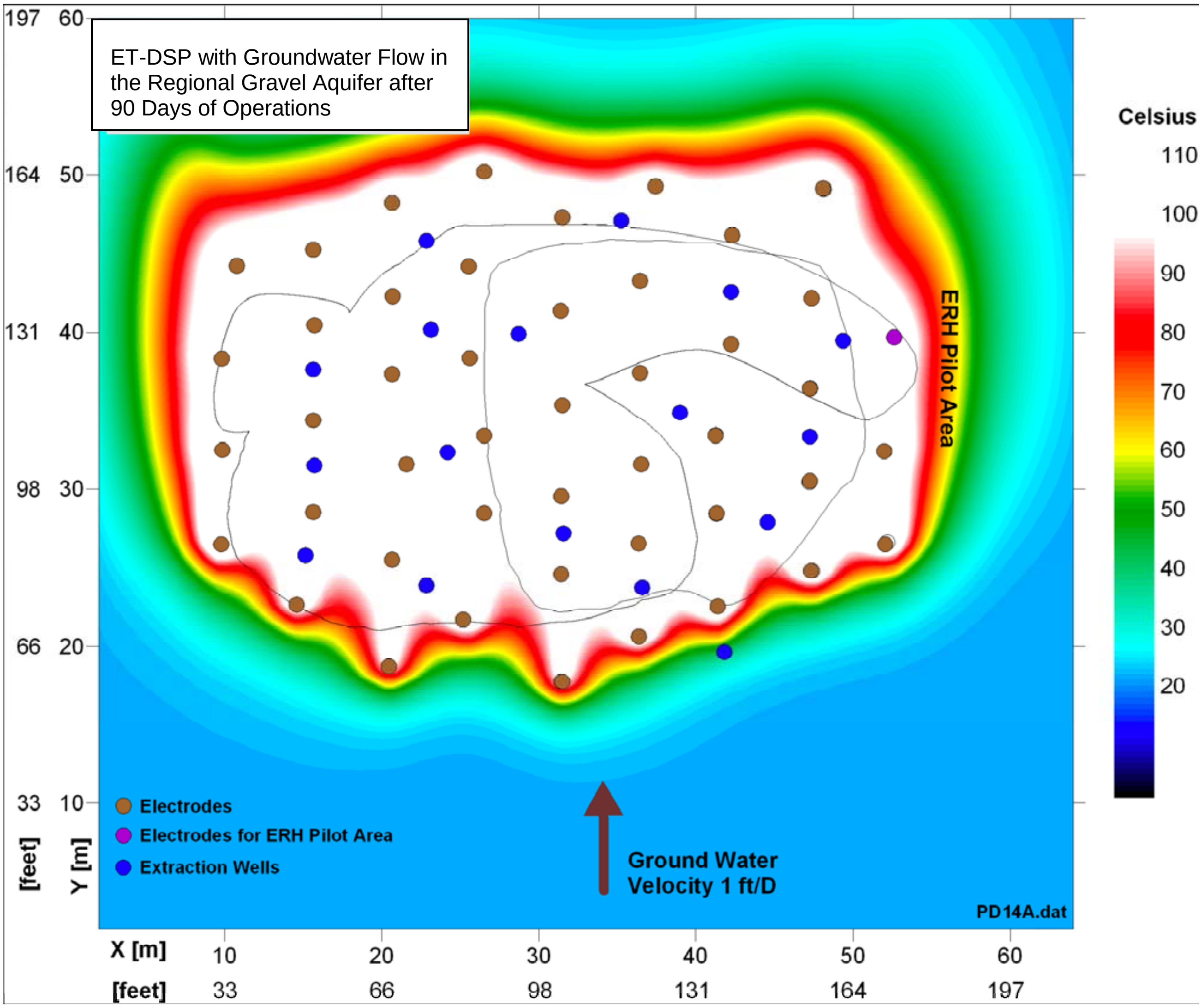

Figure 3-4: Temperature Distribution in the SE Area RGA After 90 Days at 24.8 m (80 ft) BGS with Groundwater Velocity of 1 ft/day.

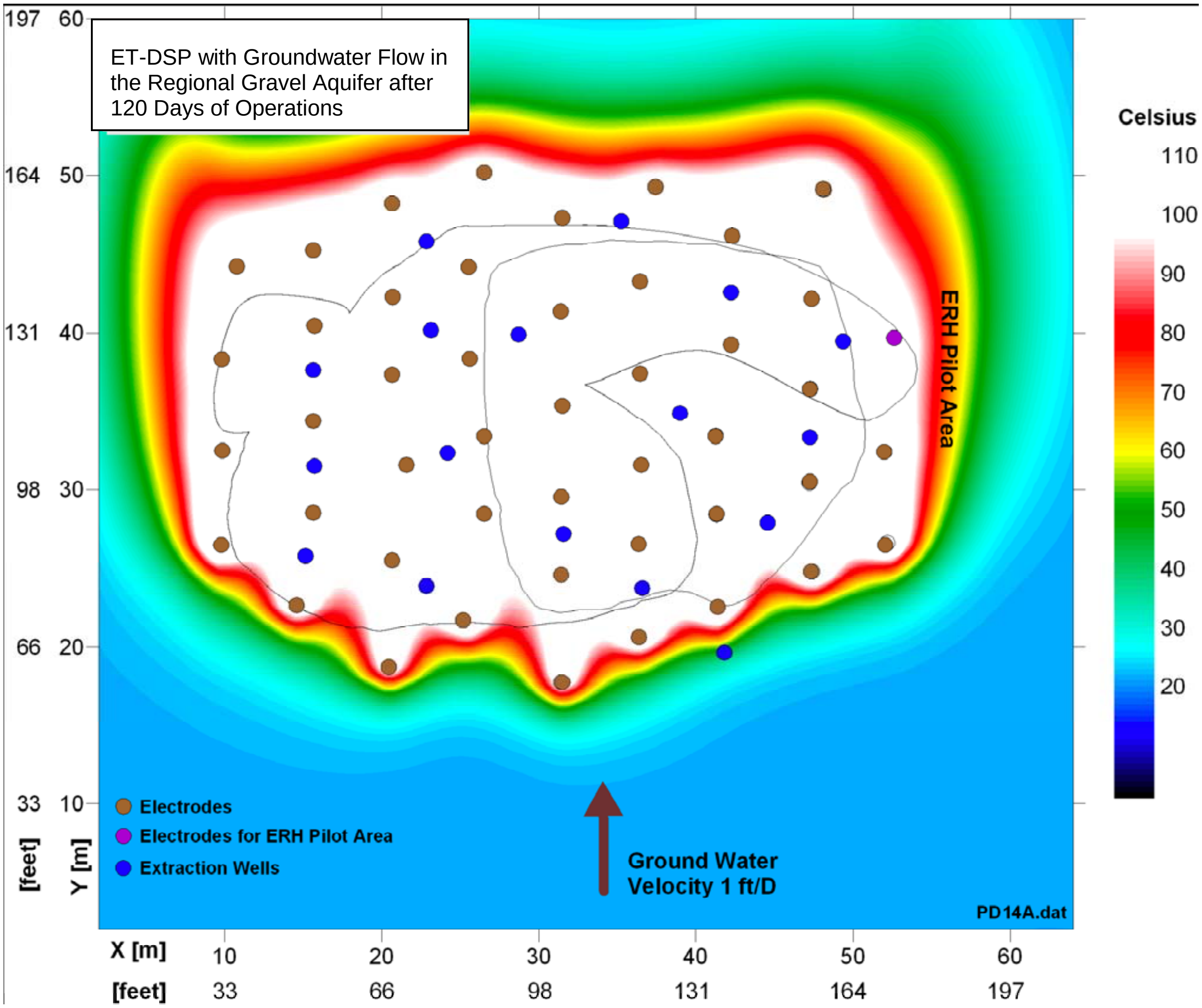

Figure 3-5: Temperature Distribution in the SE Area RGA After 120 Days at 24.8 m (80 ft) BGS with Groundwater Velocity of 1 ft/day.

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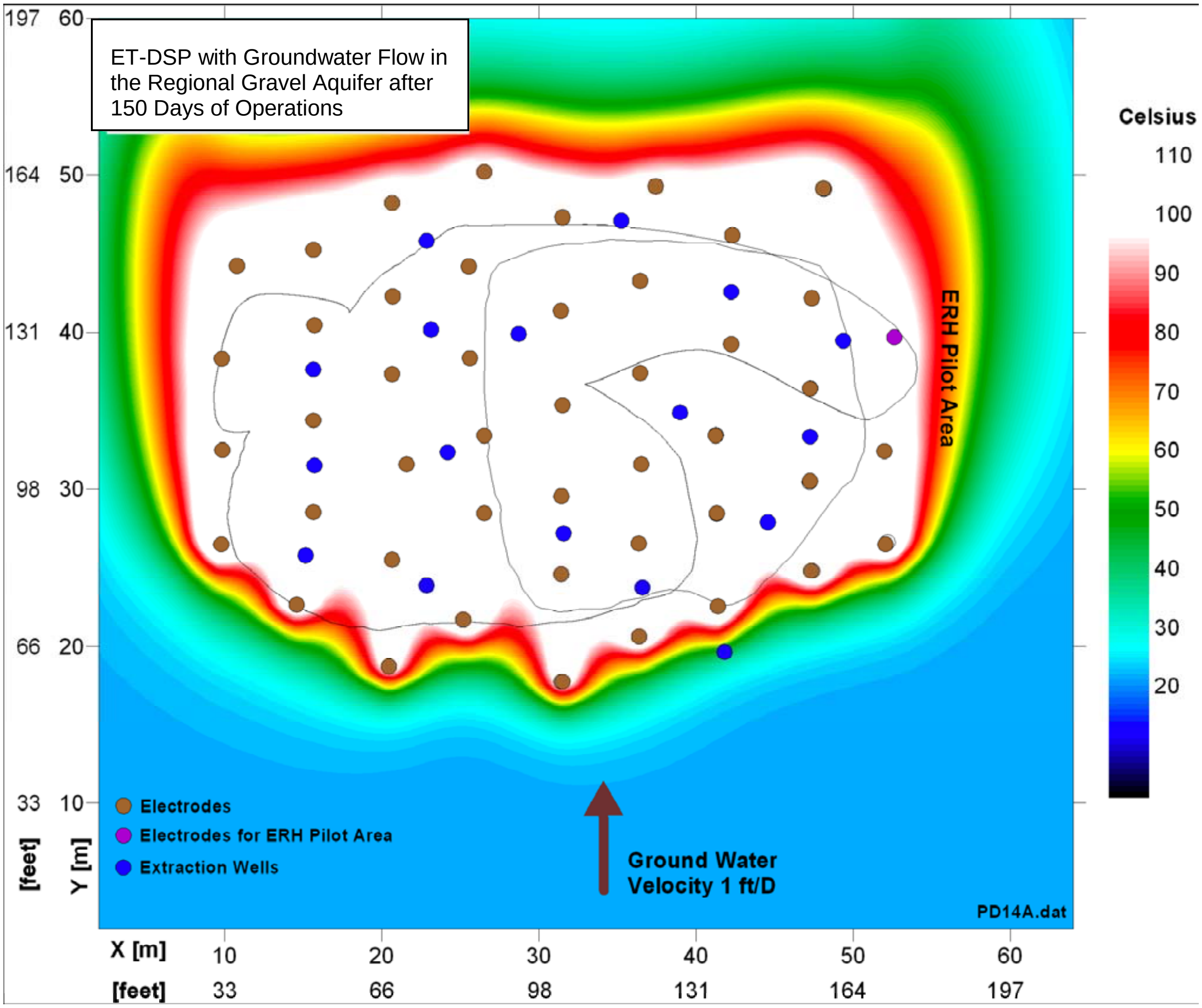

Figure 3-6: Temperature Distribution in the SE Area RGA After 150 Days at 24.8 m (80 ft) BGS with Groundwater Velocity of 1 ft/day.

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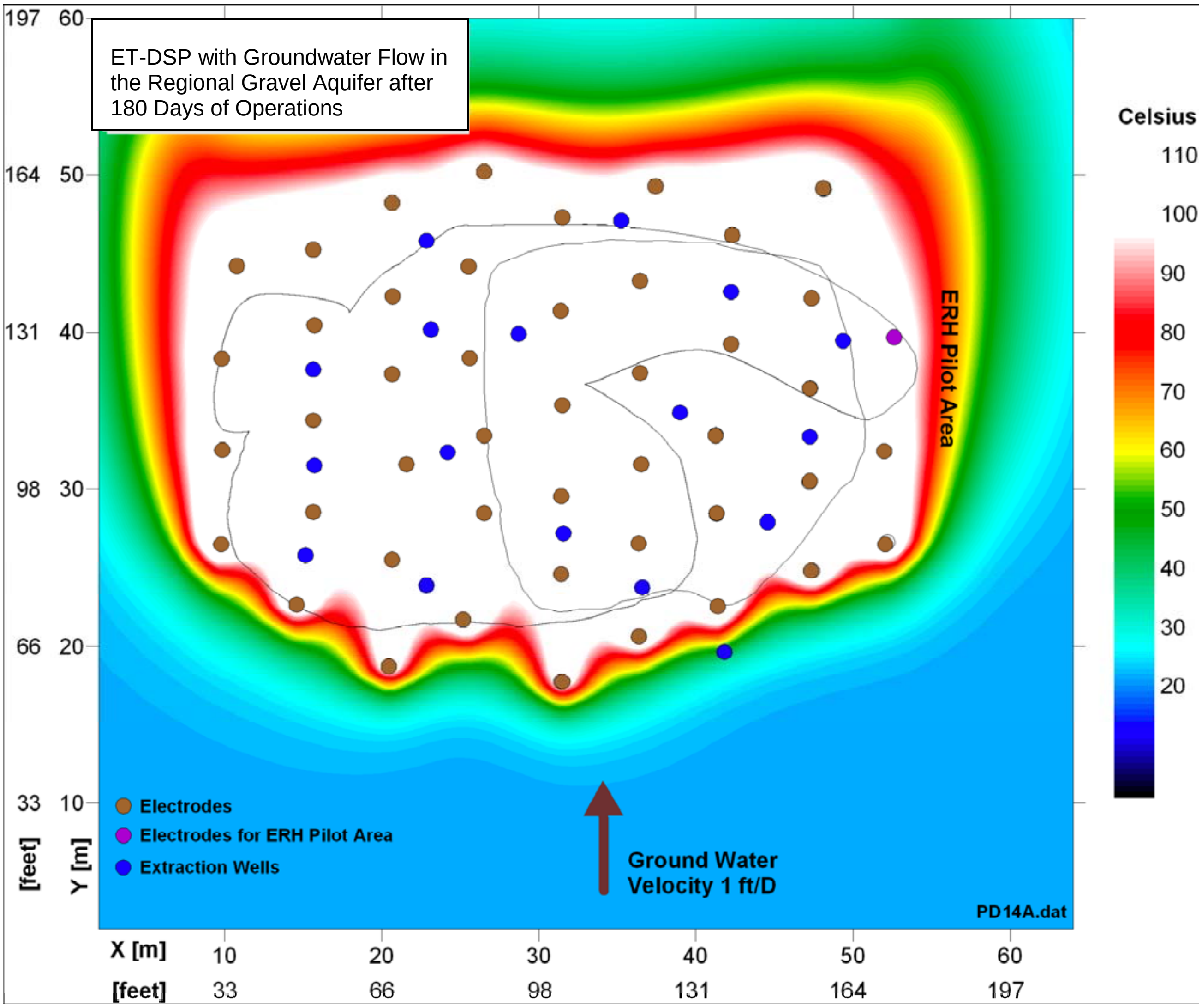

Figure 3-7: Temperature Distribution in the SE Area RGA After 180 Days at 24.8 m (80 ft) BGS with Groundwater Velocity of 1 ft/day.

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Figure 3-8 to Figure 3-10 show the impact of groundwater flow velocities of 0 ft/day, 3 ft/day, and 6 ft/day, respectively, on the development of the temperature distribution. Although stagnant groundwater conditions are not anticipated, Figure 3-8 is included for comparison purposes. Under groundwater flow velocities of 3 ft/day, the target temperature is achieved for most areas within 90 to 120 days. Note that a few small areas on the up gradient portion of the treatment zone do not achieve target temperatures. This is due to the electrode design being optimized for the 1 ft/day flow velocity. If treatment in the Southwest area, which is to be heated before the Southeast area, encounters flow velocities of 3 ft/day in the RGA, the design for the Southeast area could be revised by adding 3 electrode locations with 2 stacked electrodes located in the RGA to provide additional pre-heating of the groundwater entering the treatment area. In addition, extraction scenarios will be optimized to ensure hydraulic control. The current design has flexibility to increase extraction from individual wells by as much as ~100% to ensure hydraulic control.

Using the current design, target temperatures will not be achieved if groundwater flow velocities of 6 ft/day are encountered. The design could be modified to provide significant additional heating by adding more electrodes up-gradient and by increasing extraction.

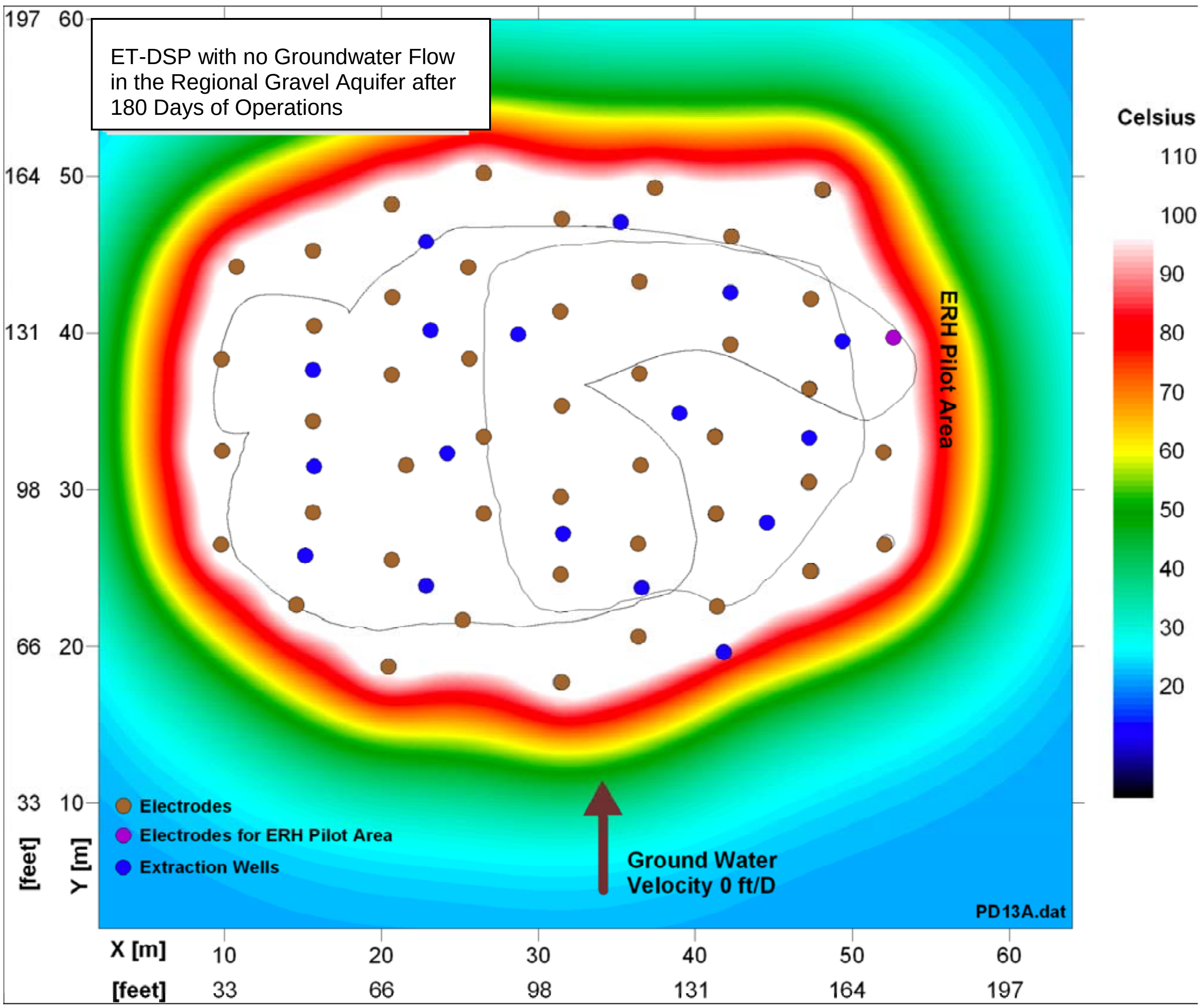

Figure 3-8: Temperature Distribution in the SE Area RGA After 180 Days at 24.8 m (80 ft) BGS with Stagnant Groundwater Velocity.

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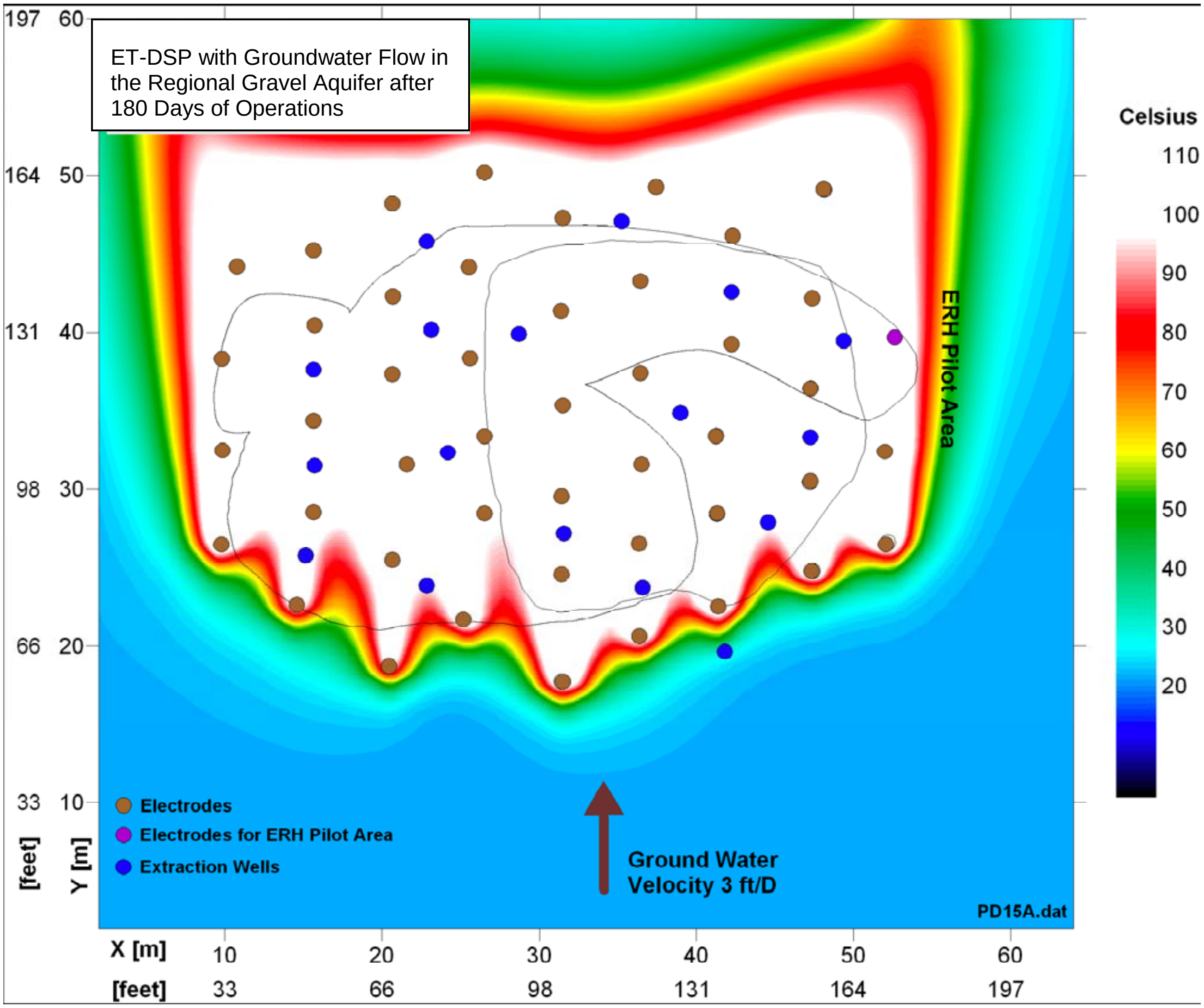

Figure 3-9: Temperature Distribution in the SE Area RGA After 180 Days at 24.8 m (80 ft) BGS with Groundwater Velocity of 3 ft/day.

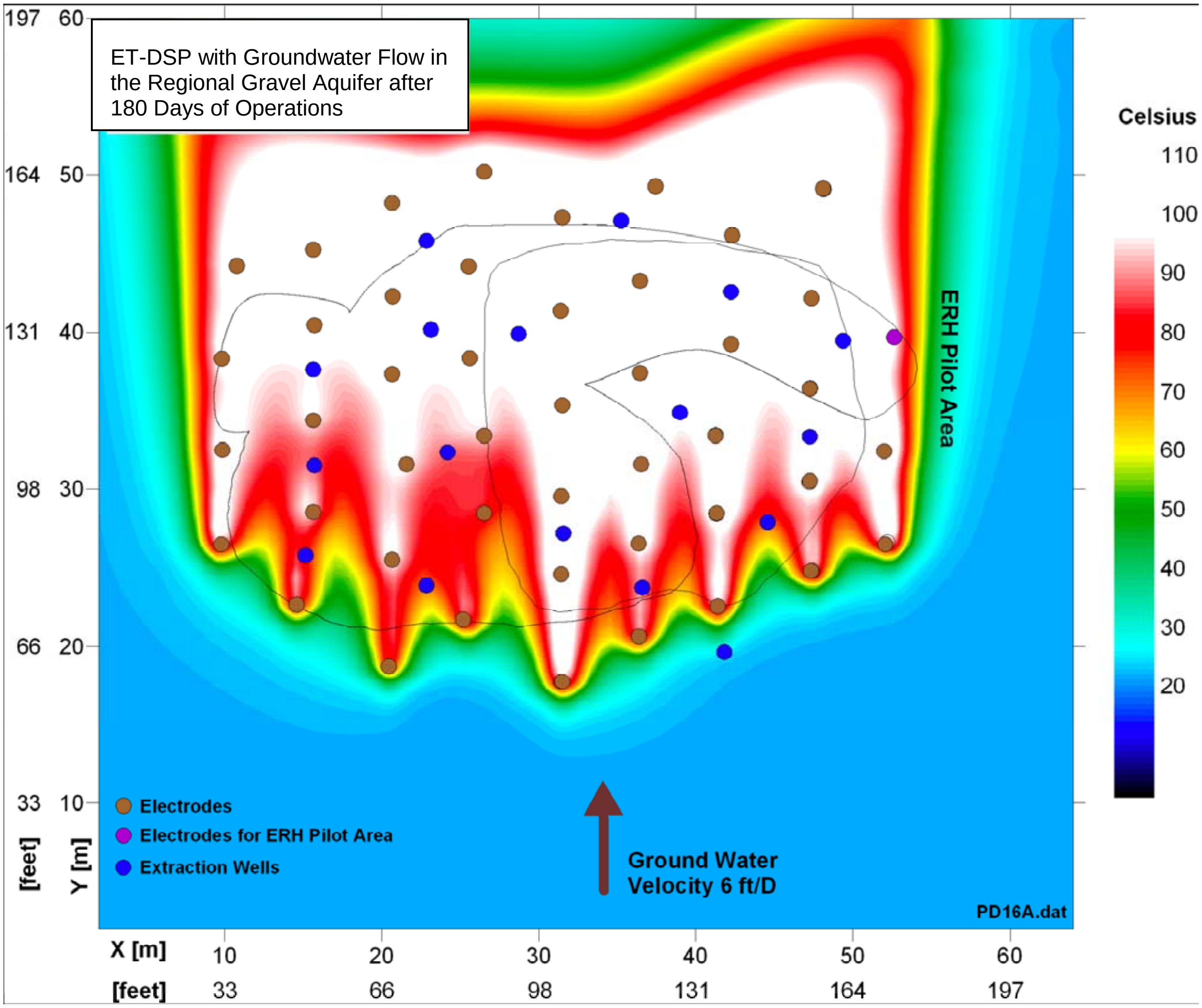

Figure 3-10: Temperature Distribution in the SE Area RGA After 180 Days at 24.8 m (80 ft) BGS with Groundwater Velocity of 6 ft/day.

3.1.3. Temperature and Energy Results

As the average temperature increases, the electrical resistance of the soil decreases and consequently the energy input rate decreases. When the average input power does not change significantly it is often a good indication that the maximum temperature of the soil has been reached. This is expected to occur at around 90 days with a continuing decrease in resistivity and input power as contaminants are removed from the soil. The peak input power to each electrode is about 14 kW for the duration of the project.

Figure 3-11 to Figure 3-26 shows the calculated temperature distributions for the Southeast corner of C-400 in the saturated zone after 180 days of operations. By the end of this period target temperatures will have been maintained in the soil for several weeks. In the saturated zone the perimeter electrodes must operate at elevated power levels relative to the internal electrodes to mitigate cooling by groundwater convection. The images are generated from three-dimensional simulation assuming no groundwater flow. While it is estimated the groundwater flow velocity in the RGA will be 1 ft/day, the effect of this after 180 days may be extrapolated from Figure 3-7.

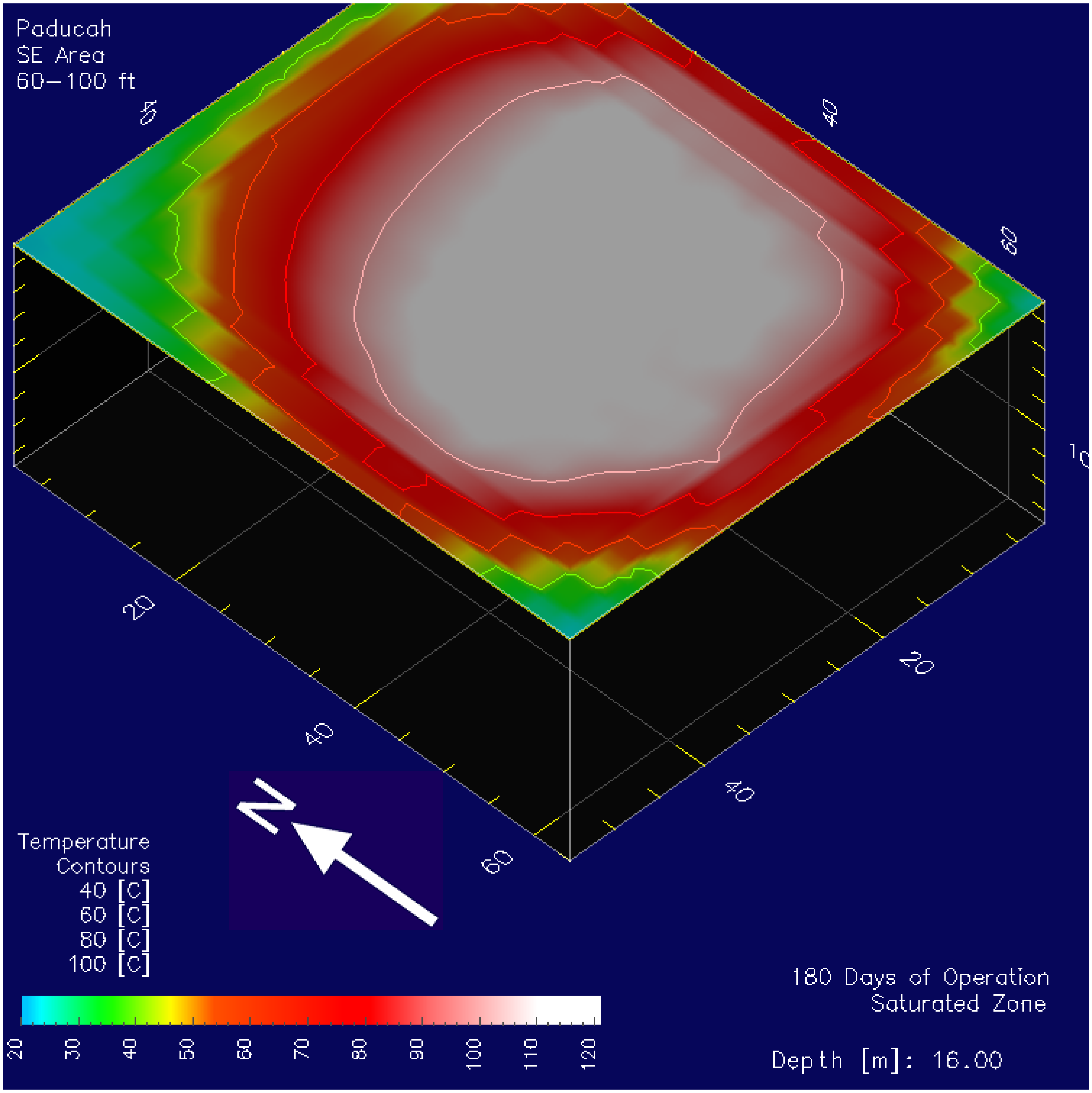

Figure 3-11: Temperature distribution from 16.0 m (52.5 ft) BGS after 180 days. The figure indicates steam temperatures are achieved in the treatment area above the deep UCRS electrode.

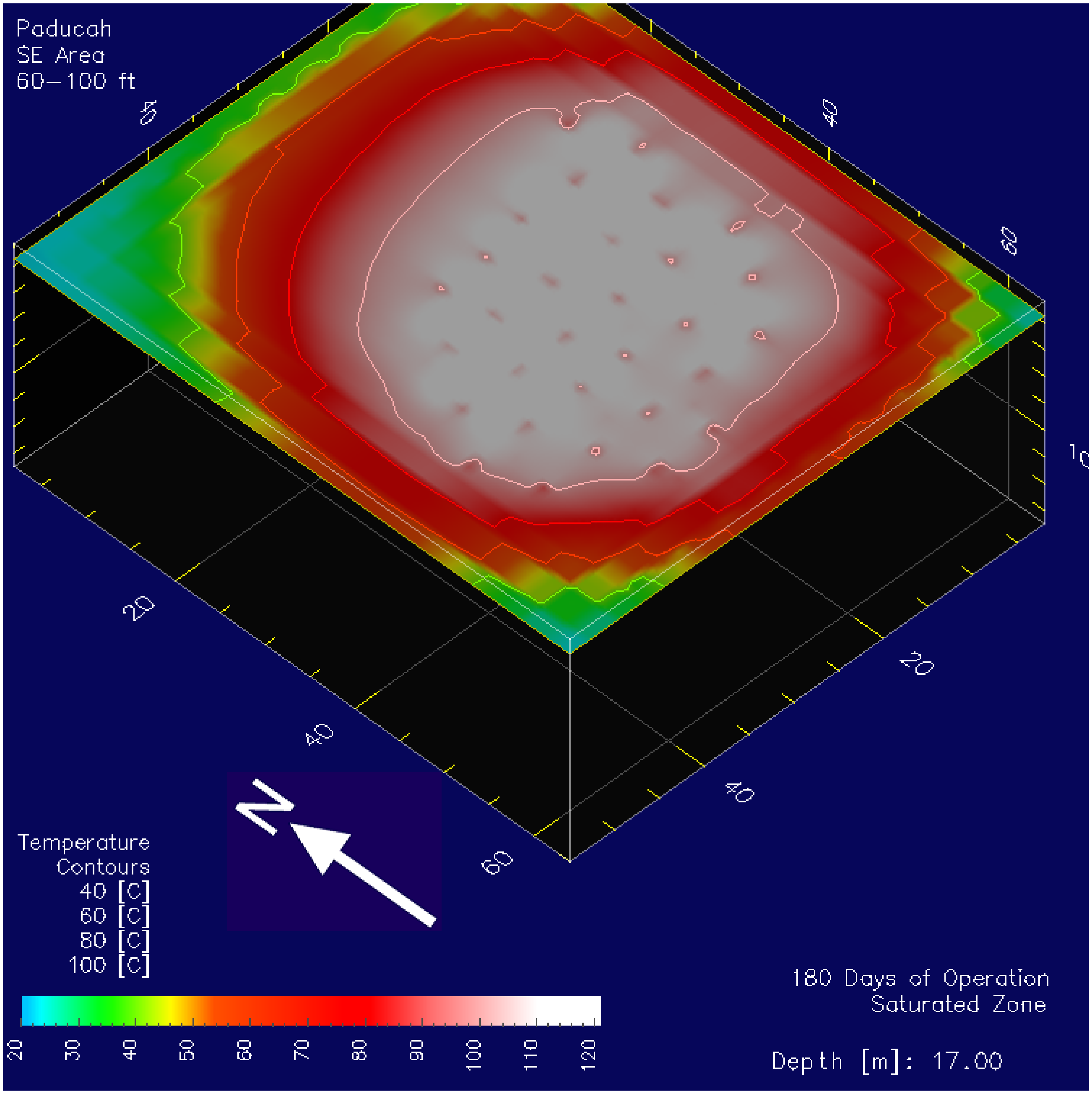

Figure 3-12: Temperature distribution from 17.0 m (55.8 ft) BGS after 180 days. The figure indicates steam temperatures are achieved in the treatment area above the deep UCRS electrode.

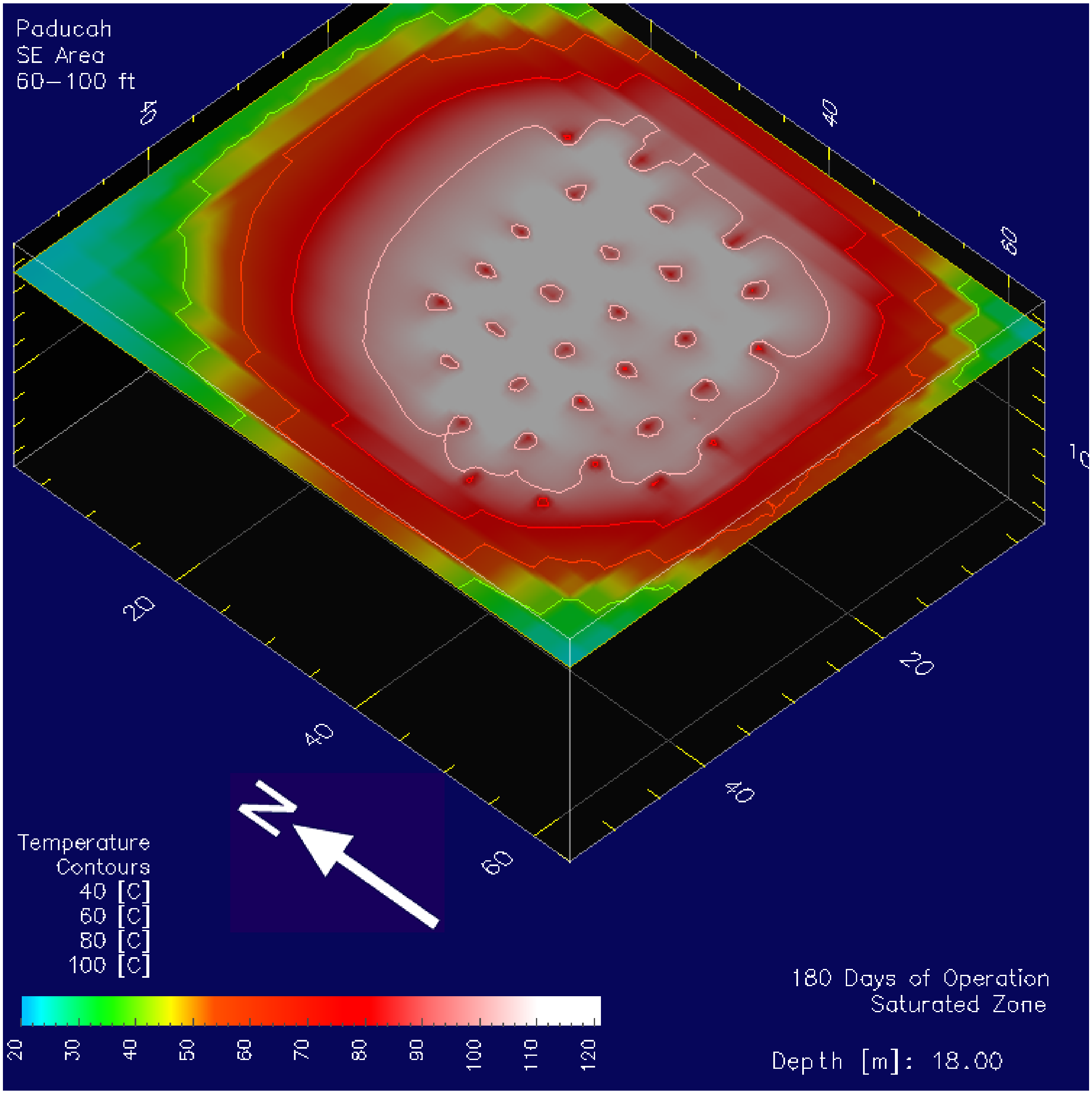

Figure 3-13: Temperature distribution from 18.0 m (59.1 ft) BGS after 180 days. The figure shows target temperatures are exceeded in the treatment area at the deep UCRS electrodes. 90°C temperatures at each electrode location are due to continuous water injection at each electrode.

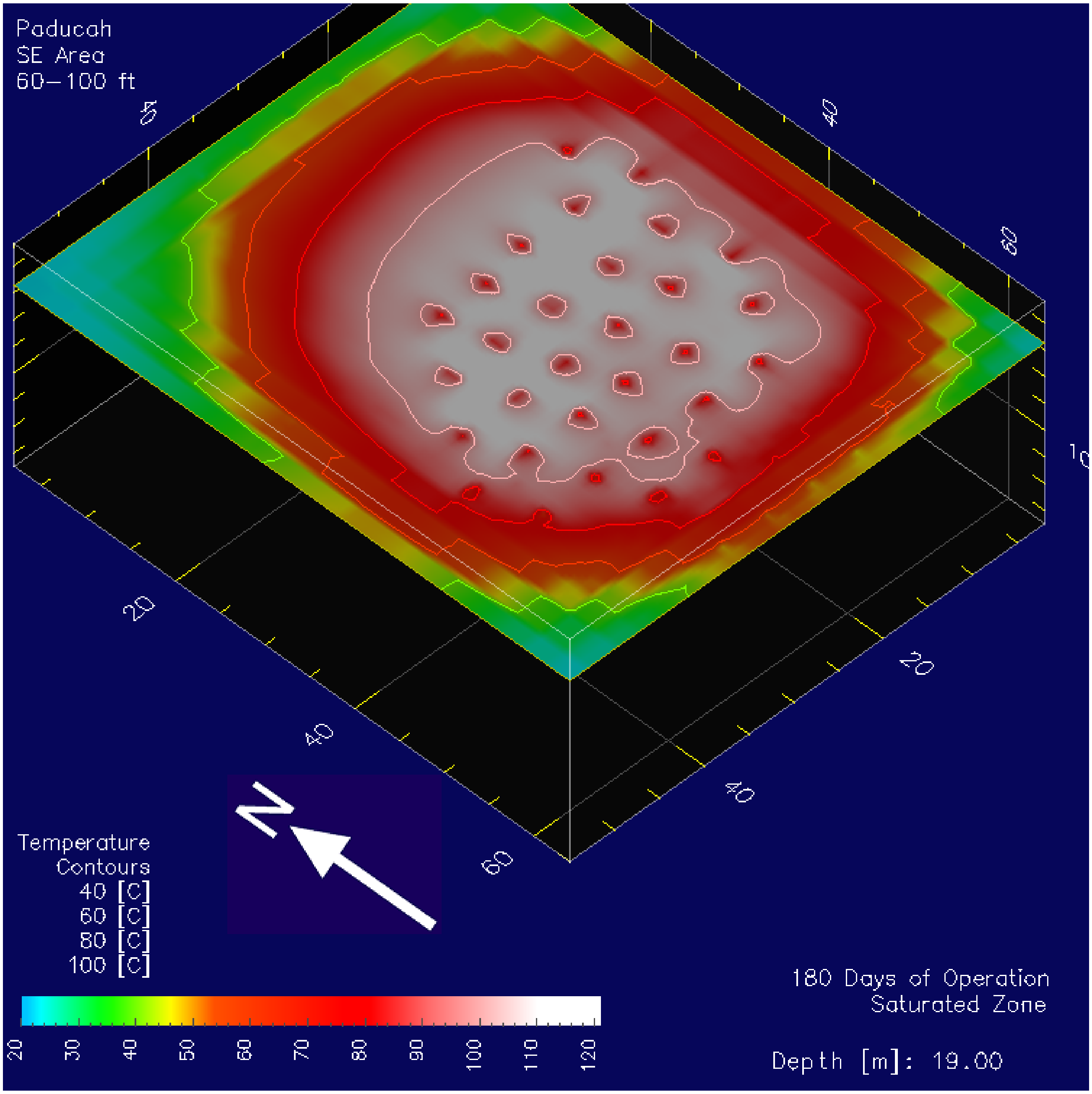

Figure 3-14: Temperature distribution from 19.0 m (62.3 ft) BGS after 180 days. The figure shows target temperatures are exceeded in the treatment area at the bottom of the deep UCRS electrodes.

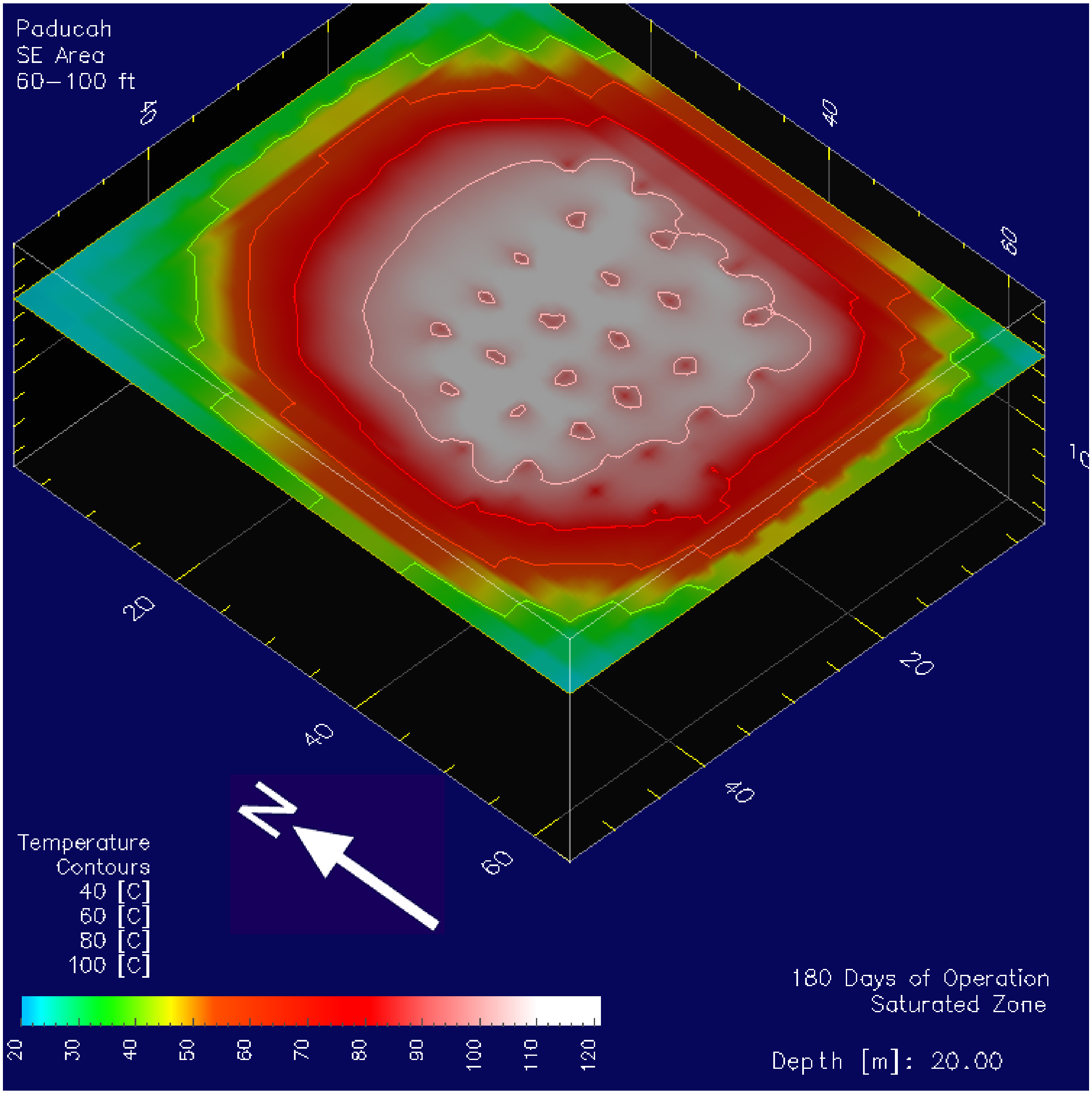

Figure 3-15: Temperature distribution from 20.0 m (65.6 ft) BGS after 180 days. This figure indicates steam temperatures are achieved in the treatment area immediately below the deep UCRS electrodes.

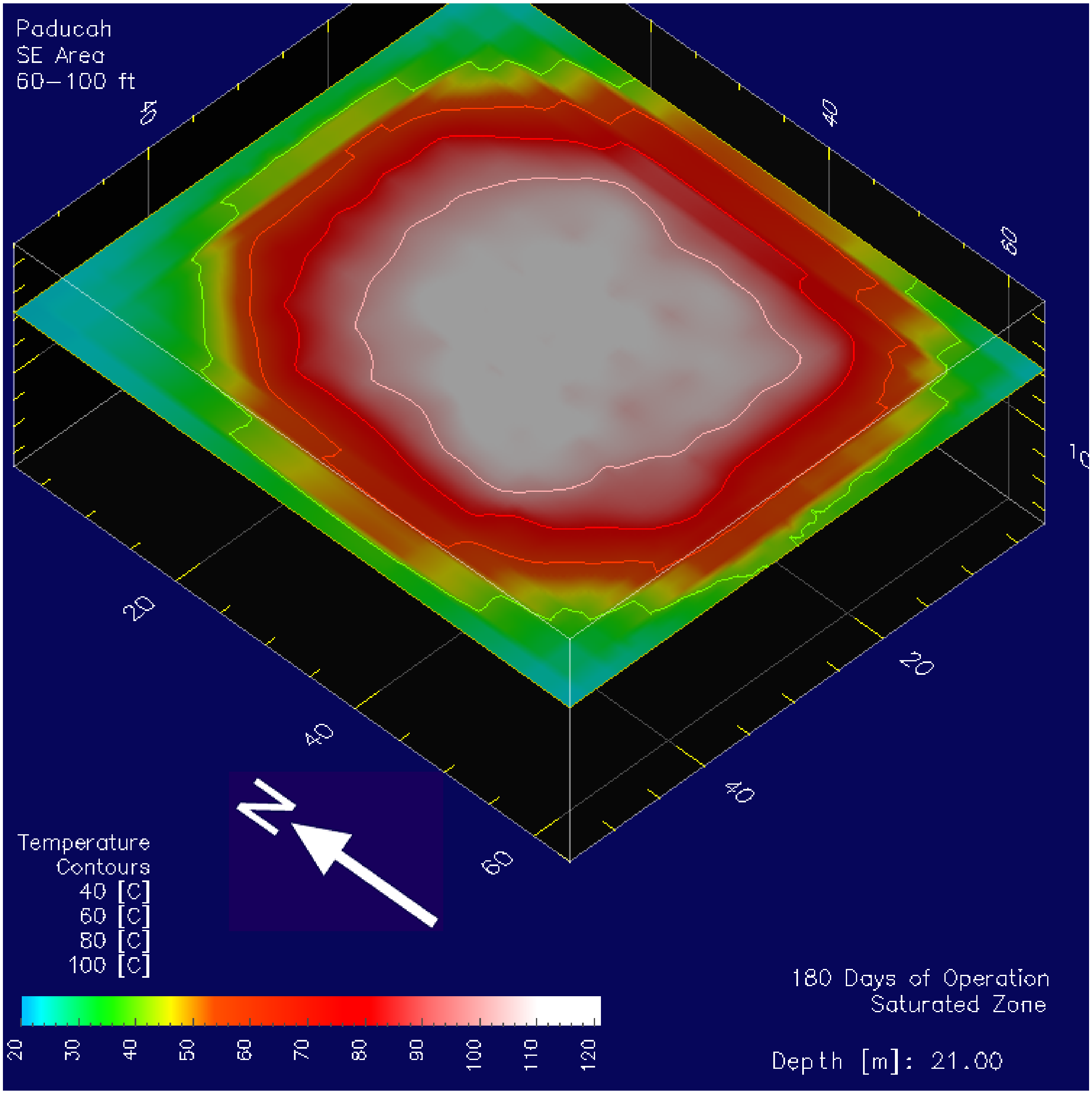

Figure 3-16: Temperature distribution from 21.0 m (68.9 ft) BGS after 180 days. This figure indicates steam temperatures are achieved in the treatment area between the deep UCRS and shallow RGA electrodes.

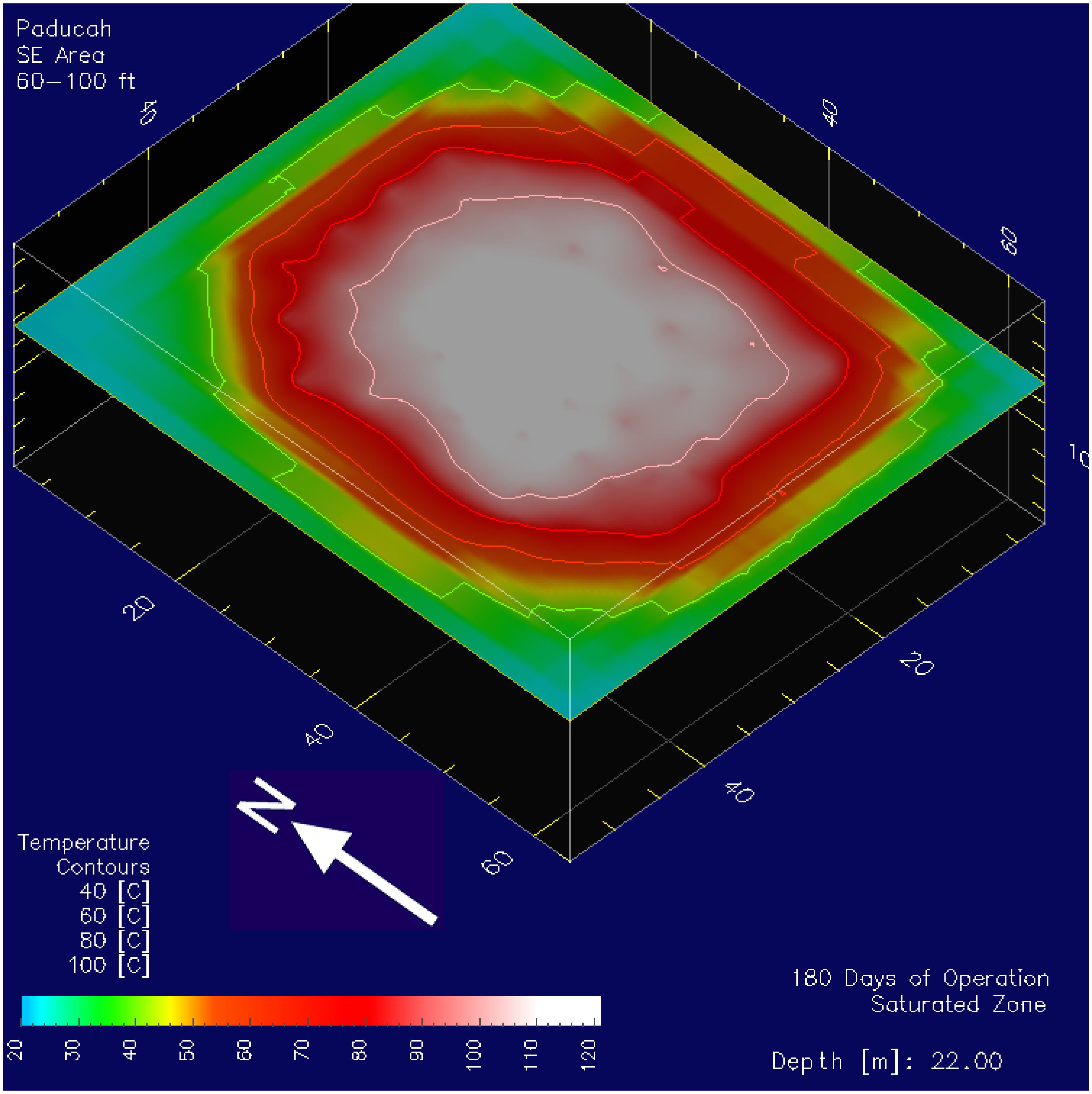

Figure 3-17: Temperature distribution from 22.0 m (72.2 ft) BGS after 180 days. This figure shows steam temperatures are achieved in the treatment area adjacent to the shallow RGA electrodes. 90°C temperatures at each electrode location are due to continuous water injection at each electrode.

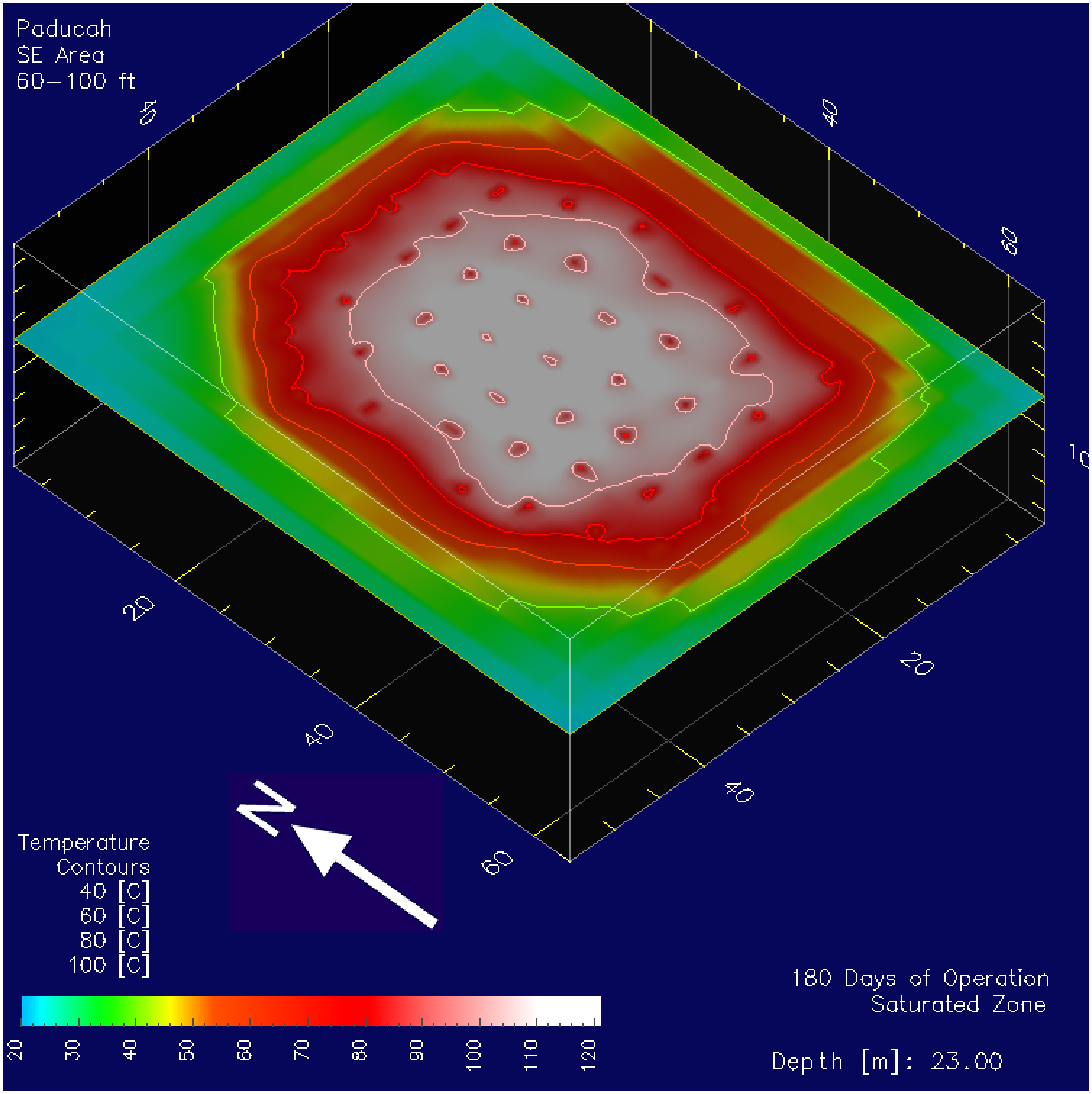

Figure 3-18: Temperature distribution from 23.0 m (75.5 ft) BGS after 180 days. This figure shows steam temperatures are achieved in the treatment area adjacent to the shallow RGA electrodes.

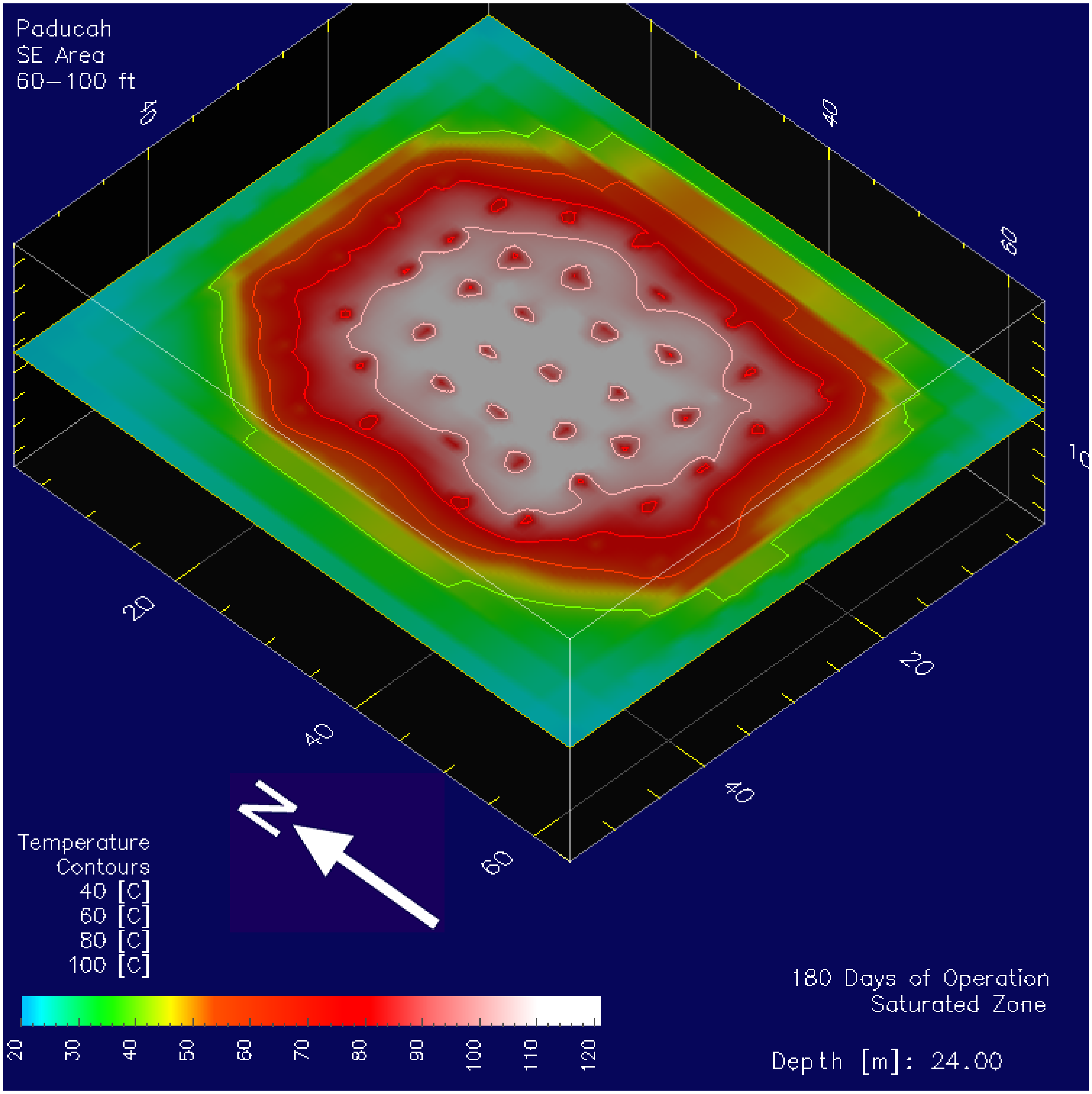

Figure 3-19: Temperature distribution from 24.0 m (78.7 ft) BGS after 180 days. This figure also represents soil temperatures adjacent to the shallow RGA electrodes.

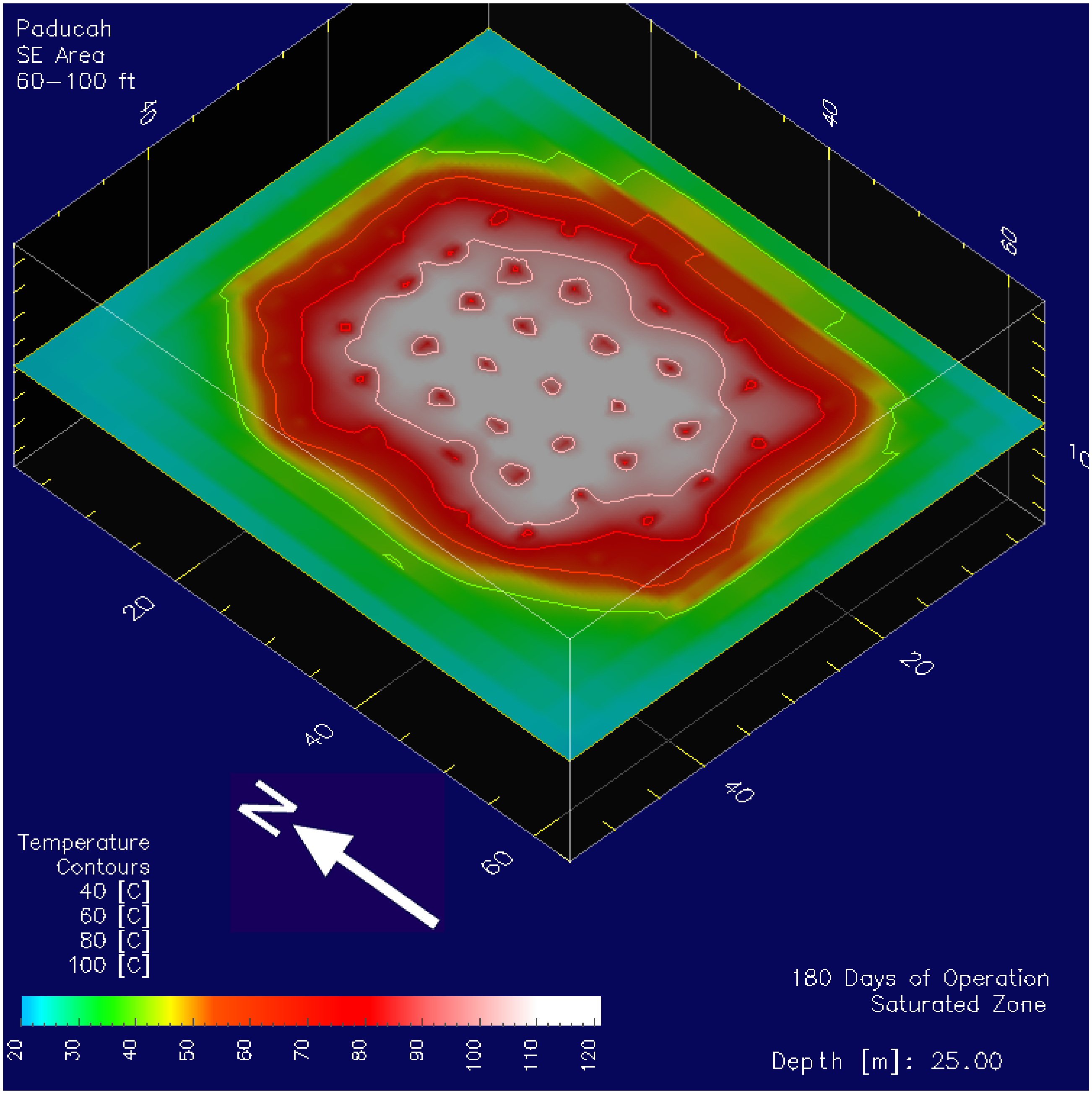

Figure 3-20: Temperature distribution from 25.0 m (82.0 ft) BGS after 180 days. This again represents soil temperatures adjacent to the shallow RGA electrodes.

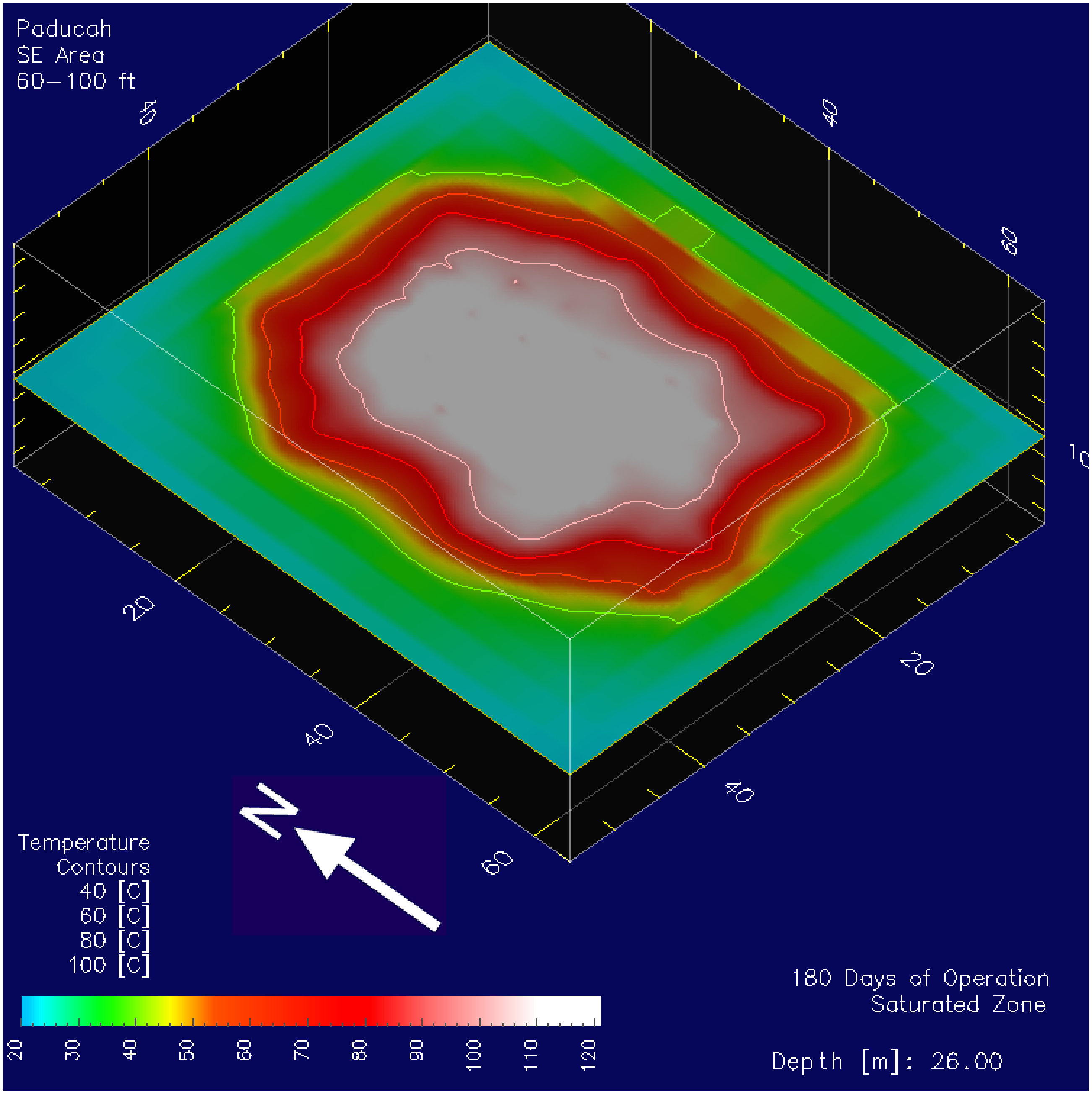

Figure 3-21: Temperature distribution from 26.0 m (85.3 ft) BGS after 180 days. This figure shows steam temperatures are achieved in the treatment area directly below the shallow RGA electrodes.

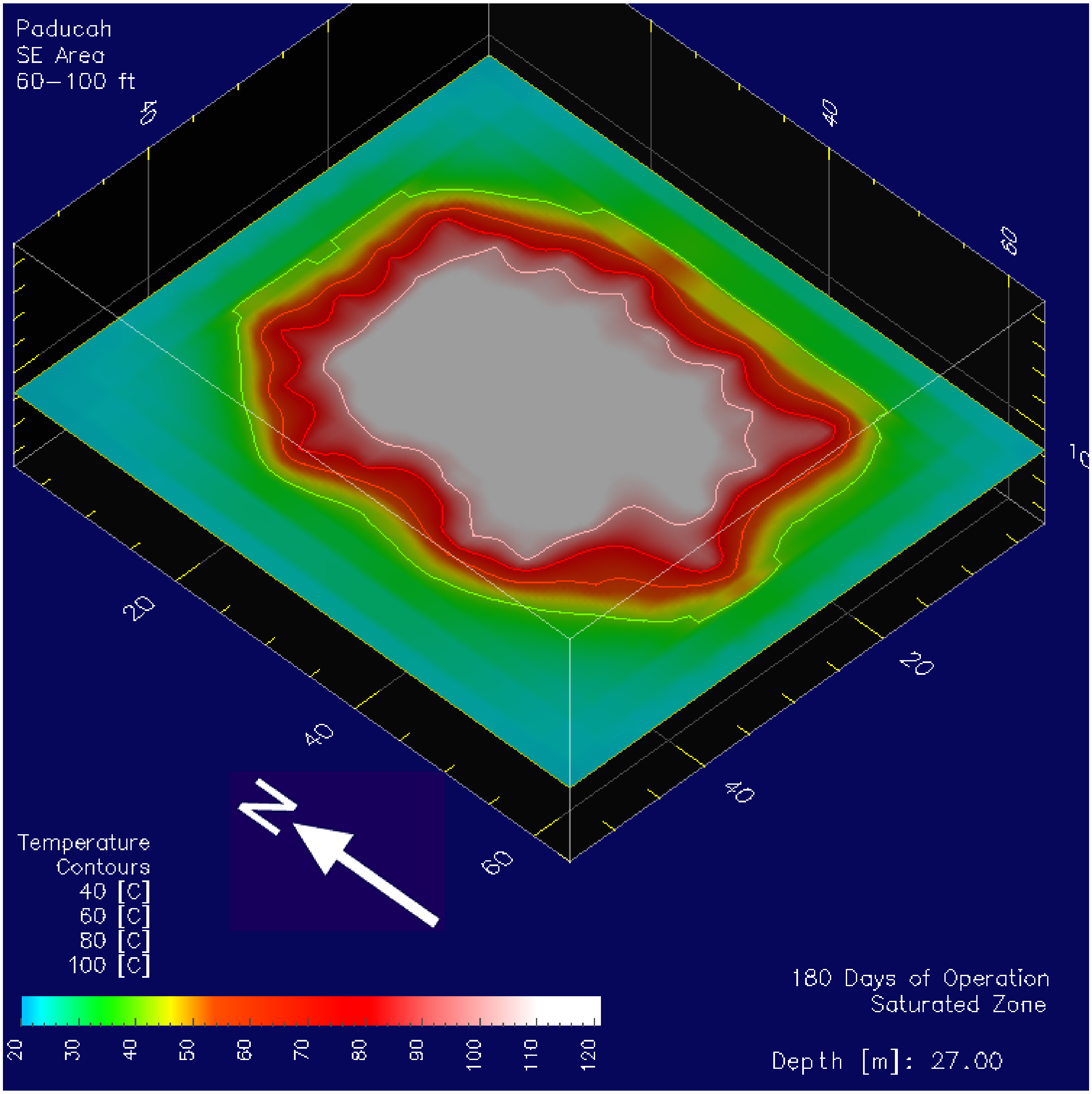

Figure 3-22: Temperature distribution from 27.0 m (88.6 ft) BGS after 180 days. The figure shows steam temperatures are achieved in the treatment area between the shallow and deep RGA electrodes.

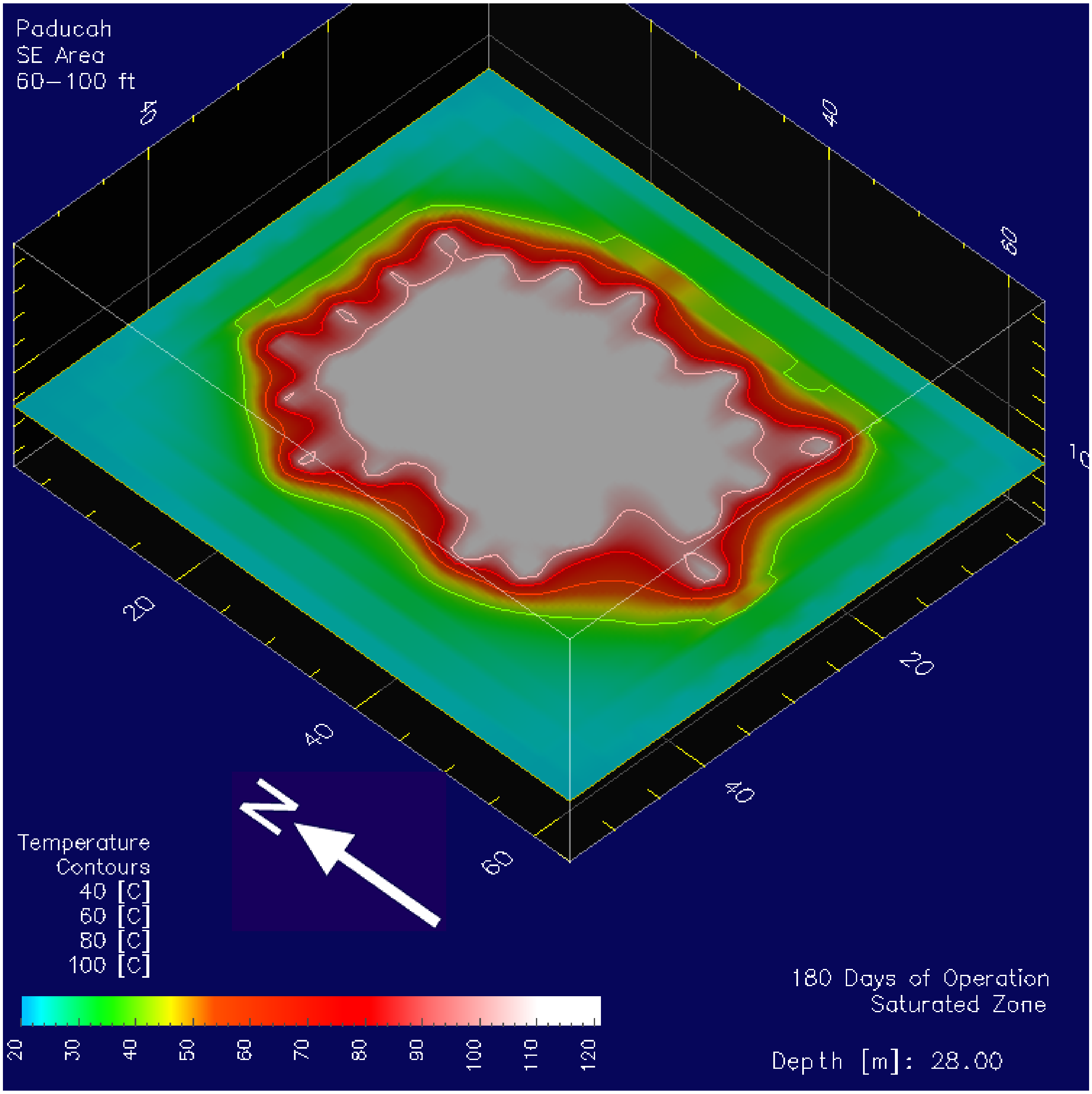

Figure 3-23: Temperature distribution from 28.0 m (91.9 ft) BGS after 180 days. The figure shows target temperatures are exceeded in the treatment area adjacent to the deep RGA electrodes.

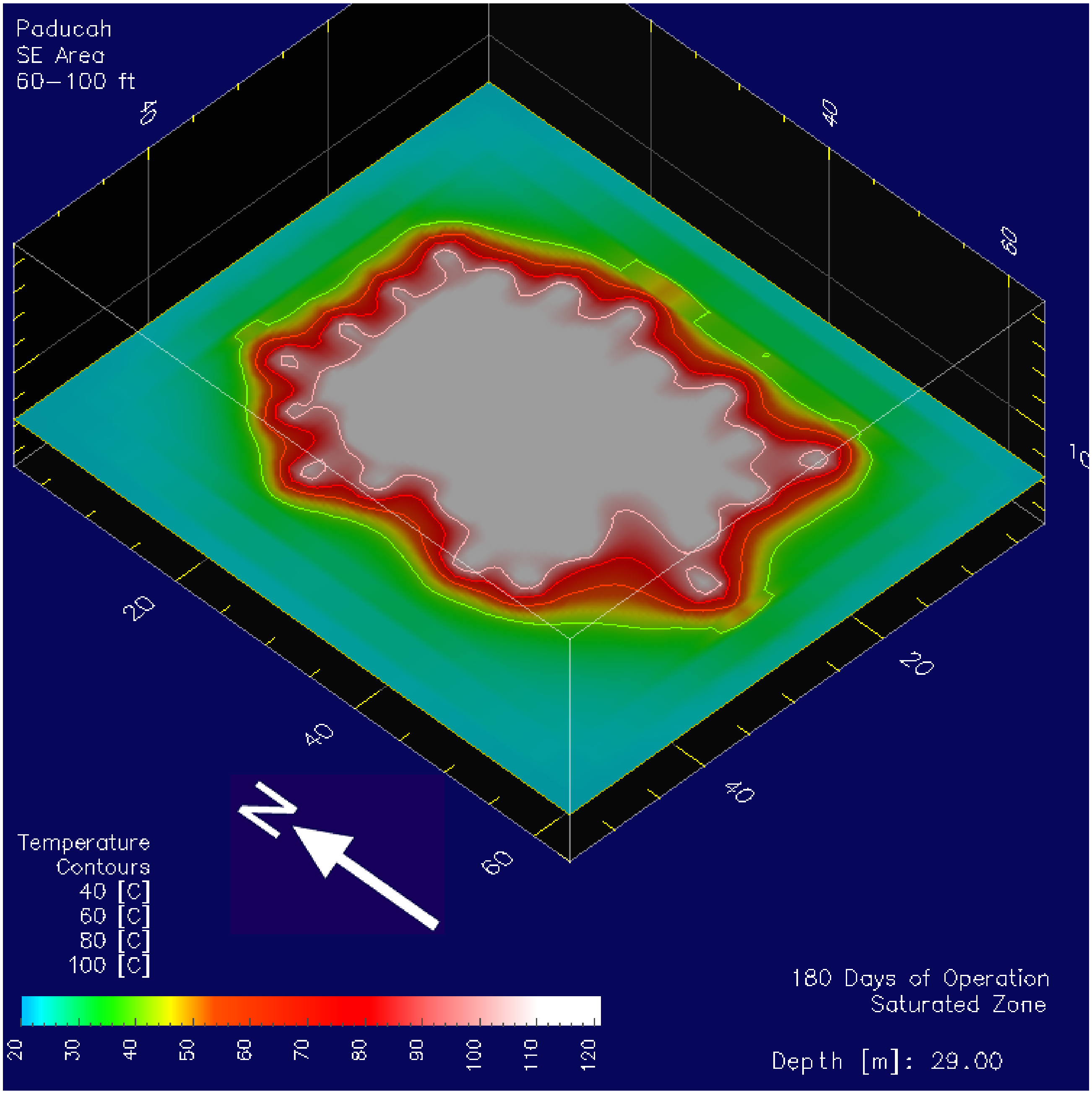

Figure 3-24: Temperature distribution from 29.0 m (95.1 ft) BGS after 180 days. This figure also shows target temperatures are exceeded in the treatment area adjacent to the deep RGA electrodes.

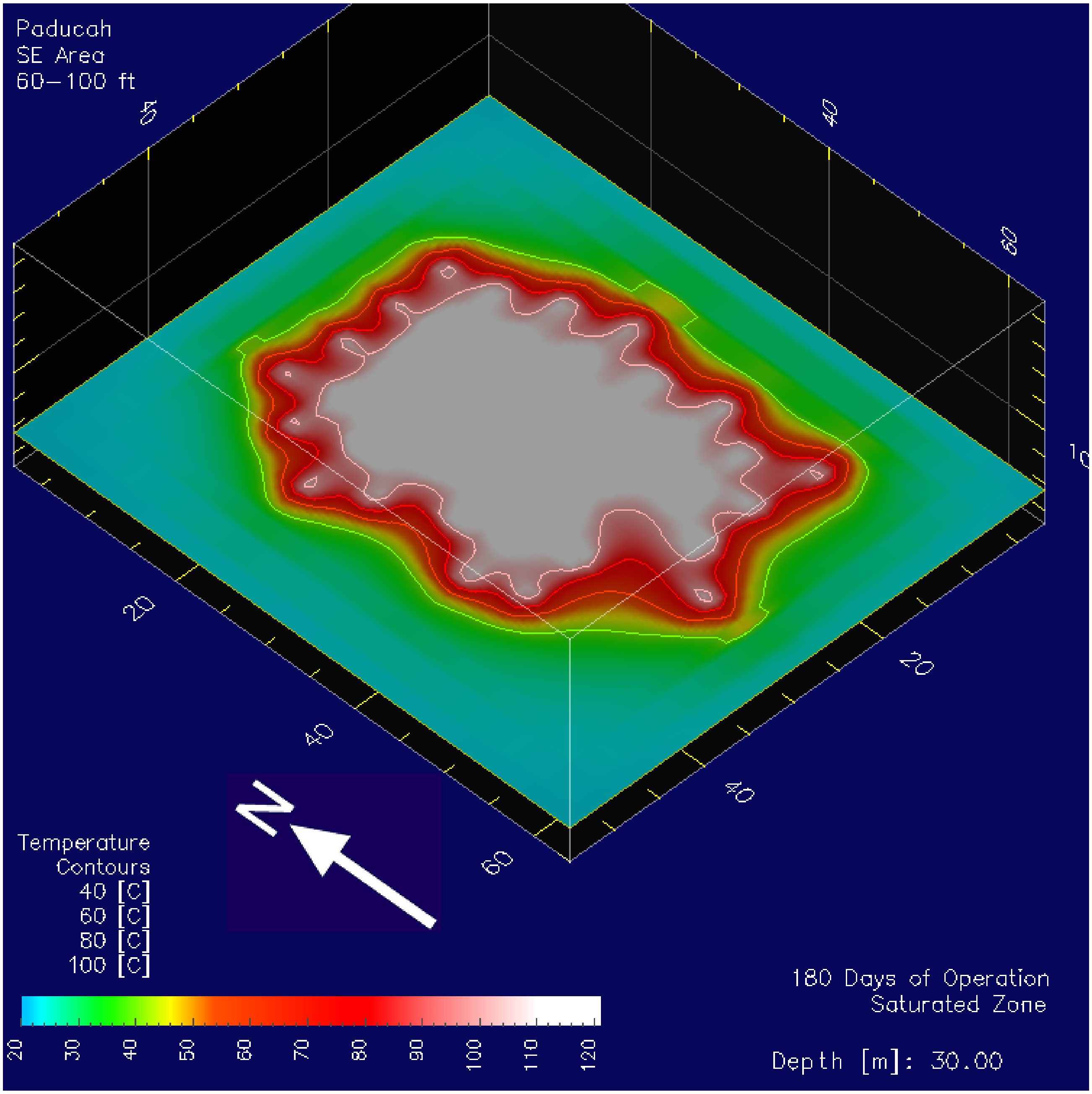

Figure 3-25: Temperature distribution from 30.0 m (98.4 ft) BGS after 180 days. The figure indicates steam temperatures are achieved in the treatment area at the bottom of the deep RGA electrodes.

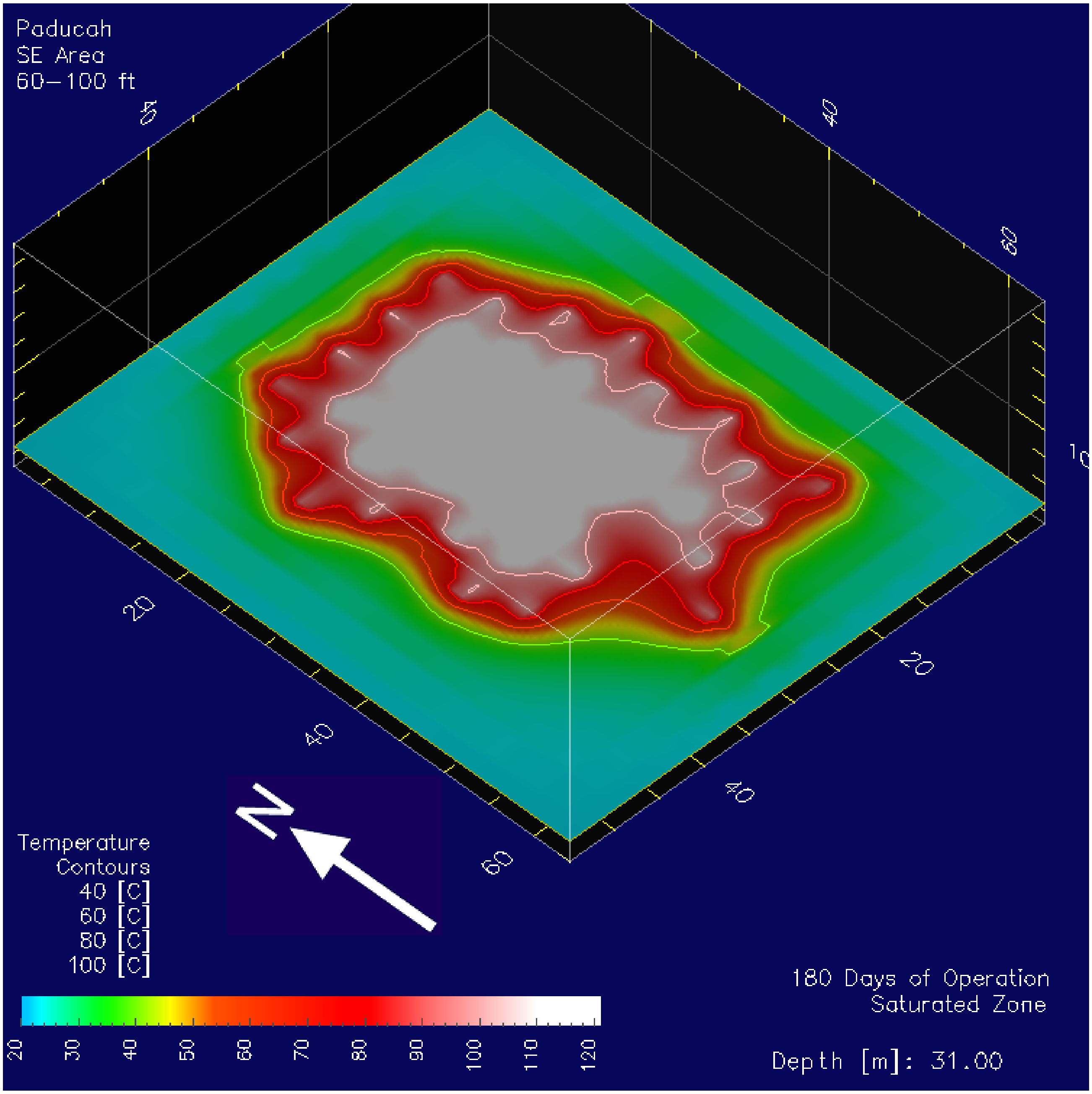

Figure 3-26: Temperature distribution from 31.0 m (101.7 ft) BGS after 180 days. The figure indicates steam temperatures are achieved below the deep RGA electrodes. Heat transfer below the electrodes will effectively mobilize contaminants in the McNairy formation.

4. Conclusions

Based on the results of the numerical simulation study, the following conclusions and recommendations are put forward for the design of an ET-DSP™ system for the Paducah C-400 Project:

1. Three arrays of 3.0 m (10 ft) electrodes will be configured to remediate the full treatment areas defined by the NAPL distribution. One to five electrodes will be stacked to cover the vertical extents of the treatment volume at each well location. For effective remediation, the Southeast, Southwest, and Eastern treatment areas of the site require a total of 369 electrodes in 110 boreholes.

2. The results of the numerical simulation calculations indicate that for optimum heating, the perimeter electrodes need to be operated at 20 to 30% greater power per electrode than the interior electrodes. This was a result of the high hydraulic conductivity of the soil and associated water inflow while maintaining hydraulic control.

3. The number of electrodes relative to the total treatment volume is increased to ensure the capture of rising vapors from above the saturated zone in the Southeast area. As well, relatively more electrodes are needed to compensate for the proportionally large surface area of three separate treatment volumes of varied shape. However, delineating the treatment volume according to the known contaminant distribution at each depth results in more efficient use of these electrodes.

4. Due to extensive utility lines present down to 3.0 m (10 ft) BGS, the uppermost electrodes will be placed to limit the heating influence to below this depth and minimize interference with existing electrical systems. Step potential tests during commissioning and operation of the ET-DSP™ system will verify surface voltages are limited to safe levels (less than 15 V).

5. Seventeen 660 kVA PDS units will provide power to the electrodes. Each PDS is capable of independent power control to each electrode via the internet.

6. Electrical conductivity of the soil and heat transfer by convection will be maintained at all electrodes using fifteen WCS units. Water injection to each electrode will vary between

0.1 to 0.2 gpm during heating. The extraction rate will be adjusted to maintain hydraulic control.

7. The MPE system will consist of vertical wells installed within the electrode arrays at depths corresponding to the defined contaminant zones. The Southeast area requires 53 extraction points, including 19 extraction borings and 34 vapor extractors installed at 4.0 m (13.1 ft) BGS in the electrode wells. The Southwest area requires 6 extraction wells and 13 electrode well vapor extractors. The East area is a shallow contaminant zone that requires 3 extraction wells and 5 electrode well vapor extractors. The extraction system will remove volatilized contaminants from the heated zones.

8. The average vapor extraction rate is 36 scfm for each deep extraction well, and 8 scfm for each shallow extraction well co-located with an interior electrode. Total vapor extraction rates will not exceed 1,200 scfm. The liquid flow rate from the MPE wells is estimated at 2.7 to 3.4 gpm per well during treatment. These extraction rates will ensure that all volatilized contaminants are captured and hydraulic control is maintained during ET-DSP™ operations.

9. The shallow VX wells co-located with interior electrodes are not operated until after 60 days of ET-DSP™ operations are completed or until the UCRS reaches temperatures close to target temperatures. This approach will ensure that target temperatures are achieved in the upper strata of the UCRS.

10. Within the heated areas, digiTAM™ strings will be installed in at least 47 sensor wells. Each digiTAM™ will be constructed to monitor temperatures for the full treatment depth at each sensor well location. This data will be used to ensure target temperatures are achieved and maintained in the soil and that heat transfer to surface is safely controlled.

11. The simulation study assumed ET-DSP™ operations for 180 days. Due to the potential for DNAPL mass removal rates exceeding the capacity of surface facilities, an additional two months of operations may be necessary to achieve the cleanup goals.

Attachment A – Model Validation

TETRAD (DYAD 88 Software, Inc.) is a finite difference simulator, originally developed for the study of multiphase fluid flow and heat flow problems associated with petroleum and geothermal resource evaluation. The program was initially released in 1979 and then used extensively by the Alberta Oil Sands Technology Research Authority. On a regular basis upgraded versions are released and the program author, Dr. Kaz Vinsome, supports the program. TETRAD has since achieved acceptance amongst its peers and is used commercially in the Petroleum Industry (Encana, Petro-Canada, Shell, Unocal, E-T Energy, etc.), Environmental Industry, Research and Government (DOE, AOSTRA, EPA, etc) institutions, as well and several universities. TETRAD is capable of simulating three-dimensional, multiphase flow in complex, heterogeneous, anisotropic systems. Vinsome and Shook (1993) describe the structure and solution methods for TETRAD in [VINSOME, P.K.W., and SHOOK, G.M.., Multi-Purpose Simulation; *J. Petroleum Science and Engineering, Vol. 9, 29-38 pp., April 1993.*].

TETRAD was the first commercial numerical simulation program to fully couple the non-linear physics of electro-thermal heating into a 3-Dimensional mass and heat transfer model in 1988 [VINSOME, K., MCGEE, B.C.W., VERMEULEN, F.E. and CHUTE, S.F., Electrical Heating; *Journal of Canadian Petroleum Technology, Vol. 33, No. 4, 29-36 pp., April 1994.*]. The electro-thermal equations used in TETRAD are developed from first principles through many years of research and development at the Applied Electromagnetics Laboratory at the University of Alberta [CHUTE, F.S., VERMEULEN, F.E. and CERVENAN, M.R., Physical Modeling of the Electrical Heating of the Oil Sand Deposits; *Technical Report, AOSTRA Agreement #31, Applied Electromagnetics Group, University of Alberta, 1978.*], [VERMEULEN, F.E., CHUTE, F.S. and CERVENAN, M.R., Physical Modeling of the Electromagnetic Heating of Oil Sand and Other Earth-Type and Biological Materials; *Canadian Electrical Engineering Journal, Vol. 4, 19-28 pp., October 1979.*], [SUMBAR, E., VERMEULEN, F.E. and CHUTE, F.S., MEGAERA 4.0: A Code for Modeling Transient Heat Flow Induced by Quasistatic Electric Fields in Lossy Media; *Technical Report, Applied Electromagnetics Group, University of Alberta, Edmonton, AB, 1989*], [HIEBERT, A.D., CAPJACK, C.E., CHUTE, F.S. and VERMEULEN, F.E., A Simulation Code for Investigating 2D Heating of Material Bodies by Low Frequency Electric Fields; *Applied Mathematical Modeling, Vol. 7, No. 5, 366–371 pp., October 1983.*], [HIEBERT, A.D., VERMEULEN, F.E. and CHUTE, F.S., Application of Numerical Modeling the Simulation of the Electric-Preheat Steam-Drive (EPSD) Process in Athabasca Oil Sands; *Journal of Canadian Petroleum Technology, Vol. 28, No. 5, 74-86 pp., September – October 1989.*].

TETRAD has since been advanced to model *n-Phase* electromagnetic fields. The program has been successfully used by McMillan-McGee for the technical approach and design for ET-DSP™ systems **on all our** remediation projects. For example, of significant importance is the budget for electrical energy needed to complete a project. The following figure shows a comparison between the predicted (budget) and actual energy expended on a project (among other design targets).

	Simulation	Actual		Performance	Comments
Project Duration	120	116	Days	96.29%	Down for weather & sampling
Electrical Energy	752,546	754,038	kwHr	100.20%	228 kWhr/yd3
Average Power	261.30	271.91	kW	104.06%	
Electrode Power	10.89	11.33	kW	104.06%	
Average Target T	85.00	98.60	C	116.00%	
Total Liquid Injected	829,236	414,620	gallons	50.00%	Maintain hydrodynamic control
Total Liquid Extracted	746,286	186,136	gallons	24.94%	
Total Vapor Extracted	48,384,000	26,404,906	scf	54.57%	
Target Mass Recovered	80%	83%		103.75%	August 10 Sampling Event

The TETRAD model accurately predicted the duration, energy, and power during the operations of the project. Differences between budget and actual results is usually an indication that the actual technical approach and field operations are significantly different than those established through the numerical modeling. In the figure, the difference between the predicted and actual extraction rates were due to limitations in the extraction facilities, which were not designed to handle the liquid and vapour phase mass during ET-DSP™ operations. The 85 Average Target T was not a simulation calculation but rather a performance metric. Simulation temperatures were very close to actual results. A recent study [MCGEE, B.C.W. and VERMEULEN, F.E., The Mechanisms of Electrical Heating for the Recovery of Bitumen from the Oil Sands; *Journal of Canadian Petroleum Technology, Vol. 46, No. 1, 29-36 pp., January 2007*] uses the full capabilities of TETRAD to predict the performance of ET-DSP™ for the recovery of Bitumen from the Athabasca Oil Sands. To date the field results have been consistent with the predictions from TETRAD.

The TETRAD numerical simulation program has been used within the U.S. Department of Energy, for example, Contract No.: DE-FC22-95BC14939, titled, **Increasing Heavy Oil Reserves in the Wilmington Oil Field Through Advanced Reservoir Characterization and Thermal Production Technologies, April 1 - June 30, 1997** An SPE presentation (and future paper) was given on a parametric study comparing projected steam drive recoveries from vertical wells and horizontal wells using the assisted gravity drainage technique. Another DOE study using TETRAD is described under **DOE Contract number:** AC07-99ID13727. The results of this work are presented in Ershaghi, I., Amili, P., University of Southern California: **Correlations for Prediction of Steamflood Oil Recovery in Steam-Assisted Gravity-Drainage Process Using Horizontal Injectors and Producers**, SPE Paper No. 38297.

Attachment B – Volume Calculations

Depth Range [ft BGS]	Depth Interval (ft)	Region	Area [ft2]	Area (m2)	Volume [ft³]	Volume [yd3]	Volume [m3]	Zone	
Southeast Area									
17-20	3	SE	10,016.5	930.6	30,049.5	1,112.9	850.9	UCRS	Unsat
20-40	20	SE	10,016.5	930.6	200,330.0	7,419.6	5,672.7	UCRS	Unsat
40-50	10	SE	5,358.5	497.8	53,585.0	1,984.6	1,517.4	UCRS	Unsat
40-55	15	SE North Arm	1,626.3	151.1	24,394.5	903.5	690.8	UCRS	Unsat
50-55	5	SE	11,770.2	1,093.5	58,851.0	2,179.7	1,666.5	UCRS	Unsat
55-60	5	SE North Arm	1,626.3	151.1	8,131.5	301.2	230.3	UCRS	Sat
55-60	5	SE	11,770.2	1,093.5	58,851.0	2,179.7	1,666.5	UCRS	Sat
60-65	5	SE	9,097.2	845.2	45,486.0	1,684.7	1,288.0	UCRS	Sat
65-100	35	SE	9,097.2	845.2	318,402.0	11,792.7	9,016.1	RGA	Sat
100-103	3	SE	9,097.2	845.2	27,291.6	1,010.8	772.8	RGA	Sat
Total SE Treatment Volume					768,031.0	28,445.6	21,748.2	UCRS, RGA, Unsat, Sat	
Total SE Heated Volume					825,372.1	30,569.3	23,371.9	UCRS, RGA, Unsat, Sat	
UCRS Heated Volume					479,678.5	17,765.9	13,583.0	Unsat and Sat	
RGA Heated Volume					345,693.6	12,803.5	9,789.0	Sat	
Unsaturated Zone Volume					367,210.0	13,600.4	10,398.2	UCRS	
Saturated Zone Volume					458,162.1	16,969.0	12,973.7	UCRS and RGA	
Southwest Area									
17-20	3	SW	6,981.6	648.6	20,944.8	775.7	593.1	UCRS	Unsat
20-40	20	SW	6,981.6	648.6	139,632.0	5,171.6	3,953.9	UCRS	Unsat
40-55	15	SW	2,394.0	222.4	35,910.0	1,330.0	1,016.9	UCRS	Unsat
55-65	10	SW	2,394.0	222.4	23,940.0	886.7	677.9	UCRS	Sat
65-100	35	SW	2,394.0	222.4	83,790.0	3,103.3	2,372.7	RGA	Sat
100-103	3	SW	2,394.0	222.4	7,182.0	266.0	203.4	RGA	Sat
Total SW Treatment Volume					283,272.0	10,491.6	8,021.4	UCRS, RGA, Unsat, Sat	
Total SW Heated Volume					311,398.8	11,533.3	8,817.8	UCRS, RGA, Unsat, Sat	
UCRS Heated Volume					220,426.8	8,164.0	6,241.8	Unsat and Sat	
RGA Heated Volume					90,972.0	3,369.3	2,576.0	Sat	
Unsaturated Zone Volume					196,486.8	7,277.3	5,563.9	UCRS	
Saturated Zone Volume					114,912.0	4,256.0	3,253.9	UCRS and RGA	
East Area									
17-20	3	NE	756.3	70.3	2,268.9	84.0	64.2	UCRS	Unsat
20-40	20	NE	756.3	70.3	15,126.0	560.2	428.3	UCRS	Unsat
40-55	15	NE	7,109.9	660.5	142,198.0	5,266.6	4,026.6	UCRS	Unsat
55-65	10	NE	7,109.9	660.5	35,549.5	1,316.6	1,006.7	UCRS	Sat
Total NE Treatment Volume					157,324.0	5,826.8	4,454.9	UCRS, RGA, Unsat, Sat	
Total NE Heated Volume					195,142.4	7,227.5	5,525.8	UCRS, RGA, Unsat, Sat	
UCRS Heated Volume					195,142.4	7,227.5	5,525.8	Unsat and Sat	
RGA Heated Volume					0.0	0.0	0.0	Sat	
Unsaturated Zone Volume					159,593	5,911	4,519	UCRS	
Saturated Zone Volume					35,550	1,317	1,007	UCRS and RGA	

Attachment C 2-D Numerical Simulation Investigation on the Impact of Groundwater Flow

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Paducah C-400

2-D Numerical Simulation Investigation on the Impact of Ground Water Flow on Electro-Thermal Heating of the RGA and ET-DSP™ for the ERH Pilot Area

by

Bruce C. W. McGee CD, Ph.D., P.Eng.
Principal Engineer

Technical Report Series **Mc2.PD.07.0001**

Paducah C-400 **November 2007**

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2-D Numerical Simulation Investigation on the Impact of Ground Water Flow on Electro-Thermal Heating of the RGA and ET-DSP™ for the ERH Pilot Area

Bruce C. W. McGee CD, Ph.D., P.Eng.

Technical Report Mc2.PD.07.0001
Engineering and Technology
McMillan-McGee Corp.

November 28, 2007

Abstract

This numerical simulation study investigates the development of the temperature distribution in the SE Area of the RGA at a depth of 24.4 m (80 ft) bgs for groundwater flows of one ft/day, three ft/day, and six ft/day and compares the result to the stagnant case (zero ft/day). This study also investigates the use of ET-DSP™ in place of steam injection in the ERH Pilot Treatment Area. It is noted that a groundwater flow velocity of one ft/day is the expected condition but modeling a flow velocity up to three ft/day is being investigated as an absolutely worst case scenario. A flow rate or six ft/day is being modeled to stress the system and confirm the effects of high ground water flow are being modeled by the simulation program. This technical note is an extension of the Numerical Simulation Study of the Paducah C-400 Project Paducah, Kentucky 90% DESIGN VERSION.

Keywords: Electro-thermal, electrodes, simulation, temperature distribution, startup, operations, ET-DSP™, ground water flow, boundary condition, aquifer

Contents

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List of Tables

1 Summary

This document summarizes ET-DSP™ design recommendations for mitigating the cooling effect of ground water flow from the RGA through the thermal volume at velocities of 1 to 6 ft/day. Design recommendations are also provided to replace the steam injection strategy in the ERH Pilot Treatment Area with ET-DSP™. This numerical simulation study investigates the development of the temperature distribution in the SE Area of the RGA at a depth of 24.4 m (80 ft) bgs with groundwater flow velocities of between 1 to 3 ft/day, and a simulation at 6 ft/day, designed to stress the calculations. The study also investigates the use of ET-DSP™ in place of steam injection in the ERH Pilot Treatment Area. It is noted that a groundwater flow velocity of 1 ft/day is the expected condition and a flow velocity of 3 ft/day is considered an absolutely worst case scenario. This technical note is an extension of the Numerical Simulation Study of the Paducah C-400 Project Paducah, Kentucky 90% DESIGN VERSION

In summary the findings are:

1. The updated 2-D simulation of the impact of ground water flow on the temperature response in the heated volume indicates that no additional up-gradient electrode or extraction wells are needed to achieve the target temperature of the heated volume at the expected ground water flow rate of one ft/day.
2. At ground water flow rates greater than one ft/day and up to three ft/day, possibly three up-gradient electrodes and or extraction wells may be installed to mitigate the impact of ground water flow into the heated volume.
3. There is sufficient water treatment capacity in the surface facilities to handle the incremental water produced at the extraction wells for all the ground water flow scenarios up to 3 ft/day. The capacity is needed to maintain hydraulic control.
4. The ERH Pilot Area can be heated with the addition of one additional ET-DSP™ electrode and a strategically placed extraction well.
5. The ground water flow velocity is an important parameter in designing and budgeting for the design of the thermal remediation process. Given the importance of this data point on the successful outcome of the remediation process and lack of certainty in its value, mitigation of risk associated with ground water flow is important, but can be managed.

2 Discussion

2.1 Background

This study is an extension of the Numerical Simulation Study of the Paducah C-400 Project Paducah, Kentucky 90% DESIGN VERSION 2-D modeling that is discussed in Section *3.1.2. Simulation Results with Groundwater Flow* .

In the previous 2-D runs an aquifer system was attached to the sides of the simulation grid (sides and bottom of the box) in order to simulate an infinite type problem. This was done to allow for small differences in the production and extraction rates to be accounted for in the simulation. For example, the volume of water produced from the extraction wells is 1.05 times more than injected into the electrodes. The 0.05 fraction of the water came from the aquifers attached to the sides grid system. However, for a problem with significant ground water flow and high permeability, the use of aquifers on the sides of the grid problem can influence the flow of ground water (ground water spilling into and out of the grid, out of and into the aquifers) and give the incorrect solution of the problem being modeled.

In these runs, the 0.05 fraction of produced water over injected water (5 to less than 1 percent of the total produced water) comes from an aquifer attached to the bottom of the grid. The z direction permeability is set to 1/100 the horizontal permeability to minimize the influence of the aquifer layer on the results. This approach is taken to prevent flow into and from the sides that impacts the ground water flow into the heated volume. In summary, the modeling assumptions for modeling the impact of ground water flow on the temperature distribution are:

1. The RGA ground water flow velocity is varied from stagnant, to one, three, and six ft/day.
2. The aquifers connected to the sides of the simulation grid are removed. This allows for a more predictable accounting of the water balance, which consists of the water injected for ground water flow, $\dot{Q}_{gw}$, the water produced at the extraction wells, $\dot{Q}_x$, and the water injected into the electrodes, $\dot{Q}_e$.
3. The total water extraction rate from the N_x extraction wells is equal to 1.05 times the total water injected into the N_e electrodes and is increased to offset the flow of ground water into the heated volume. Therefore the extraction rate from extraction well i is determined by
$$\dot{Q}_{x,i} = \frac{1.05 \cdot \sum_{j=1}^{N_e} \dot{Q}_{e,j} + \dot{Q}_{gw}}{N_x}$$
This approach is taken to yield hydraulic control.
4. Thermal treatment of the ERH Pilot Area is achieved using ET-DSP™ [1] instead of steam.

[1] Recent delineation data from the ERH Pilot Area suggests that only one additional electrode will be required.

5. Three additional extraction well locations within the heated volume, as recommended by the ITRC, have been added to the existing 14 extraction well locations for a total of 17 extraction wells in the RGA.

6. For the three and six ft/day cases, the water injection rate into the nine up-gradient electrode well locations was doubled to a 0.2 gpm to test the strategy of increasing energy input to mitigate the impact of ground water flow into the heated volume.

By way of background, the approach to calculate the volume of water flowing into the heated volume is reviewed. The ground water flow velocity, v_f, is the velocity of the advancing water front at its surface. The volume of soil swept by the advancing ground water is

$$\frac{\Delta V}{\Delta t} = v_f \cdot w_{RGA} \cdot h_{RGA}$$

where w_{RGA} and h_{RGA} are the width and height of the heated volume in the RGA perpendicular to the direction of ground water flow. The volume of water flowing through the heated volume is:

$$\frac{\Delta V_w}{\Delta t} = \frac{\Delta V}{\Delta t} \cdot \phi = \dot{Q}_{gw} = v_f \cdot w_{RGA} \cdot h_{RGA} \cdot \phi$$

2.2 Model Details

2.2.1 Grid and Boundary Conditions

The 2-D grid block simulation model is shown in Figure 1. Horizontal injection (yellow) and production wells are placed at each end of the problem. The injection and production rates into the horizontal wells are calculated so that the necessary flux is achieved into the heated volume. In effect, the horizontal wells establish a boundary condition for a constant flux. There are no aquifers attached to boundaries of the grid. The sides of the grid system have no-flow boundary conditions for mass flow. Thermal energy is allowed to flow out of the grid system to account for heat loss.

Water balance is determined from injection wells, extraction wells, and electrodes. Note that only the electrode well locations are shown in this figure. Each square on the background grid is 5 m by 5 m. The width of the heated volume, w_{RGA} is 44 m and the height, h_{RGA} is 12.192 m. The distance between the horizontal wells is 62 m.

The injection rate into the horizontal well is calculated as previously discussed. An example calculation using the 6 ft/day ground water flow velocity is provided below. Using a grid with a width of 66 m, RGA thickness of 12.192 m and φ of 0.30[2] , the injection and production rates into the horizontal wells are 442 m^3/d or 81 gpm. The width of the heated volume perpendicular to the direction of ground water flow is about 44 m. Approximately 44/66 ·81 = 54 gpm (294.3 m^3/day) of ground water flows into the heated volume as defined in the numerical model. The power per boring in the RGA is varied with the requirements to heat the ground water flowing into the heated volume.

[2] The permeability in the RGA is estimated at 150,000 mD.

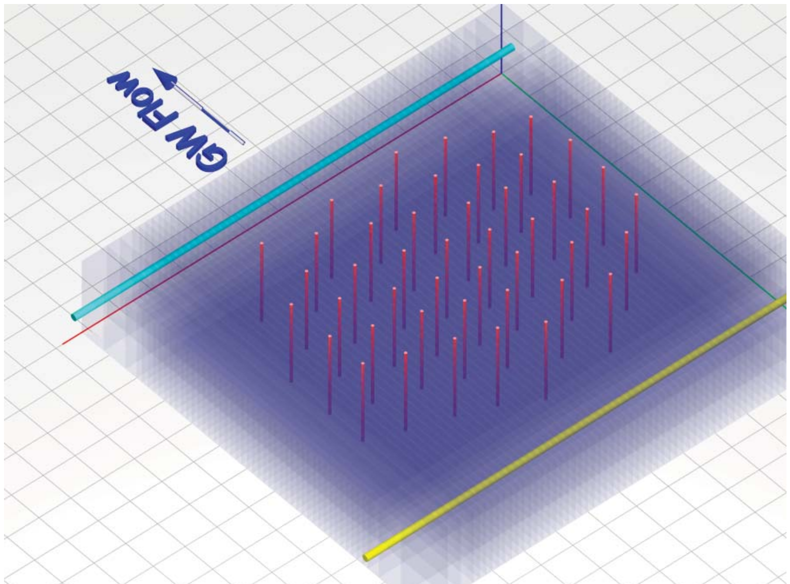

Figure 1: Simulation model.

2.2.2 Electrode and Extraction Well Locations

There are three classification of electrodes:

1. Electrode locations within the heated volume are designated, for example, by E022,
2. Electrode locations designated for the ERH Pilot Area are designated, for example, by ES03
3. Ground water control electrode locations are similarly designated by EG03,
4. Extraction well locations in the heated volume are designated, for example, by X09,
5. Ground water control extraction well locations are designated, for example, by XG02, and
6. Extraction well locations designated for the ERH Pilot Area are designated, for example, by XS01.

As with the previous runs, there are 45 electrodes within the heated volume. A single electrode has been added to replace the steam injection well in the ERH Pilot Area for a total of 46 electrode well locations.[3] The number of ground water control electrode and extraction locations are not recommended from this investigation. There is a single extraction well assigned for the ERH Pilot Area.

[3]There are effectively 2 to 2 1/2 electrodes in each electrode well location.

3 Results

Figure 2 shows the temperature distribution after 180 days of ET-DSP™ operations with no ground water flow. Target temperatures are achieved in less than 90 days.

Figures 3 to 8 shows the development of the temperature distribution in 30 day increments of ET-DSP™ operations with 1 ft/D ground water flow velocity. This is the expected ground water flow rate.

The results indicate that by balancing the extraction rate from the extraction wells and increasing power to the up-gradient electrodes, the target heating objectives can be achieved in between 90 and 120 days. It is noted that power to the down gradient electrodes can be optimized (reduced as needed) to reduce energy costs. Also, maximum current to the electrodes is set at 150 A and this limitation was never reached during the simulation of the 1 ft/day scenario. Power to the up-gradient electrodes can be adjusted with increased water injection to create a higher up-gradient energy source. This approach was not modeled for the 1 ft/day case (water injection was doubled for the 3 and 6 ft/day cases), however, it could provide additional assurance that the heated volume target temperatures can be achieved.

Figure 9 shows the impact of a groundwater flow velocity of 3 ft/day on the development of the temperature distribution. Under these conditions the average temperature of the treatment volume achieves target temperature after about 120 days. There are two points worth noting from the temperature distribution:

1. Although the average temperature distribution in the heated volume exceeds the target temperature after 90 to 120 days of heating, there are locations within the heated volume, in the up-gradient direction, towards ground water flow, that fall below the target temperature.

2. As ground water flows past the heated volume at higher rates, the amount of heat drawn away with the ground water begins to be a concern as indicated by the increased temperatures down gradient of the heated volume.

It may be possible to reconfigure the existing design to mitigate the impact of high ground water flow rates (3 ft/day) on the temperature distribution. The 3 and 6 ft/day scenarios had the injection rates into the up-gradient electrodes doubled to increase input power at these well locations. This approach was effective. Other approaches might be to reconfigure the layout of electrode well locations to maximize the heat distribution. A likely more effective approach is to introduce up-gradient electrodes (three at most) to compensate for ground water flow into the heated volume. More data is needed to confirm which approach is most effective.

The 6 ft/day case is shown in Figure 10. This case was run to stress the limits of the design. To compensate for the impact of ground water flow at this rate would require a complete redesign of the thermal remediation approach.

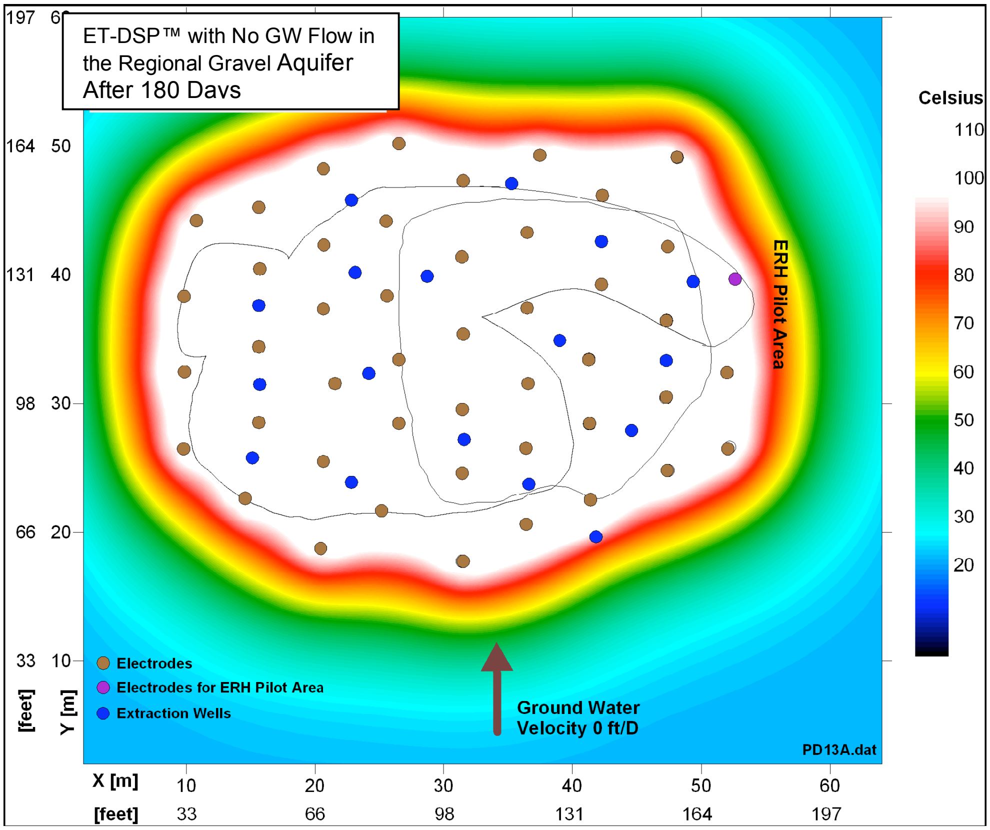

Figure 2: Temperature distribution after 180 days of ET-DSP™ operations with no ground water flow.

Table 1 provides a summary of the input energy and power into the heated volume for the different ground water flow cases. As expected, the faster water flows into the heated volume, the more cold water that needs to be heated to the target temperature, the more input energy that is needed. The table emphasizes the amount of energy to deal with ground water flow and in the expected worst case scenario, the amount of energy to reach target temperature in the RGA doubles. For the 1 ft/day, the amount of energy is still reasonable.

Case	Total Energy (kW-hr)	Average Total Power (kW)	Power to Electrode Location (kW)
Stagnant	2,477,106	573.40	12.46
1 ft/day	3,230,837	747.88	16.26
3 ft/day	5,075,766	1,174.94	25.54
6 ft/day	5,717,622	1,323.52	28.77

Table 1: RGA energy balance for the SE Area.

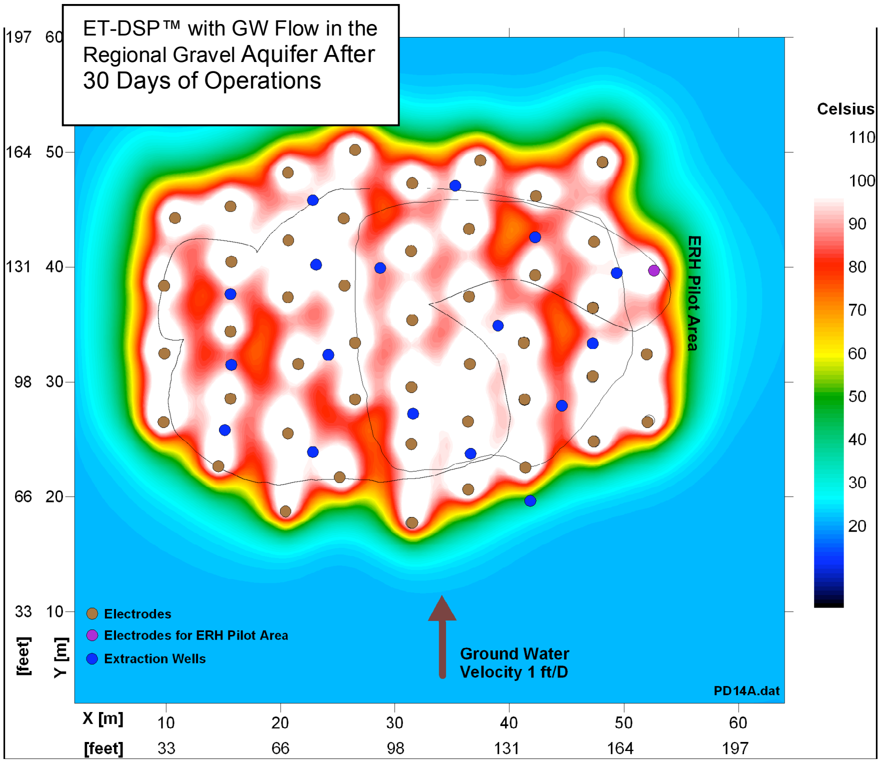

Figure 3: Temperature distribution after 30 days of ET-DSP™ operations with 1 ft/D ground water flow velocity.

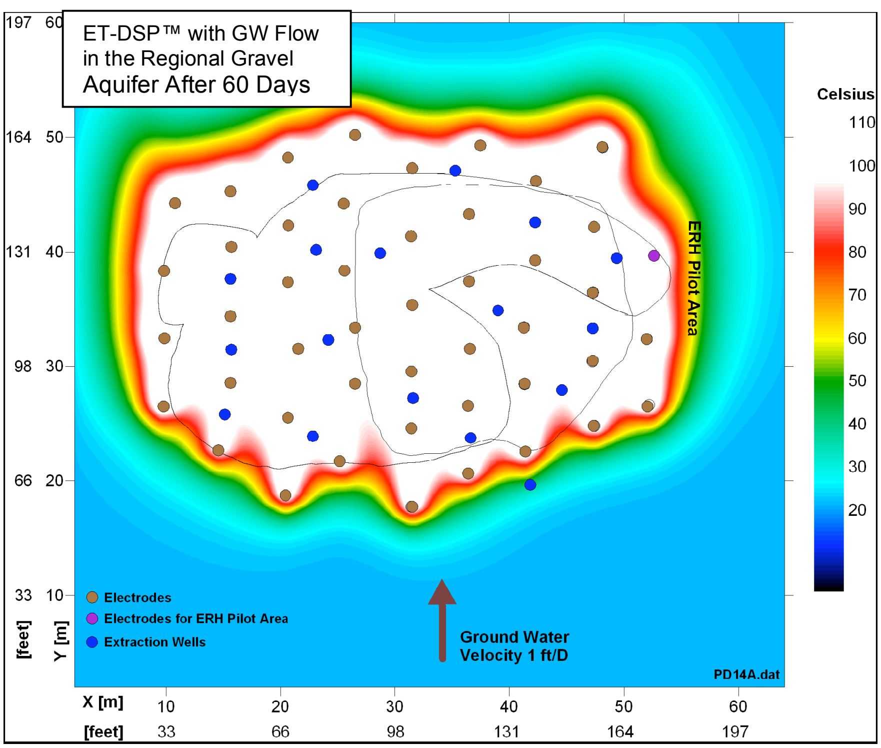

Figure 4: Temperature distribution after 60 days of ET-DSP™ operations with 1 ft/D ground water flow velocity.

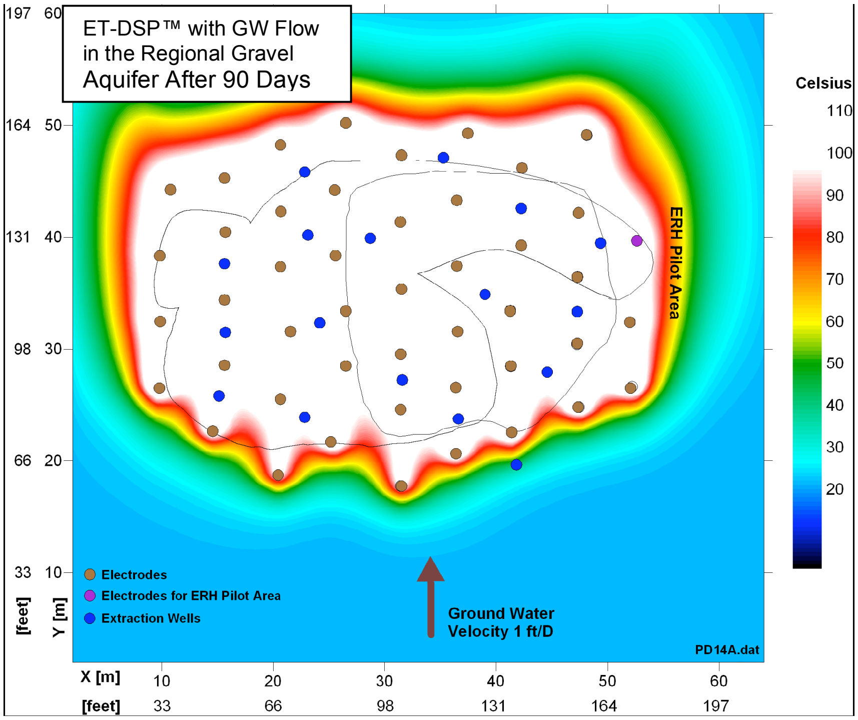

Figure 5: Temperature distribution after 90 days of ET-DSPTM operations with 1 ft/D ground water flow velocity.

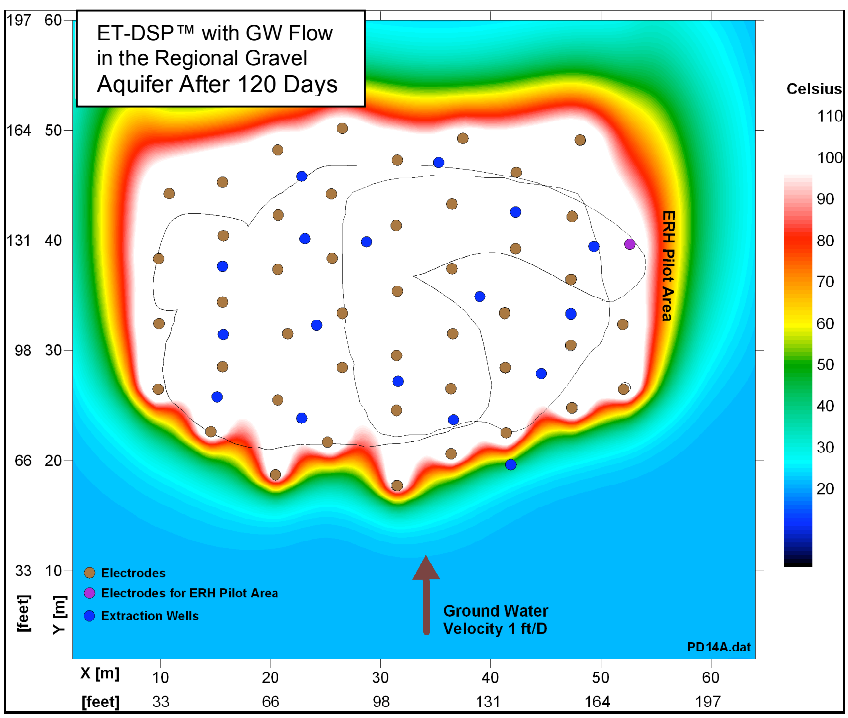

Figure 6: Temperature distribution after 120 days of ET-DSPTM operations with 1 ft/D ground water flow velocity.

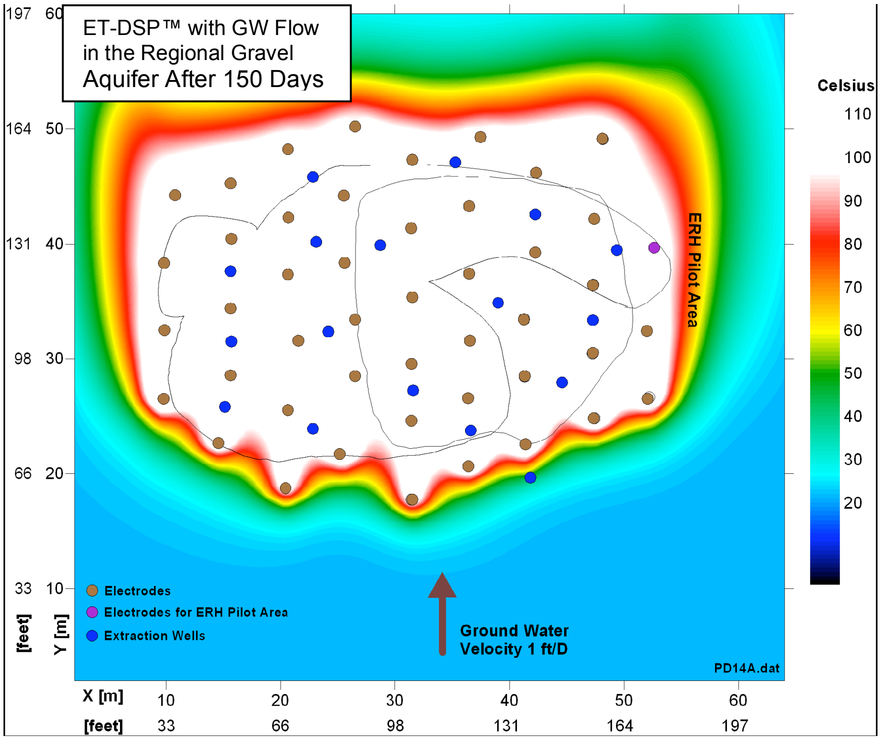

Figure 7: Temperature distribution after 150 days of ET-DSPTM operations with 1 ft/D ground water flow velocity.

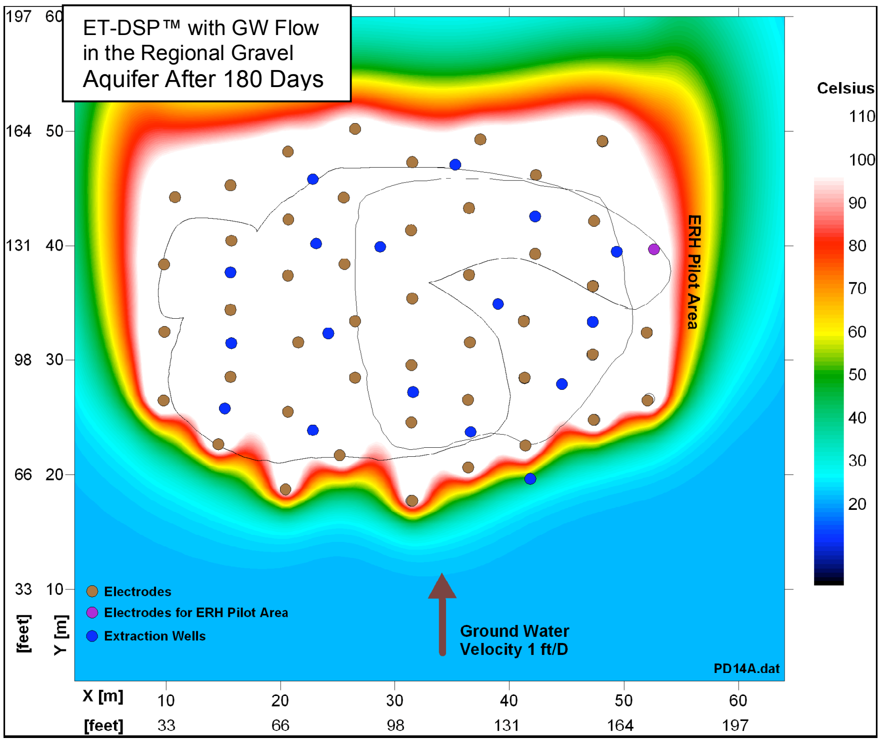

Figure 8: Temperature distribution after 180 days of ET-DSPTM operations with 1 ft/D ground water flow velocity.

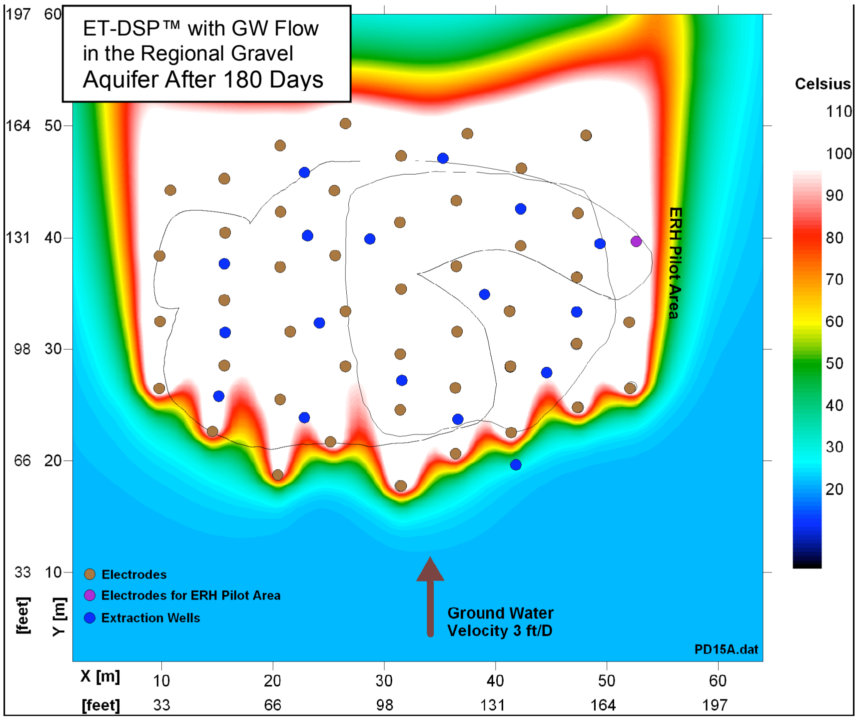

Figure 9: Temperature distribution after 180 days of ET-DSPTM operations with 3 ft/D ground water flow velocity.

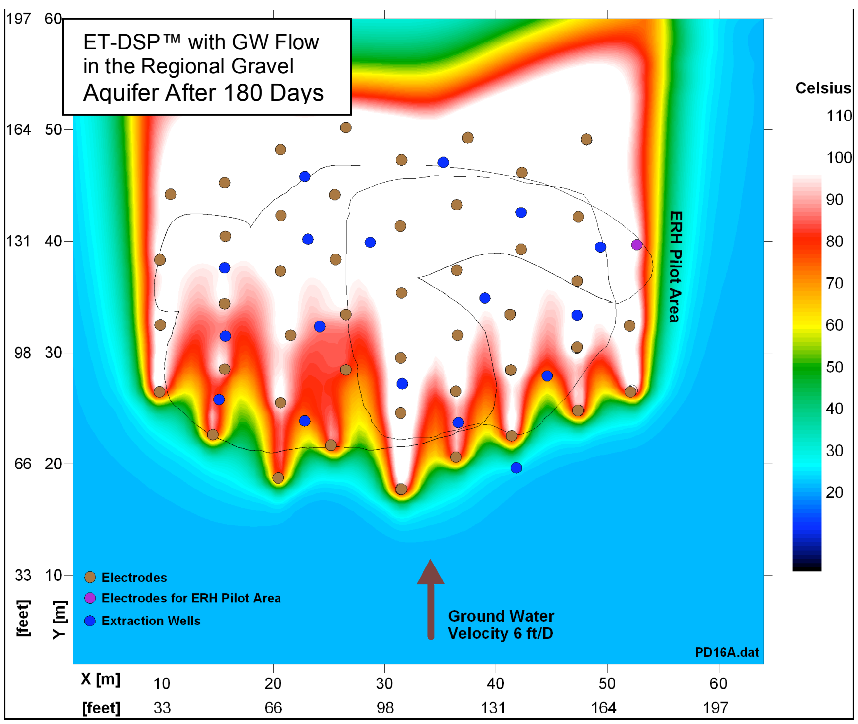

Figure 10: Temperature distribution after 180 days of ET-DSPTM operations with 6 ft/D ground water flow velocity

Figure 11 provides a graphical summary of the input power over the duration of ET-DSPTM operations for the different cases. It clearly shows the additional input energy required to compensate for additional flow of water into the heated volume.

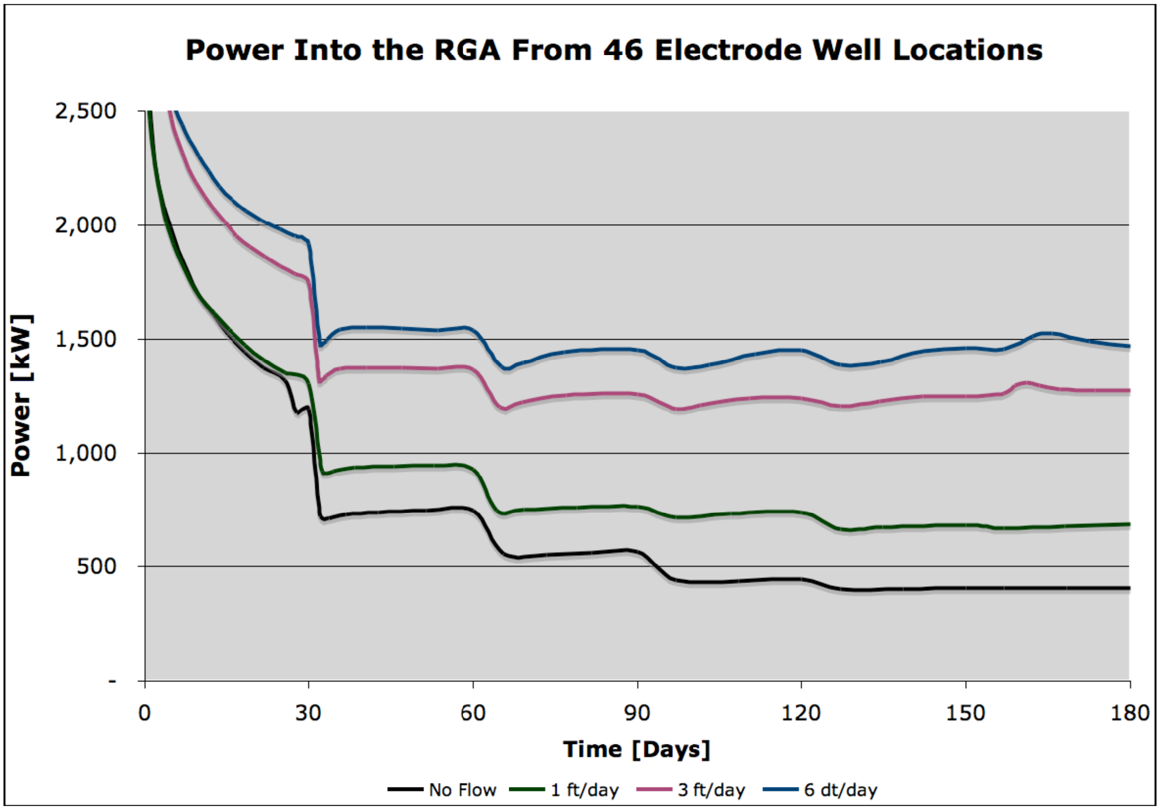

Figure 11: Input power to the RGA for the different ground water flow rates.

Table 2 provides a summary of the water balance for the different cases ground water flow (RGA only). The point of this data is that even for the expected worst case scenario, 3 ft/day, there is sufficient capacity in the surface facilities to manage the flow. Given this extra capacity, it may be worth considering the addition of up-gradient extraction wells to mitigate the ground water flow into the heated volume.

$\dot{Q}_{x,i} = \frac{1.05 \cdot \sum_{j=1}^{N_e} \dot{Q}_{e,j} + \dot{Q}_{gw}}{N_x}$				
	$\dot{Q}_{gw}$ Ground Water	$\dot{Q}_e$ Electrode Locations	$\dot{Q}_x$ Extraction Wells	
Case	m^3/d		m^3/d	gpm
Stagnant	N/A	62.69	65.82	12.07
1 ft/day	49.06	62.69	114.89	21.08
3 ft/day	147.16	74.95	225.86	41.43
6 ft/day	294.32	74.95	373.02	68.43

Table 2: RGA water balance for the SE Area..

4 Conclusions and Recommendations

The following recommendations are put forward for consideration:

1. The updated 2-D simulation of the impact of ground water flow on the temperature response in the heated volume indicates that no additional up-gradient electrode or extraction wells are needed to achieve the target temperature of the heated volume at the expected ground water flow rate of one ft/day.

2. At ground water flow rates greater than one ft/day and up to three ft/day, possibly three up-gradient electrodes and or extraction wells may be installed to mitigate the impact of ground water flow into the heated volume.

3. There is sufficient water treatment capacity in the surface facilities to handle the incremental water produced at the extraction wells for all the ground water flow scenarios up to 3 ft/day. The capacity is needed to maintain hydraulic control.

4. The ERH Pilot Area can be heated with the addition of one additional ET-DSP™ electrode and a strategically placed extraction well.

5. The groundwater flow velocity is an important parameter in designing and budgeting for the design of the thermal remediation process. Given the importance of this data point on the successful outcome of the remediation process and lack of certainty in its value, mitigation of risk associated with groundwater flow is important, but can be managed.

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Attachment D – Laboratory Report on Electrical Resistivity Testing

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Laboratory Report on Electrical Resistivity Tests for the Paducah Gaseous Diffusion Plant C400 Complex Paducah, Kentucky

McMillan-McGee Corp.

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November 9, 2006

Revisions: December 27, 2007

Submitted to Paducah Remediation Services, LLC

Contents

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Declaration of Quality Assurance

The undersigned declare that all reasonable efforts were made to strictly follow quality standards in the measurement and analysis of laboratory data. The following assurances are made regarding lab procedures:

1. The treatability samples were received in good order on Sept. 22, 2006.
2. The samples were kept sealed and refrigerated upon receipt and between laboratory tests.
3. Laboratory instruments used to acquire electro-thermal data were calibrated prior to the experiments. Measurements were verified with field instruments during testing.
4. Laboratory test procedures began as soon as possible after the samples were opened to ensure material remained as representative as possible of subsurface conditions.
5. No more than half a pore volume of laboratory tap water was added to each sample prior to resistivity testing. The electrical conductivity of the lab water was representative of the expected site groundwater.
6. High electrical heating rates were required for accelerated conditions relative to field operations. The maximum power density of 250 kW/m^3 was achieved during the Dynamic Resistivity Tests.

Eric Ringdahl P.Eng.
Project Engineer
McMillan-McGee Corp.

1 Summary

The static electrical properties of site representative soil samples were measured at ambient temperature for various subsurface depths. The Dynamic Resistivity Tests were performed on two typical samples from the lower sand and upper silt layers. The following is a summary of the outcome of this work:

1. The soil resistivity at ambient temperature was within the suitable range for ET-DSP^{TM} according to the **Static Resistivity Tests**. The soil types varied widely among the core samples, and included fine and coarse sands, silt, and gravel. The electrical resistivity ranged from 11 $\Omega \cdot m$ for the fine sand at 96 ft BGS to 134 $\Omega \cdot m$ for a coarse sand and gravel mixture from the lower treatment zone.

2. The resistivity of the deep sand is expected to decrease by a factor of *3.15* during heating to ET-DSP^{TM} target temperatures as determined from the **Dynamic Resistivity Tests**. Similarly, the resistivity of the upper zone silt is expected to decrease by a factor of *3.60* during heating. During field operations, the resistivity will decrease further as contaminants are extracted from the impacted soil, providing an indication that the soil is being remediated.

2 Introduction

The investigation was performed by McMillan-McGee Corp. in the electro-thermal laboratory (lab facility shown in Figure 1). The purpose of this report is to present results of the Electrical Resistivity Tests. Contaminated soil material was obtained from the Paducah Gaseous Diffusion Plant C400 Complex in Paducah, Kentucky.

Figure 1: McMillan-McGee electro-thermal laboratory

As electrical soil heating operates by applying a voltage across installed electrodes to induce current in the soil, site treatability using this method depends on the soil resistivity. The Static Resistivity Tests are conducted to determine the general power requirements of the Electro-Thermal Dynamic Stripping Process (ET-DSP™) at the project site. If the soil resistivity at ambient temperature exceeds 200 to 300 Ω-m, it may be difficult to treat the soil using electro-thermal methods without applying a higher voltage to the electrodes, spacing the electrodes closer together, or injecting an electrolytic solution.

Another key property of the soil in determining its electro-thermal treatability is the electrical resistivity as a function of temperature. Generally, as water saturated soils are heated to the boiling point, the electrical resistivity will decrease to one third of its initial value. Power controls for the electrical heating process must be capable of adjusting for these variations. In the Dynamic Resistivity Tests, the thermal effect on resistivity is determined as the soil sample is heated from ambient to maximum temperature.

The sample material consisted of varied soil types covering depths from surface to 97 ft BGS. All soil was composed of either sand or silt, while some samples had a large proportion of gravel resulting in a higher resistivity. Usually wetted sands and silts are sufficiently conductive for ET-DSP™ , depending on electrolyte content of the groundwater. The samples as received were sealed in coolers, and retained high moisture content. Up to half a pore volume of representative water was added to restore moisture in the soil prior to testing as needed. No odor consistent with the presence of hydrocarbons was detected.

3 Procedures

3.1 Preparation

On Oct. 3, 2006, the treatability samples were prepared for the Static Resistivity Tests. Each sample container had soil from a given depth section as shown in Figure 2. The sample under test was removed from the package and tightly packed in the test holder. The soil content appeared relatively uniform such that no further soil preparation was required in most cases. Note that bench-to-field scaling parameters are based on homogeneous soil content so that the testing results can be used to represent a type of soil, e.g., silty sand.

Some of the cores contained small rocks that had to be removed from the test material. Removal of the rocks was required due to the size of the electrodes used in the test. The test electrodes are relatively small and if rocks were left in the samples, they would skew the results to make the resistivity much higher than what it would be for a full-sized electrode.

Figure 2: Soil samples received from the site

For the laboratory tests, temperatures and electrical data are collected in real time using a computer controlled data acquisition system. The equipment was designed so that all procedures are conducted with minimum changes to the data acquisition setup between tests. Voltage and current readings are verified by field meters during testing. The data acquisition system is based on the real-time web monitoring technology developed by McMillan-McGee for field operations.

The data acquisition equipment used for laboratory testing is shown in Figure 3. The equipment includes digital sensors for monitoring soil temperature, and transducers for measuring electrical current.. The electronics control power delivery and measure temperature and electrical current.

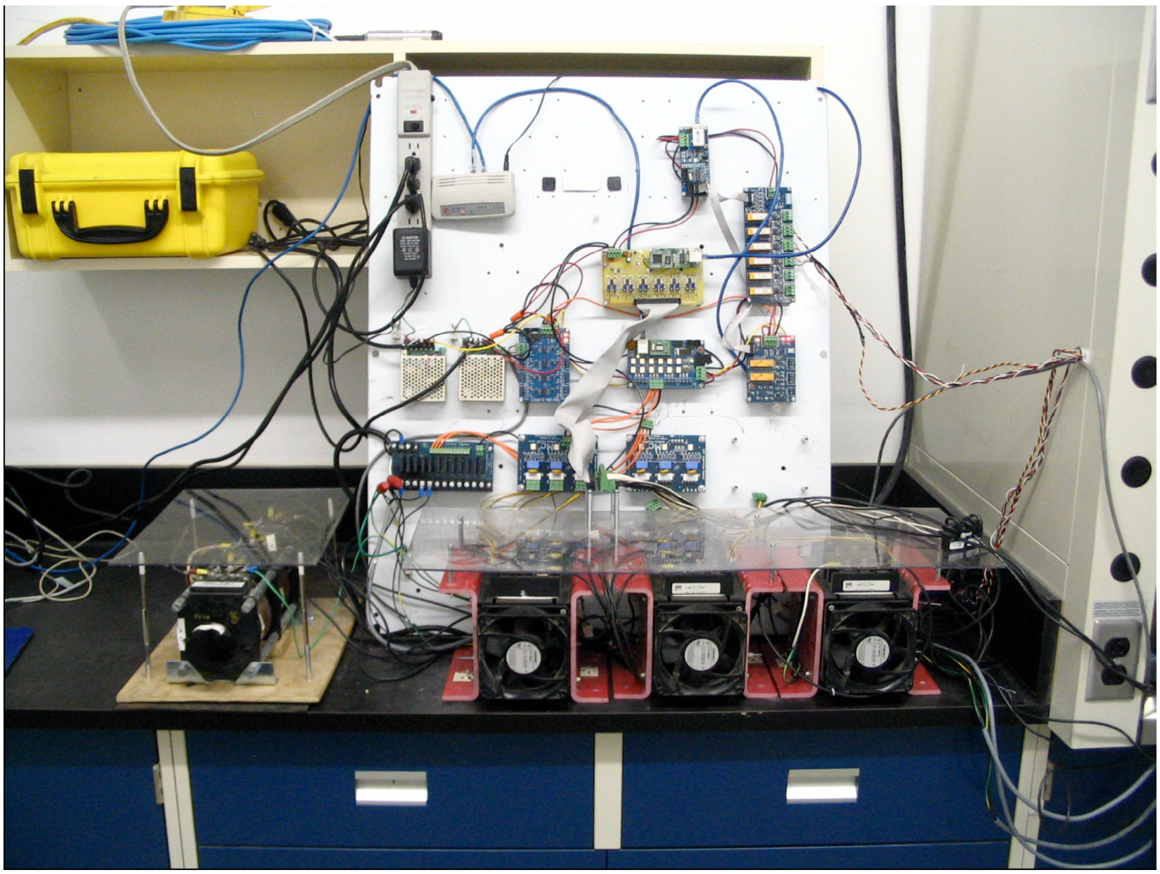

Figure 3: Data Acquisition Equipment

3.2 Static Resistivity Tests

The objective of the Static Resistivity Tests is to determine the electrical resistivity of the test material at ambient temperature. Electrodes are placed so that current passes horizontally through the sample and data are collected on electrical parameters. The electrodes must make even contact with the soil to ensure uniform current density.

The static resistivity test procedure for each sample is as follows (begin with sample at room temperature):

1. Position the copper electrodes at the ends of the sample holder.

2. Pack the sample in the test apparatus to a high density. This is done to replicate the natural soil density.

3. Add site groundwater as required to restore moisture in the soil (not to exceed a 1/2 pore volume).

4. Measure the dimensions of the sample using calipers.

5. Connect the Variac power supply, voltage meter, current meter, and data acquisition system to the electrodes.

6. Set the Variac to a nominal voltage to limit thermal fluctuation.

7. Obtain the voltage and current readings as rapidly as possible to minimize any thermal effects on electrical resistivity.

8. Determine the electrical resistivity from the equation:

$$\rho = \frac{\sum_{i=1}^{5} V_i}{\sum_{i=1}^{5} I_i} \frac{A}{l}$$

where l is the distance between the interior faces of the electrodes, A is the cross-sectional area of the sample, and I and V are the measured current and voltage.

9. Turn off the Variac and retain set-up for next sample.

For example, the first static test was performed on the sample labelled C400-RDSI-9, representing depths from 48 to 55 ft BGS. The sample consisted of brown silt. The sample remained sufficiently moist and was packed in the test holder as shown in Figure 4. On applying a voltage across the electrodes, a soil resistivity of 33 $\Omega \cdot m$ was observed.

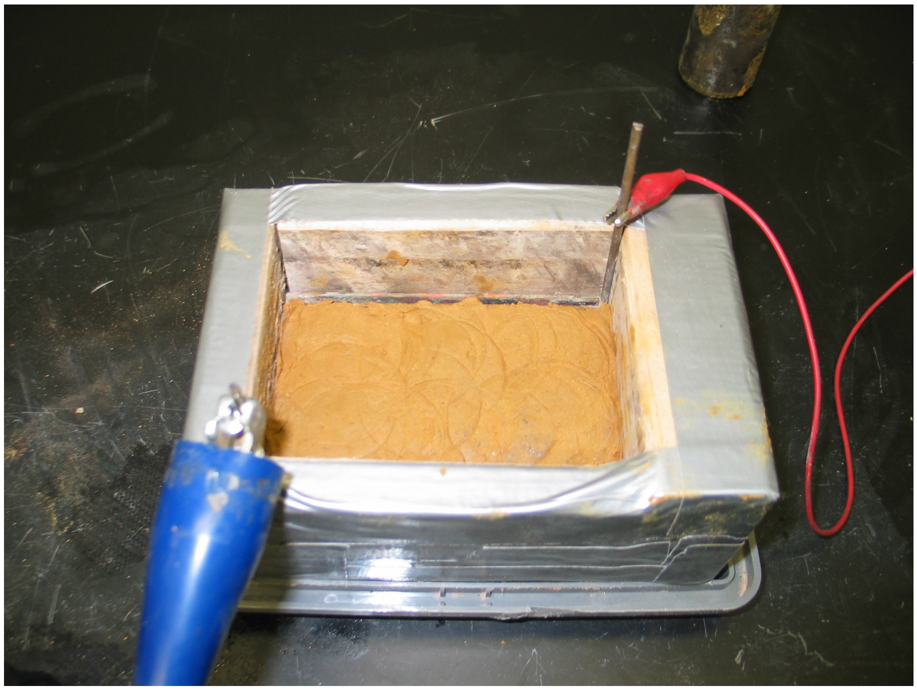

Figure 4: For the C400-RDSI-9 sample, the soil was moist and had a resistivity of 33 $\Omega \cdot m$

3.3 Dynamic Resistivity Tests

In the Dynamic Resistivity Tests, electrical and temperature data are collected in real time to determine the electrical properties of the sample as a function of increasing temperature. Digital temperature sensors are inserted in the sample to monitor temperature.

The dynamic resistivity test procedure is as follows (begin with sample at room temperature):

1. Place the temperature sensor in the center plane of the sample.
2. Set the Variac output voltage to a nominal voltage such that the power density is sufficient to heat the soil.
3. At regular intervals of time record the voltage, current, and temperature (done automatically).
4. Plot
$$\frac{V(t)}{I(t)}\frac{A}{l}$$
versus the temperature and heating time. l is the distance between the interior surfaces of the copper electrodes, A is the cross-sectional area of the sample, and I and V are the measured current and voltage. This will give a direct plots of electrical resistivity as a function of temperature.
5. Turn off the Variac and allow soil to cool.

4 Results

4.1 Static Resistivity Tests

The following points are made regarding the results:

1. The soil samples received from the site were shipped in coolers and in most cases had sufficient moisture content for testing. The samples had no odor consistent with hydrocarbon contamination.

2. The resistivity was calculated using $\rho = R \cdot \frac{A}{l}$ where R is resistance in Ohms, l is the sample length and A is the cross-sectional area of the electrodes.

3. The soil resistivity at ambient temperature was within the suitable range for ET-DSP^{TM}. The soil types varied widely among the core samples, and included fine and coarse sands, silt, and gravel. The electrical resistivity ranged from 11 $\Omega \cdot m$ for a fine sand to 134 $\Omega \cdot m$ for a coarse sand and gravel mixture. The static resistivity for the 15 core samples is summarized in Appendix A.

4. The C400-RDSI-1, 36-38 ft BGS sample shown in Figure 5 consisted of brown silt. The resistivity was low at 23 $\Omega \cdot m$.

Figure 5: Static testing of soil, C400-RDSI-1 sample

5. The C400-RDSI-2, 29-36 ft BGS sample shown in Figure 6 consisted of brown silt with gravel. The resistivity was 93 $\Omega \cdot m$ after removing large rocks from the soil.

Figure 6: Static testing of soil, C400-RDSI-2 sample

6. The C400-RDSI-3, 20-26 ft BGS sample shown in Figure 7 consisted of silty sand. The resistivity was 84 $\Omega \cdot m$ after removing large rocks and breaking up clumps of soil.

Figure 7: Static testing of soil, C400-RDSI-3 sample

7. The C400-RDSI-4, 20-26 ft BGS sample shown in Figure 8 also consisted of silty sand. The resistivity was 132 $\Omega \cdot m$ after removing large rocks and breaking up clumps of soil.

Figure 8: Static testing of soil, C400-RDSI-4 sample

8. The C400-RDSI-5 through C400-RDSI-7 samples appeared as shown in Figure 9 and consisted of brown silt with a resistivity of about 37 $\Omega \cdot m$. Samples 5 and 6 covered depths from 0-20 ft BGS, and sample 7 covered 46-48 ft BGS.

Figure 9: Static testing of soil, C400-RDSI-5 sample

9. The C400-RDSI-8, 38-46 ft BGS sample consisted of a silt mixture with a resistivity of 32 $\Omega \cdot m$. The C400-RDSI-9 sample previously shown in Figure 4 indicated similar resistivity over 48-55 ft BGS.

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10. The C400-RDSI-10, 55-62 ft BGS sample shown in Figure 10 consisted of wet sand with a resistivity of 50 $\Omega \cdot m$.

Figure 10: Static testing of soil, C400-RDSI-10 sample

11. The C400-RDSI-11, 62-78 ft BGS sample shown in Figure 11 consisted of wet sand and gravel. The resistivity was 95 $\Omega \cdot m$ after removing large rocks from the soil.

Figure 11: Static testing of soil, C400-RDSI-11 sample

12. The C400-RDSI-12, 62-78 ft BGS sample consisted of wet sand with gravel. The resistivity was 72 $\Omega \cdot m$ after removing large rocks from the soil.

13. The C400-RDSI-13 and C400-RDSI-14 samples appeared as shown in Figure 12 and consisted of wet sand with gravel. The resistivities were high at 134 $\Omega \cdot m$ and 112 $\Omega \cdot m$, respectively. The two samples represented core depths of 77 to 95 ft BGS.

Figure 12: Static testing of soil, C400-RDSI-13 sample

14. The C400-RDSI-15, 95-97 ft sample shown in Figure 13 consisted of dark fine sand with a low resistivity of 12 $\Omega \cdot m$.

Figure 13: Static testing of soil, C400-RDSI-15 sample

15. The expected groundwater conductivity of 395 µS/cm indicates suitable mineral content for ETDSP™. Laboratory tap water used to moisten the samples ranges in conductivity from 320 to 490 µS/cm. The laboratory tap water and groundwater have similar conductivities, and, therefore the tap water will not affect the resistivity of the sample.

16. **With an appropriate moisture and electrolytic control strategy, the soil resistivity at the site will be maintained within the optimal range for ET-DSP^{TM}. McMillan-McGee's water circulation system and patented electrode design can achieve this control for an effective application of electro-thermal treatment.**

4.2 Dynamic Resistivity Tests

The results for the Dynamic Resistivity Tests are presented in Appendix B. These data are used to determine the resistivity trend and to numerically model the process.

As the temperature of soil increases from room temperature to near the boiling point, the resistivity generally decreases by a factor of three. The resistivity will begin to increase again as moisture in the soil is vaporized[2]. Boiling temperature was achieved in both dynamic tests.

The following points are made regarding the results:

1. Therst dynamic test was performed in the test holder on the C400-RDSI-11 core representing depths from 62-77 ft BGS.

2. The resistivity was observed to decrease by a factor of 3.15 with an increase in temperature from 10.0 ºC to 96.0 ºC for sample C400-RDSI-11.

3. The second dynamic test was performed on the C400-RDSI-05 core representing depths from 0-20 ft BGS.

4. The resistivity was observed to decrease by a factor of 3.60 with an increase in temperature from 10.5 ºC to 99.0 ºC for sample C400-RDSI-05.

5. Figures 16 and 20 show the trend of resistivity decreasing with heating time for each of the dynamic tests. The soil behavior is best illustrated in Figures 14 and 15, which directly plot the resistivity response as a function of temperature.

6. Included in Figures 17 and 21 are plots of electrical conductivity as a function of heating time for the two tests. Figures 19 and 23 show the conductivity trend with respect to increasing temperature. The dynamic conductivity responses are used for numerical modelling of ETDSP™.

[2] Soil dessication is generally undesirable at the treatment site, and is prevented during field operations with ongoing water injection to the electrodes.

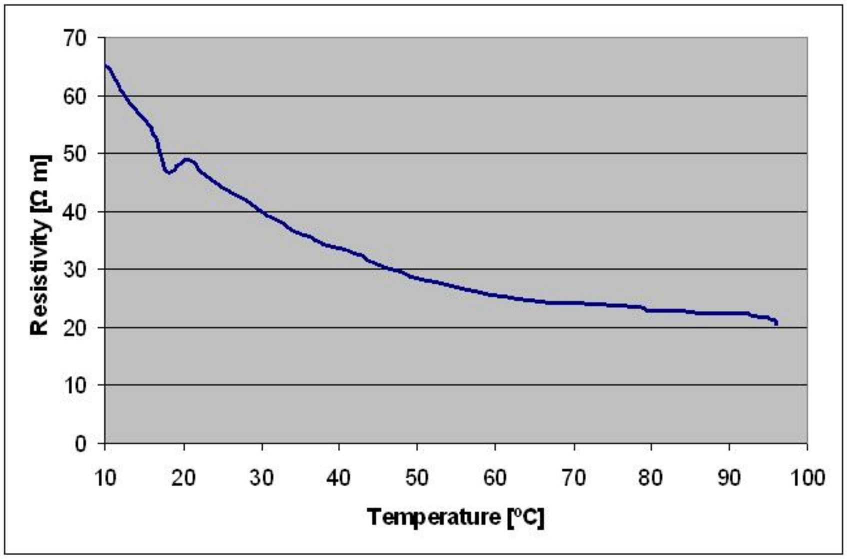

Figure 14: Resistivity Thermal Response during the first Dynamic Resistivity Tests. The temperature increased from 10.0°C to 96.2°C during testing on sample C400-RDSI-11.

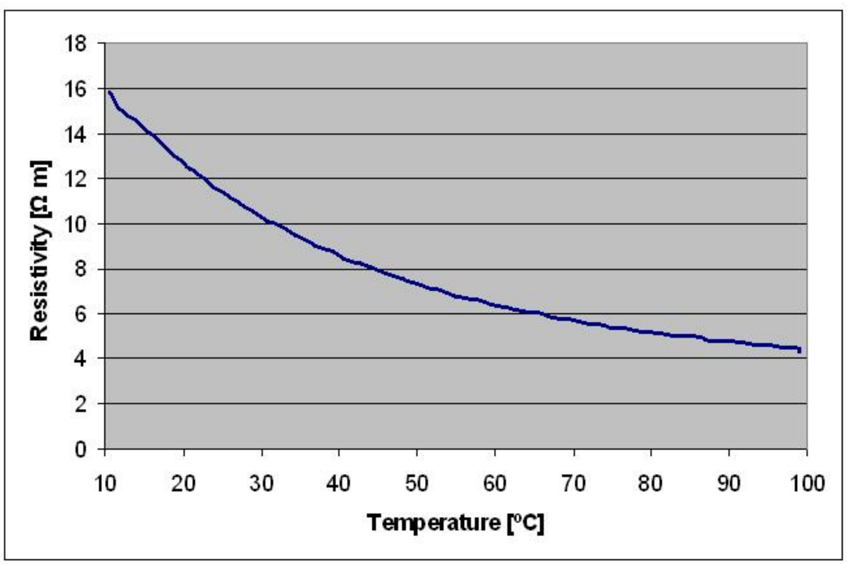

Figure 15: Resistivity Thermal Response during the second Dynamic Resistivity Tests. The resistivity decreased by a factor of *3.60* during heating of sample C400-RDSI-05.

5 Conclusions and Recommendations

The following conclusions are presented from the results of this laboratory investigation of the treatability samples received from the Paducah Gaseous Diffusion Plant C400 Complex:

1. The electrical properties measured in the Static Resistivity Tests for the various soil types indicate the resistivity covers a wide range from 11 to 134 $\Omega \cdot m$. With an appropriate moisture and electrolytic control strategy, the electrical resistivity will be maintained within the optimal range for ET-DSP^{TM}.

2. During the Dynamic Resistivity Tests, electrical resistivity decreased by a factor of *3.15* for the lower sand zone and *3.60* for the upper silt zone. Full control of electrical current to the ET-DSP^{TM} electrodes is required to compensate for such heating effects.

The following recommendations are made:

1. Based on the Electrical Resistivity Tests, it is recommended that the design of the thermal remediation system consist of a multi-layer electrode layout for electrical heating combined with an appropriate contaminant recovery strategy. The electrodes will be evenly spaced with extraction wells situated within the electrode array. A water circulation system capable of moisture and electrolytic control at each electrode is required to maintain electrical resistivity within the effective range for ET-DSP^{TM}.

2. It is recommended that the data obtained be used to quantify electrical power requirements, voltage and current operating conditions, operating strategy and other field scale considerations for ET-DSP^{TM} at the Paducah Gaseous Diffusion Plant C400 Complex.

3. Additional analysis is required to correlate the behavior observed in the lab with what is expected in a field scale operation. This will be done by McMillan-McGee using numerical modelling techniques.

A Static Resistivity Test Data

Sample Holder Dimensions	
Length [m]	0.122
Width [m]	0.074
Electrode Height [m]	0.051

Static Resistivity Summary

Sample ID [ft]	Depth [ft BGS]	**Resistivity** [$\Omega \cdot m$]	**Soil Type**
C400-RDSI-01	36-38	23.0	silt
C400-RDSI-02	29-36	93.1	silt/gravel
C400-RDSI-03	20-26	84.5	silty sand
C400-RDSI-04	20-26	131.8	silt/gravel
C400-RDSI-05	0-20	37.6	silt
C400-RDSI-06	0-20	37.7	silt
C400-RDSI-07	46-48	36.8	silty sand
C400-RDSI-08	38-46	31.9	silt
C400-RDSI-09	48-55	33.1	silt
C400-RDSI-10	55-62	50.2	sand
C400-RDSI-11	62-77	95.4	sand/gravel
C400-RDSI-12	62-77	72.4	silty sand/gravel
C400-RDSI-13	77-95	133.9	sand/gravel
C400-RDSI-14	77-95	111.6	sand/gravel
C400-RDSI-15	95-97	11.8	fine sand

Table 1: Summary of Static Resistivity Tests

B Dynamic Resistivity Test Data

Dynamic Resistivity Data

Temperature [°C]	**Voltage** [V]	**Current** [A]	ρ [$\Omega \cdot m$]
10.0	68.6	53.3	65.4
16.0	215.2	201.4	54.3
20.5	215.0	223.1	49.0
25.0	214.6	247.0	44.1
29.5	214.6	269.8	40.4
34.0	214.6	294.8	37.0
39.0	214.6	322.9	33.8
44.0	214.5	347.8	31.1
50.0	214.6	382.2	28.5
55.0	215.3	404.8	27.0
61.0	215.3	432.1	25.3
64.5	214.9	440.5	24.8
69.5	214.6	450.5	24.2
75.0	214.5	460.8	23.6
80.0	214.5	473.1	23.0
85.0	215.1	481.1	22.7
90.0	215.4	487.1	22.5
96.0	214.9	523.8	20.8

Table 2: Dynamic Resistivity Test Data for Lower Sand Zone

Dynamic Resistivity Data

Temperature [°C]	**Voltage** [V]	**Current** [A]	ρ [$\Omega \cdot m$]
10.5	100.4	322	15.8
15.0	100.6	358	14.3
20.0	100.4	401	12.7
25.0	100.6	447	11.4
30.0	100.4	496	10.3
34.5	100.4	537	9.5
40.0	100.4	594	8.6
45.0	100.3	642	7.9
49.5	100.5	691	7.4
54.5	100.3	744	6.8
59.5	100.3	792	6.4
65.0	100.0	843	6.0
70.0	100.0	889	5.7
75.5	99.9	941	5.4
79.5	99.7	973	5.2
84.5	99.9	1,020	5.0
90.0	100.0	1,063	4.8
95.0	99.9	1,104	4.6
99.0	99.6	1,160	4.4

Table 3: Dynamic Resistivity Test Data for Upper Silt Zone

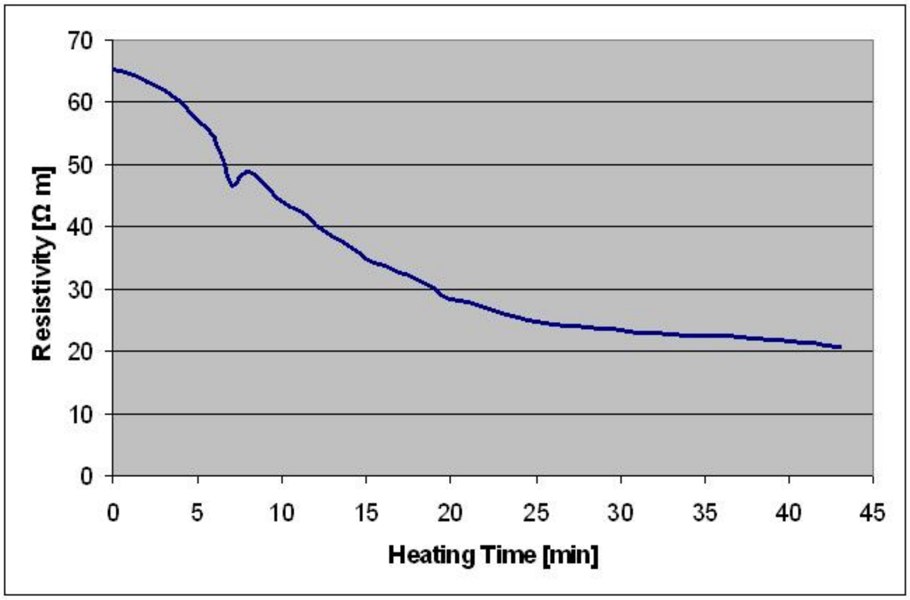

Figure 16: Resistivity Response during Dynamic Test #1. The temperature increased from 10.0°C to 96.0°C during the test.

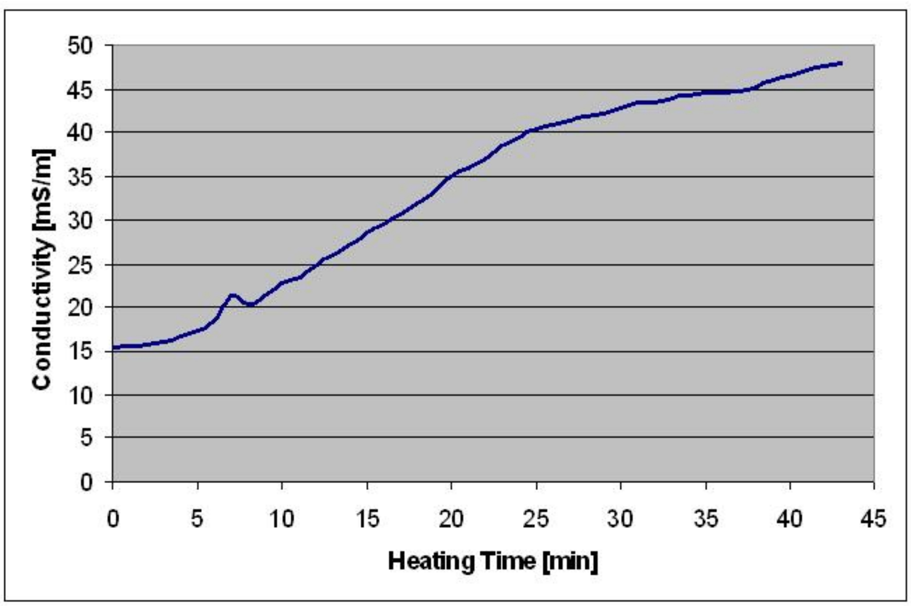

Figure 17: Conductivity Response during Dynamic Test #1. A steady increase in conductivity was observed until the soil began desiccating.

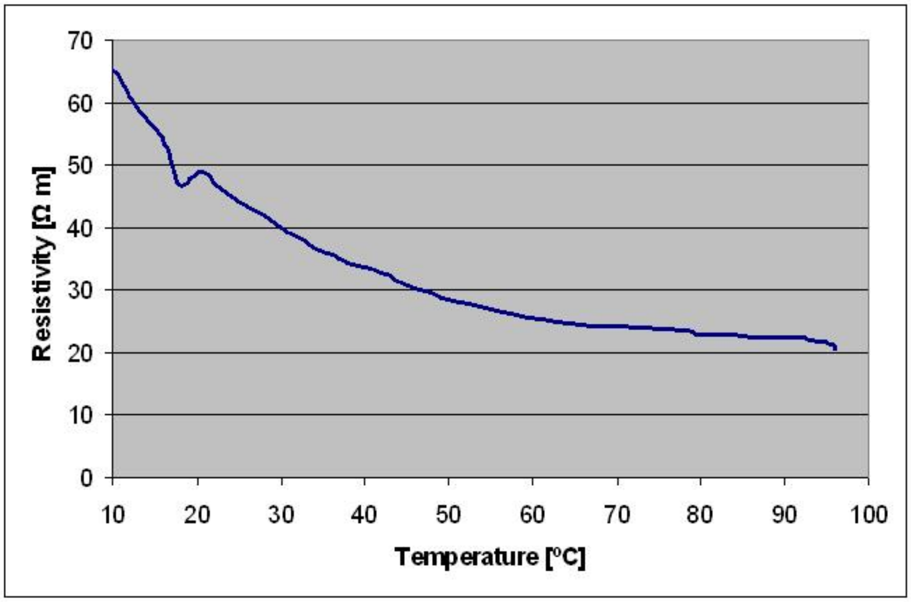

Figure 18: Resistivity Thermal Response for Dynamic Test #1. The resistivity decreased to 20 $\Omega \cdot m$ near boiling temperature.

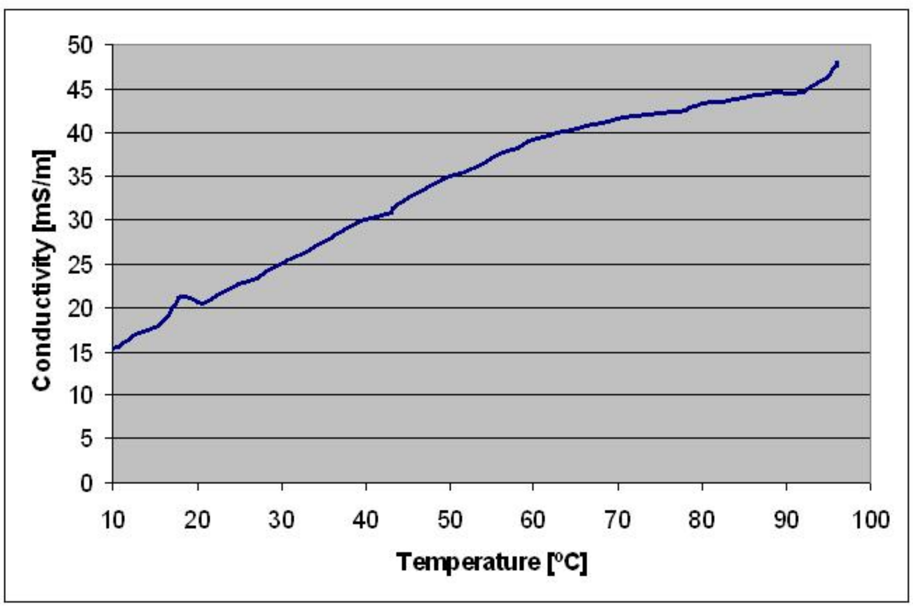

Figure 19: Conductivity Thermal Response for Dynamic Test #2. The conductivity increased by a factor of 3.15 during heating.

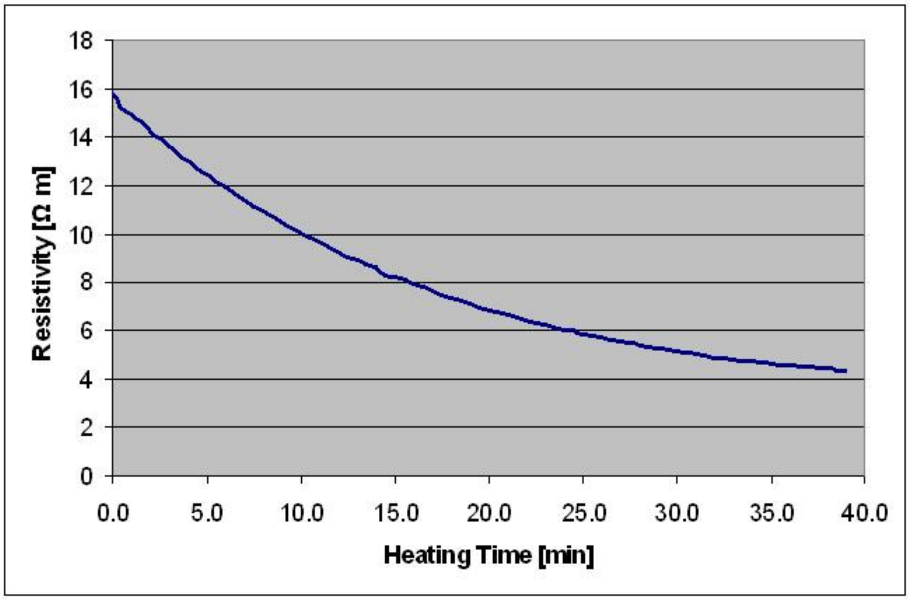

Figure 20: Resistivity Response during Dynamic Test #2. The temperature increased from 10.5°C to 99.0°C during the test.

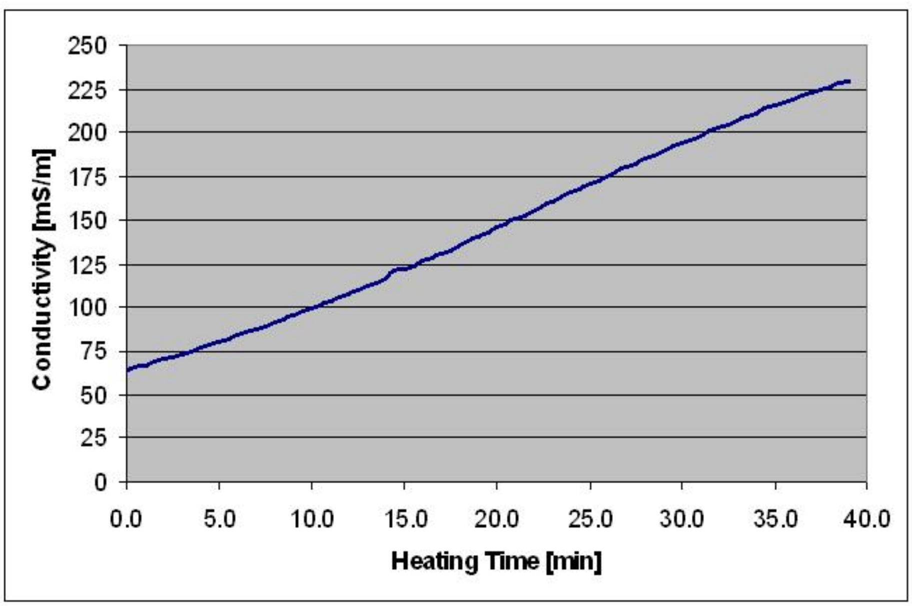

Figure 21: Conductivity Response during Dynamic Test #2. A steady increase in conductivity was observed for the duration of heating.

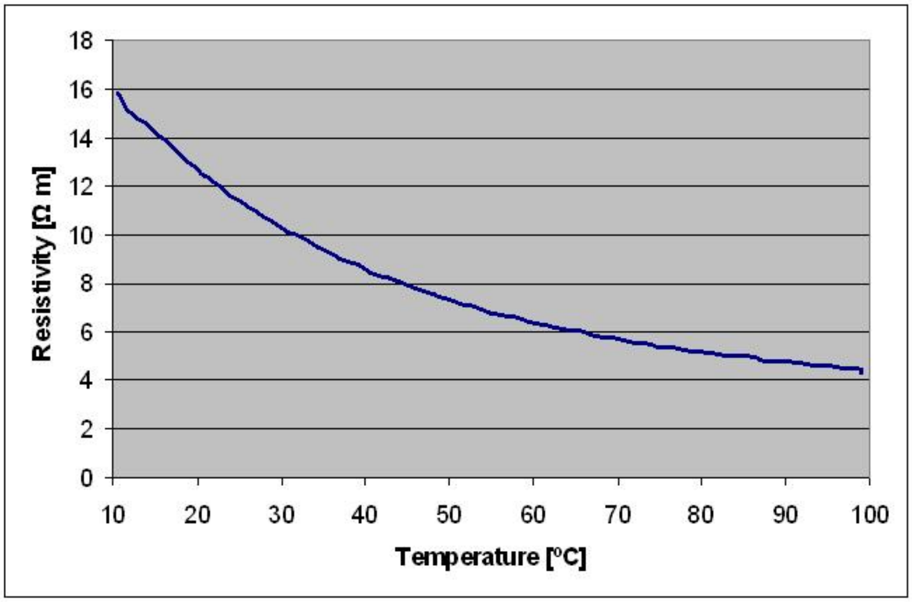

Figure 22: Resistivity Thermal Response for Dynamic Test #2. The resistivity decreased to 4.4 $\Omega \cdot m$ at boiling temperature.

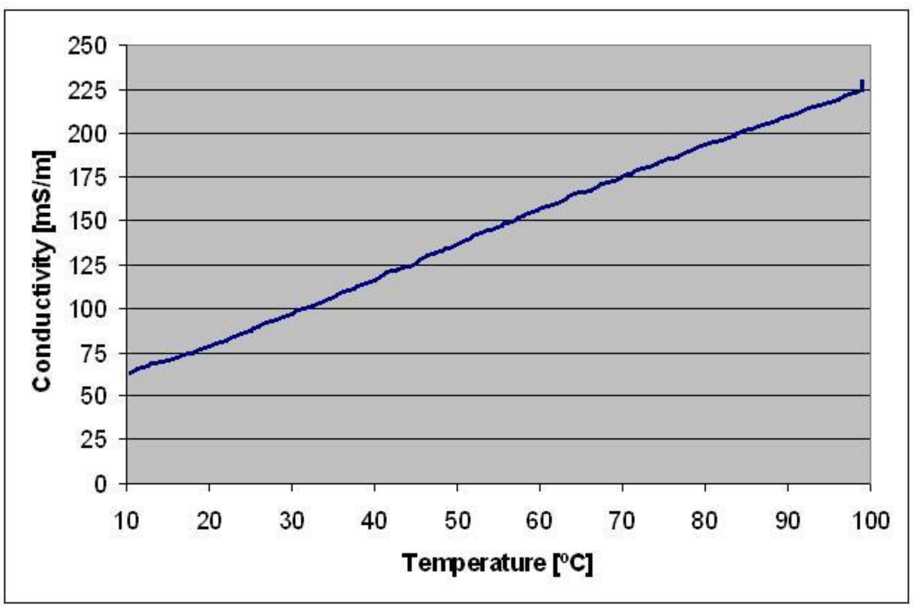

Figure 23: Conductivity Thermal Response for Dynamic Test #2. The conductivity increased by a factor of 3.60 during heating.

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APPENDIX F

VAPOR AND GROUNDWATER TREATMENT SYSTEM DESIGN DRAWINGS

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DRAWING LIST

Drawing Number	Title
M7DC40000A002	Groundwater/Vapor Treatment System Treatment Area Equipment Layout
J7DC40000A001	Equipment, Piping, Instrument Identification and Control System Standards
P7DC40000A001	Soil Vapor and Groundwater Treatment Systems Process Flow Diagram
P7DC40000A005	Soil Vapor and Groundwater Treatment Systems Utilities Process Piping and Instrumentation Diagram
P7DC40000A008-1	Soil Vapor Extraction and Vapor Conditioning Process Piping and Instrumentation Diagram
P7DC40000A008-2	Soil Vapor Extraction and Vapor Conditioning Process Piping and Instrumentation Diagram
P7DC40000A009	Vapor Treatment Systems Steam Regenerated Carbon Adsorption System Process Piping and Instrumentation Diagram
P7DC40000A0010	Vapor Treatment Systems Carbon and Zeolite Polishing Adsorbers Process Piping and Instrumentation Diagram
P7DC40000A011-1	Water Treatment Systems Groundwater Treatment Process Piping and Instrumentation Diagram
P7DC40000A011-2	Water Treatment Systems Groundwater Treatment Process Piping and Instrumentation Diagram
P7DC40000A012	Water Treatment Systems Air Stripper Systems Process Piping and Instrumentation Diagram
P7DC40000A013	Water Treatment Systems Groundwater Treatment Process Piping and Instrumentation Diagram
P7DC40000A014	Soil Vapor Treatment System Process Flow Diagram
P7DC40000A015	Groundwater Treatment System Process Flow Diagram
P7DC40000A016	Soil Vapor and Groundwater Treatment Systems Utilities Process Flow Diagram
P7DC40000A023	Soil Vapor Extraction Wells Process Piping and Instrumentation Diagram
E7DC40000A010	Groundwater/Vapor Treatment System Electrical Treatment System One Line Diagram
E7DC40000A011	Groundwater/Vapor Treatment System Electrical Treatment System One Line Diagram
E7DC40000A019	Groundwater/Vapor Treatment System Electrical Treatment System One Line Diagram

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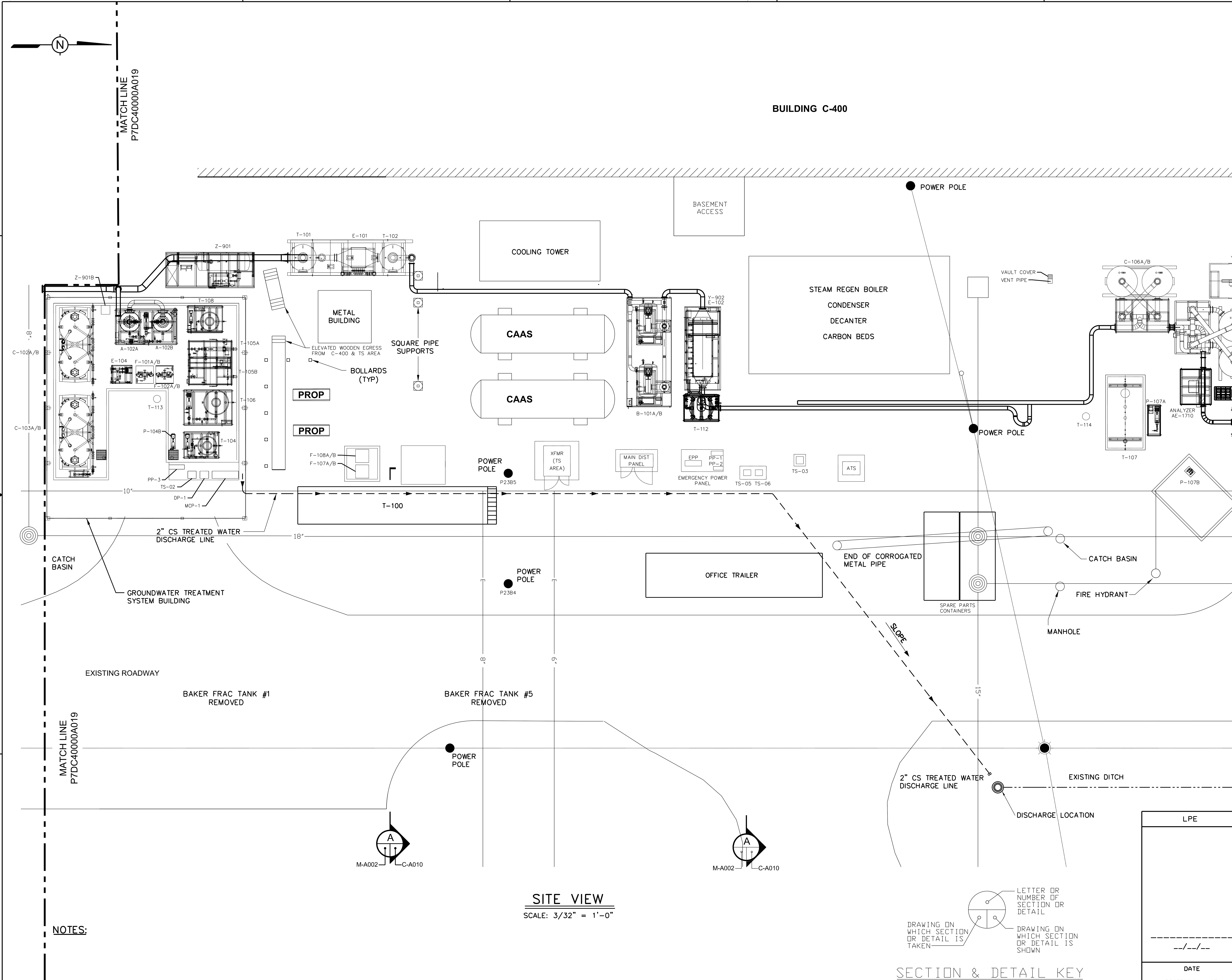

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/NUCL SFTY	FAC MGR	E&TS MGR
7	/ /	AS-BUILT - UPDATE							
6	1/18/12	PHASE IIA DESIGN	HDH	DJH	MWI	JTP	SJD	JRW	RES

DRAWING REVISIONS

LPE

--/--/--

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
GROUNDWATER/VAPOR TREATMENT SYSTEM TREATMENT AREA EQUIPMENT LAYOUT

CAD FILE NAME	BUILDING	PLANT	CLASS
M7DC40000A002 REV 7.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
AS SHOWN	M7DC40000A002	7

GENERAL EQUIPMENT

- COOLING TOWER
- PRESSURE VESSEL
- FLAT BOTTOM TANK w/CLOSED TOP
- CONE BOTTOM TANK
- SLANT PLATE CLARIFIER OR SEPARATOR
- AIR COMPRESSOR
- HEAT EXCHANGER FOR VAPOR SERVICE (FIN TUBE)
- ELECTRIC HEAT EXCHANGER
- HEAT EXCHANGER FOR LIQUID SERVICE (PLATE OR SHELL & TUBE)
- CENTRIFUGAL FAN
- CENTRIFUGAL PUMP
- ROTARY PUMP
- DIAPHRAGM PUMP
- VACUUM BLOWER
- FAN (FAN)
- CENTRIFUGAL PUMP (IN TANK) (M)
- ELECTRICAL COIL HEATER (STEAM)
- CARBON BED WITH STEAM REGEN (CARBON)

GENERAL EQUIPMENT (cont'd)

- ROTARY, CENTRIFUGAL & WATER SEALED COMPRESSORS & VACUUM PUMPS
- SUMP PUMP (M)

EQUIPMENT NUMBER IDENTIFICATION

C-102A

- DUPLICATE OR SPARE
- SEQUENCE NUMBER
- EQUIPMENT LETTER (SEE BELOW)
  - A – AIR STRIPPER
  - B – BLOWER
  - C – COLUMN, ADSORBER/ABSORBER
  - E – HEAT EXCHANGER
  - F – FILTER
  - P – PUMP
  - T – TANK
  - Y – MISCELLANEOUS EQUIPMENT
  - Z – MISCELLANEOUS EQUIPMENT

GENERAL PIPING

- PRIMARY PROCESS FLOW
- SECONDARY PROCESS OR UTILITY FLOW
- SOLIDS FLOW OR INTERMITTENT FLOW
- CONCENTRIC REDUCER OR INCREASER
- ECCENTRIC REDUCER OR INCREASER
- FLEXIBLE CONNECTION
- HOSE CONNECTION
- FLANGED JOINT
- DRAIN w/RECOVERY (D)
- SAMPLE CONNECTION (S)
- ATMOSPHERIC VENT
- SPRAY NOZZLE
- BASKET STRAINER OR BAG FILTER
- INSULATED
- INSULATED & HEAT TRACED
- MAGNETIC FLOW METER (M)
- MUFFLER

MISCELLANEOUS

DWG.# — LINE BREAK OR RESUMPTION POINT

VALVE NOTATION

CONTROL VALVE BODIES (OPEN / CLOSED)

- GATE (GA)
- BALL (BA)
- BUTTERFLY (BF)
- PLUG (PL)
- NEEDLE (NE)
- CHECK (CK)

DIAPHRAGM ACTUATED VALVES (TYPICAL)

HV, NO, FC

- NORMAL MODE (SEE NOTE BELOW)
- FAILURE MODE – FO,FC,FL,FI

NOTE:

FAIL POSITIONS ALL BODY STYLES
- FO – FAIL OPEN
- FC – FAIL CLOSED
- FL – FAIL LOCKED/LAST POSITION
- FI – FAIL INDETERMINATE
- CSO – CAR SEAL/LOCK OPEN
- CSC – CAR SEAL/LOCK CLOSED

NORMAL MODE IDENTIFICATION (I.E. NO, NC.) SHOULD ONLY BE USED FOR ON-OFF TYPE VALVES WHOSE POSITION CANNOT BE SHOWN BY SHADING THE VALVE BODY.

VALVE ACTUATORS

- HAND OR HAND WHEEL
- PNEUMATIC DIAPHRAGM
- SOLENOID (S)

GENERAL INSTRUMENTS

- INSTRUMENT FOR SINGLE MEASURED VARIABLE AND ANY NUMBER OF FUNCTIONS. INSTRUMENT IS FIELD MOUNTED
- INSTRUMENT IS MOUNTED IN FRONT OF LOCAL PANEL.

SHARED DISPLAY OR VIRTUAL (SOFTWARE BASED) SYMBOLS AND SWITCH

- REMOTE OR BLIND INDICATOR/CONTROLLER
- CENTRAL PLC OR CONTROL ROOM INDICATOR/ CONTROLLER/RECORDER OR ANNUNCIATION POINT
- INTERLOCK (I)

(NOTE A) ON / OFF — E (NOTE B), C_2 (NOTE C) — E (NOTE B), C_2 (NOTE C)

GENERAL INSTRUMENTS (cont'd)

ALARM & CONTROL DESIGNATIONS

S/S, HH, H, L, LL — 0-100%

- HH – HI-HI ALARM (CONTROL ROOM)
- H – HI ALARM (CONTROL ROOM)
- L – LO ALARM (CONTROL ROOM)
- LL – LO-LO ALARM (CONTROL ROOM)
- S/S – START/STOP FROM CONTROL ROOM
- 0-100% – ADJUSTABLE RANGE OF OUTPUT

NOTE A: SHOWN ON THE UPPER AND LOWER LEFT HAND SIDE WILL BE THE DISPLAY SUCH AS ON/OFF, OPEN/CLOSED, SET/RESET, LAH, LAL, LDA (STEEPING DEVIATION). LDA APPLIES TO VIRTUAL (SOFTWARE) ALARMS ONLY. IT IS UNDERSTOOD THAT A VIRTUAL SWITCH EXISTS WITH A UNIQUE TAG NUMBER FOR THE LOOP.

NOTE B: ELECTRICAL AND HAND SWITCH DESIGNATION WILL BE SHOWN ON THE UPPER RIGHT HAND SIDE

NOTE C: PANEL/CONSOLE DESIGNATION WILL BE SHOWN ON THE LOWER RIGHT HAND SIDE. IF NO PANEL IS DESIGNATED, THE SWITCH OR DISPLAY WILL APPEAR ON THE CONSOLE IN THE AREA OF THE DRAWING ON WHICH THE SYMBOLS APPEAR.

- CONNECTION TO PROCESS OR INSTRUMENT INPUT
- ELECTRICAL SIGNAL OR INTERNAL SYSTEM LINK

TYPICAL CONNECTION ANY VARIABLE

- DIRECT CONNECTION PROCESS BLOCK VALVE SYMBOL OPTIONAL

PRESSURE SENSORS

- DIRECT CONNECTED
- WITH DIAPHRAGM SEAL PIPE MOUNTED
- WITH DIAPHRAGM SEAL LINE MOUNTED (FLANGED)

SELF-ACTIVATED PRESSURE DEVICES

- PCV — PRESSURE REDUCING REGULATOR
- PSE — RUPTURE DISK OR SAFETY HEAD FOR PRESSURE RELIEF
- PRV — PRESSURE RELIEF VALVE

LINE NUMBER IDENTIFICATION

PA-4016-3"-E

- MATERIAL SPECIFICATION
  - A – SCHEDULE 10 CARBON STEEL
  - B – SCHEDULE 40 CARBON STEEL
  - C – SCHEDULE 40 PVC
  - D – SCHEDULE 80 PVC
  - E – SCHEDULE 80 GALVANIZED STEEL
  - F – STAINLESS STEEL TUBING
  - G – 12 GAUGE CARBON STEEL
- LINE SIZE
- SEQUENTIAL NUMBER
- FLOW TYPE
  - CFR – COOLING FLUID RETURN
  - CFS – COOLING FLUID SUPPLY
  - CWR – COOLING WATER RETURN
  - CWS – COOLING WATER SUPPLY
  - DW – POTABLE WATER
  - IA – INSTRUMENT AIR
  - PA – PLANT AIR
  - PC – PROCESS CONDENSATE
  - PL – RECOVERED DNAPL
  - PV – PROCESS VAPOR
  - UW – PROCESS WATER

INSTRUMENT IDENTIFICATION

AE	ANALYZING ELEMENT
AI	ANALYSIS INDICATOR
ASH	ANALYSIS SWITCH HIGH
FAL	FLOW ALARM LOW
FE	FLOW ELEMENT
FI	FLOW INDICATOR
FIC	FLOW INDICATOR CONTROL
FSL	FLOW INDICATOR CONTROL
FV	FLOW VALVE
HS	HAND SWITCH
KI	TIMER INDICATOR
LAH	LEVEL ALARM HIGH
LAHH	LEVEL ALARM HIGH-HIGH
LAL	LEVEL ALARM LOW
LALL	LEVEL ALARM LOW-LOW
LG	LEVEL GLASS (VIEWING)
LIC	LEVEL INDICATOR CONTROL
LSH	LEVEL SWITCH HIGH
LSHH	LEVEL SWITCH HIGH-HIGH
LSL	LEVEL SWITCH LOW
LSLL	LEVEL SWITCH LOW-LOW
PAL	PRESSURE ALARM LOW
PCV	PRESSURE CONTROL VALVE
PI	PRESSURE INDICATOR
PIC	PRESSURE INDICATOR CONTROL
PSH	PRESSURE SWITCH HIGH
PSHH	PRESSURE SWITCH HIGH-HIGH
PSL	PRESSURE SWITCH LOW
PSLL	PRESSURE SWITCH LOW-LOW
PV	PRESSURE VALVE
SC	SPEED CONTROL
SI	SPEED INDICATOR
TAH	TEMPERATURE ALARM HIGH
TAHH	TEMPERATURE ALARM HIGH-HIGH
TAL	TEMPERATURE ALARM LOW
TALL	TEMPERATURE ALARM LOW-LOW
TE	TEMPERATURE ELEMENT
TI	TEMPERATURE INDICATOR
YS	PROXIMITY SWITCH

FOR INFORMATION ONLY

LPE

--/--/--

DATE

PROFESSIONAL SEAL

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
4	1/18/12	PHASE IIA DESIGN	HOH	OJH	MWI	JTP	SJO	JRW	RES

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY

PADUCAH, PORTSMOUTH PROJECT OPERATIONS, PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC — managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020, Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: C-400 REMEDIATION DESIGN

TITLE: EQUIPMENT, PIPING, INSTRUMENT IDENTIFICATION AND CONTROL SYSTEM STANDARDS

CAD FILE NAME	BUILDING	PLANT	CLASS
J7DC40000A001 REV 4.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	J7DC40000A001	4

NOTES:

1. FLOW RATES ARE BASED ON TYPICAL RUN DATA FROM PHASE I OPERATION.
2. VOC CONCENTRATION FOR VAPOR STREAMS ARE DRY AIR BASIS.
3. ALL STREAMS IDENTIFIED AS TBD WILL BE ADDRESSED IN CFC PACKAGE.

A-102A/B
AIR STRIPPER

C-106A/B
POLISHING VAPOR CARBON ADSORBERS

E-104
AIR STRIPPER EFFLUENT COOLER

B-101A/B
VACUUM BLOWERS

C-107A/B
POLISHING VAPOR ZEOLITE SYSTEM

F-101A/B
AIR STRIPPER EFFLUENT FILTERS

F-108A/B
T-100 EFFLUENT FILTERS

P-103A
AIR STRIPPER TRANSFER PUMP

P-105
SEPARATOR WATER PUMP

P-108
LIQUID TCE PUMP

P-113
T-102 CONDENSATE PUMP

T-101
LIQUID/VAPOR SEPARATOR 1

T-104
HOT GROUNDWATER TANK

T-107
LIQUID TCE STORAGE TANK

C-102A/B
ION EXCHANGE

E-101
VAPOR COOLER

F-102A/B
AIR STRIPPER INFLUENT FILTERS

P-100
FEED SURGE PUMP

P-103B
AIR STRIPPER EFFLUENT PUMP

P-106
AIR STRIPPER FEED PUMP

P-111
T-101 CONDENSATE PUMP

P-141
E-102 CONDENSATE PUMP

T-102
LIQUID/VAPOR SEPARATOR 2

T-105A/B
DNAPL SEPARATOR

T-108
CONDENSATE SUMP TANK

C-103A/B
LIQUID CARBON ADSORBERS

E-102
VAPOR CHILLER

F-107A/B
T-100 EFFLUENT FILTERS

P-101
LIQUID/VAPOR SEPARATOR PUMP

P-104
WATER INJECTION PUMP

P-107
TCE TRANSFER PUMP

P-112
E-101 CONDENSATE PUMP

T-100
FEED SURGE TANK

T-103A/B
AIR STRIPPER EFFLUENT TANK

T-106
AIR STRIPPER FEED TANK

Y-903
STEAM GENERATOR

Z-107
STACK

NOTE:

FLOW RATES SHOWN ON THIS TABLE ARE INDICATIVE OF EXPECTED RUN DATA BASED ON MODELING OF McMILLAN-McGEE REPORT AND PHASE I DATA

STREAM NO. / COMPONENT		1	2	3	4	5A	5B	6	7	8	9	10	11	12	13
		VAPOR FROM SVE HEADER	VAPOR COOLER INLET	VAPOR COOLER OUTLET	CONDENSATE FROM VAPOR COOLER	VAPOR FROM VACUUM BLOWER	VAPOR FROM VACUUM BLOWER	VAPOR FROM CHILLER	CONDENSATE FROM VAPOR CHILLER	AQUEOUS FROM DECANTER	CARBON OUTLET VAPOR	CONDENSATE FROM COOLER/CHILLER	AIR BLEED FOR VACUUM CONTROL	POTABLE WATER TO STEAM BOILER	TCE FROM DECANTER
DRY AIR	lb/hr	3,099	3,099	3,099		1550	1550	4,055			3,647.292		TBD		
STEAM/WATER VAPOR	lb/hr	972	880	165		82.5	82.5	30.5			26.94		TBD		3
TOTAL VOCs (PRIMARY TCE)	lb/hr	29	29	29	0.03	14.5	14.5	29	0.01		0.288	0.045	TBD		28.6
GROUNDWATER /CONDENSATE	lb/hr				867				135			1,094	TBD		
TOTAL STREAM FLOW	lb/hr	4,100	4,008	3,293	867	1,785	1,785	4,146	135		3,674.52	1,094	TBD		
GAS FLOW	acfm												TBD		
LIQUID FLOW	gpm				1.8				0.3	2.61		2.2	TBD	2.4	0.45
TOTAL VOCs	ppmv (mg/L)	7,000	5,668.491	5,668.491	(34)				(74)			(40)	TBD		
TEMPERATURE	°F	203	199	105	105	138	138	70	70	50	50	101	TBD	80	50
PRESSURE	psia	6.81	6.58	6.38	14.9	14.9	14.9	14.7	14.95	14.9	14.9	14.7	TBD	70	14.9

STREAM NO. / COMPONENT		14	15	17	19	20	21	22	23	24	25	26	27	28	29	49
		CARBON ADSORBER OUTLET	STEAM FOR HUMIDITY	VAPOR TO STACK	CONDENSATE	GROUNDWATER FROM MPE WELLS	AIR STRIPPER FEED	AIR TO STRIPPER	AIR FROM STRIPPER	AIR STRIPPED GROUNDWATER	GROUNDWATER TO E-104	HOT GROUNDWATER TO REINJECTION	GROUNDWATER TO C-103A/B	GROUNDWATER TO DISCHARGE	DNAPL TO DISPOSAL	COOLING WATER TO CONDENSER
DRY AIR	lb/hr	3,640		3,640	TBD			1,454	955.1						TBD	
STEAM/WATER VAPOR	lb/hr	20	107	127	TBD				152.9						TBD	
TOTAL VOCs (PRIMARY TCE)	lb/hr	0.05		0.02	TBD	44.1	44.4		0.246	0.21	0.05	0.16	0.05		TBD	
GROUNDWATER /CONDENSATE	lb/hr				TBD	40,032	44,083			42,553	10,708	31,825	10,708	10,708	TBD	
TOTAL STREAM FLOW	lb/hr	3,660.05	107	3,767.02	TBD	40,076	44,128	1,454	1,108.246	42,553	10,708	31,826	10,708	10,708	TBD	
GAS FLOW	acfm		30		TBD										TBD	
LIQUID FLOW	gpm				TBD	80	88			85	21.4	63.6	21.4	21.4	TBD	100
TOTAL VOCs	ppmv (mg/L)	14		5	TBD	(1,100)	(1,006)		217	(5)	(5)	(5)	(5)		TBD	
TEMPERATURE	°F	50	220	50	TBD	203	194	70	139.6	157	157	157	100	100	TBD	100
PRESSURE	psia	14.9	14.9	14.9	TBD	14.7	14.7	15.6	14.9	14.7	14.7	14.7	14.7	14.7	TBD	50

LPE

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DATE

PROFESSIONAL SEAL

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
4	/ /	AS-BUILT - UPDATE							
3	1/18/12	PHASE IIA DESIGN	HDH	DJH	MWI	JTP	SJD	JRW	RES

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY

PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

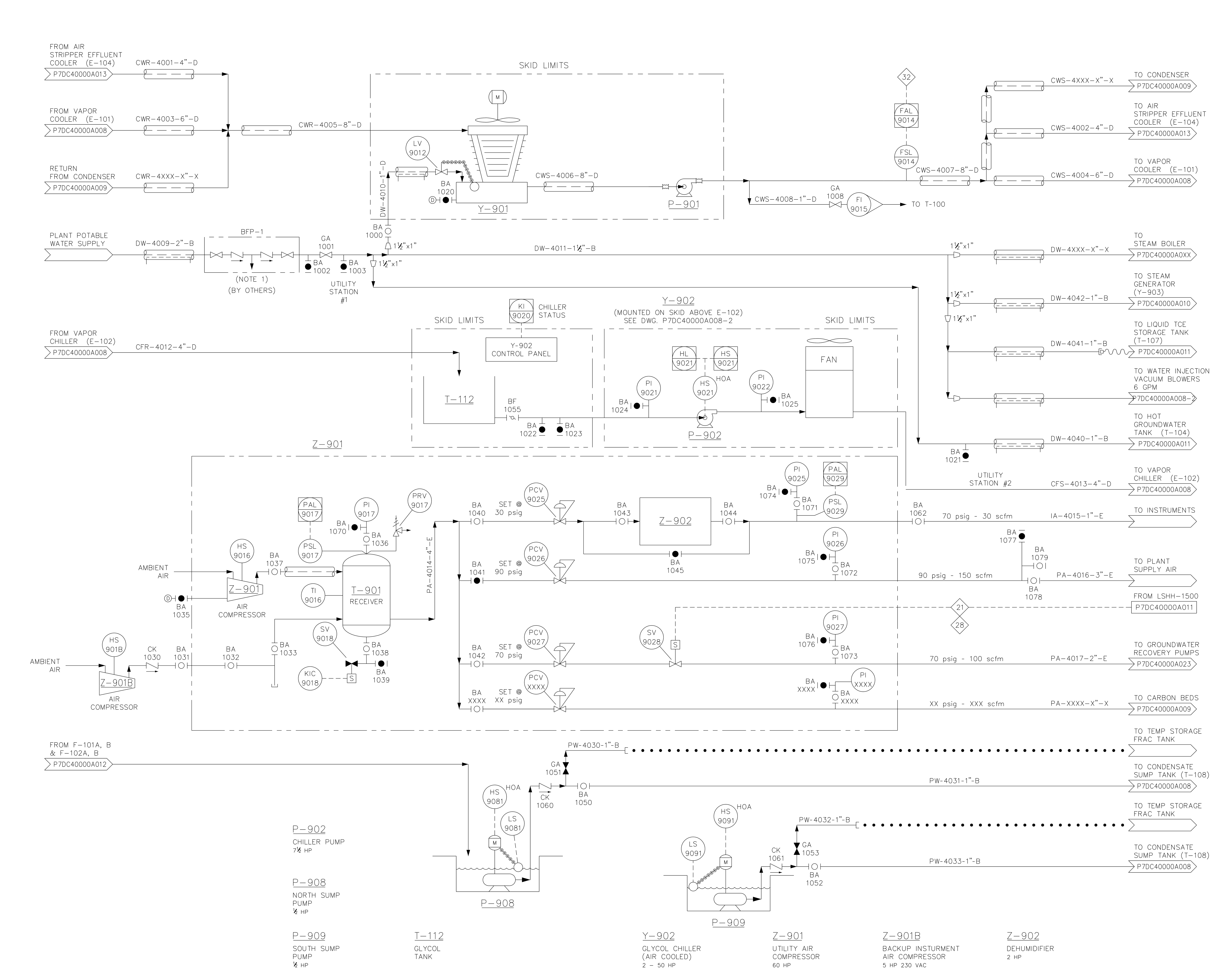
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
SOIL VAPOR AND GROUNDWATER TREATMENT SYSTEMS PROCESS FLOW DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A001 REV 4.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A001	4



NOTES:

1. A BACKFLOW PREVENTER WITH INTERMEDIATE VENT IS USED TO PROVIDE POSITIVE ASSURANCE AGAINST CONTAMINATION OF POTABLE WATER.

INTERLOCKS:

21 HIGH-HIGH LEVEL IN DNAPL SEPARATOR (T-105A, B) WILL SHUT DOWN AIR TO WELL PUMPS AND P-101, ALARM & NOTIFY TELEMANAGER.

28 HIGH-HIGH TCE/VOC CONCENTRATION IN THE VAPOR AT THE STACK SHUTS DOWN THE VAPOR (CLOSES SV-9028) AND GROUNDWATER SYSTEMS (STOPS VACUUM BLOWERS B-101A, B)

32 LOW COOLING WATER FLOW SHUTS DOWN COOLING WATER PUMP P-901

INSTRUMENT LEGEND:

AE INSTRUMENT MOUNTED LOCALLY OR ON SKID CONTROL PANEL

TAH INSTRUMENT MOUNTED ON LOCAL SKID CONTROL PANEL OR SKID PLC HMI

AI INSTRUMENT DISPLAY ON HMI OF CENTRAL PLC

FOR INFORMATION ONLY

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
8	/ /	AS-BUILT - UPDATE							
7	/ /	REVISED PER PHASE IIA DESIGN							
6	/ /	AS-BUILT - UPDATE							

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

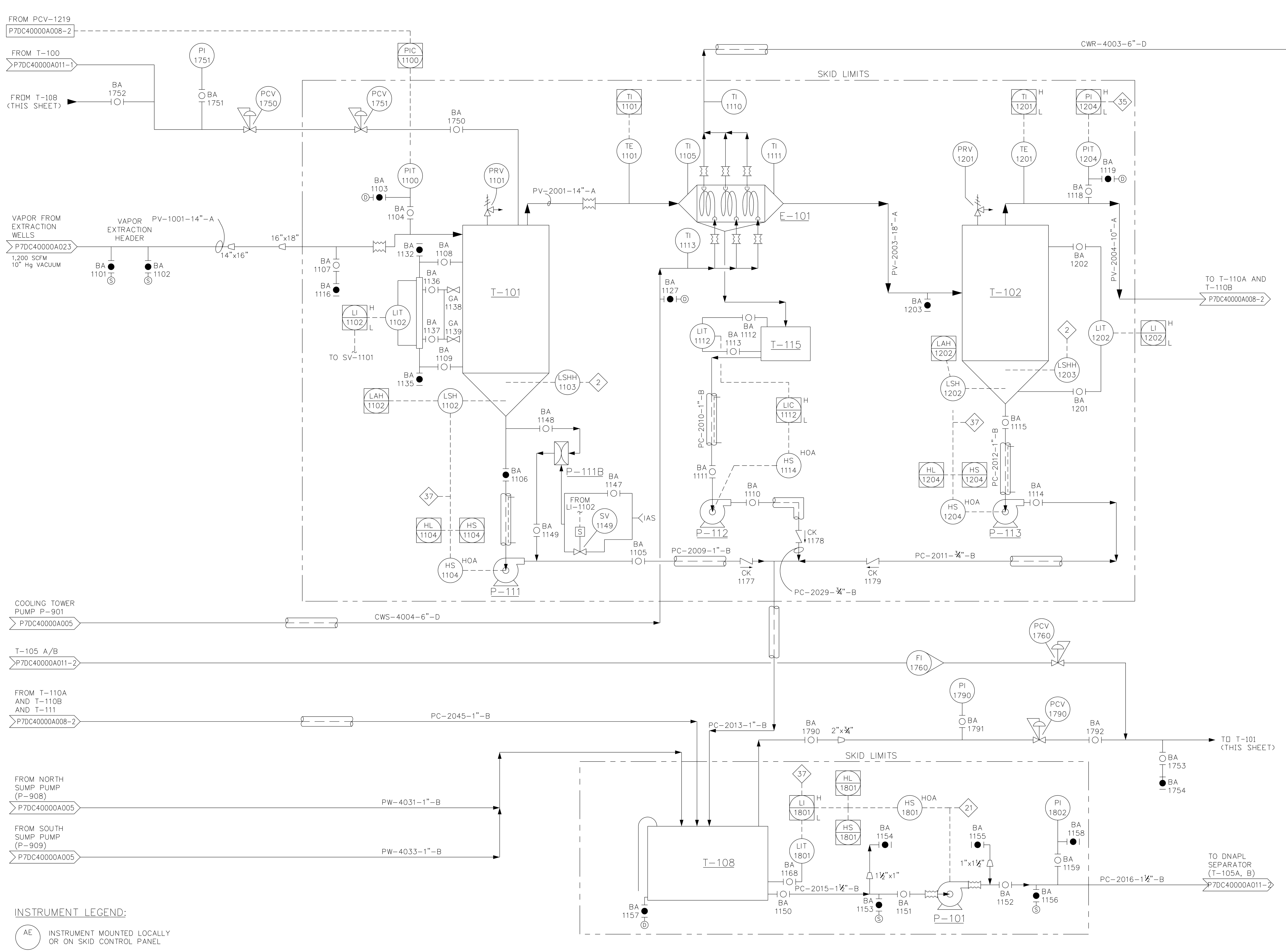
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
SOIL VAPOR AND GROUNDWATER TREATMENT SYSTEMS UTILITIES PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A005 REV 8.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A005	8



INTERLOCKS:

2 — HIGH-HIGH LEVEL IN EITHER LIQUID/VAPOR SEPARATOR (T-101 OR T-102) WILL SHUT DOWN VACUUM BLOWERS (B-101A, B) AND ACTIVATE ALARM VIA PLC CONTROL

21 — HIGH-HIGH LEVEL IN DNAPL SEPARATORS (T-105A, B) SHUTS DOWN AIR TO WELL PUMPS AND P-101

35 — VACUUM BLOWERS WILL BE SHUT DOWN IF DIFFERENTAL PRESSURE (PIT-1129 & PIT-1204) EXCEEDS 10 PSIG

37 — HIGH-HIGH LEVEL IN T-108 SHUTS DOWN P-111, P-112, P-113, P-141 AND VACUUM BLOWERS B-101A, B

INSTRUMENT LEGEND:

- AE — INSTRUMENT MOUNTED LOCALLY OR ON SKID CONTROL PANEL
- TAH — INSTRUMENT MOUNTED ON LOCAL SKID CONTROL PANEL OR SKID PLC HMI
- AI — INSTRUMENT DISPLAY ON HMI OF CENTRAL PLC

E-101	P-101	P-111	P-112	P-113	T-101	T-102	T-108	T-115
VAPOR COOLER	LIQUID/VAPOR SEPARATOR PUMP ½ HP	T-101 CONDENSATE PUMP ½ HP	E-101 CONDENSATE PUMP ½ HP	T-102 CONDENSATE PUMP ½ HP	LIQUID/VAPOR SEPARATOR 1	LIQUID/VAPOR SEPARATOR 2	CONDENSATE SUMP TANK	E-101 CONDENSATE TANK

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
6	/ /	AS-BUILT - UPDATE							

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS, PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
SOIL VACUUM EXTRACTION AND VAPOR CONDITIONING PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A008-1 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A008-1	6

INTERLOCKS:

- (2) HIGH-HIGH LEVEL IN EITHER LIQUID/VAPOR SEPARATOR (T-101 OR T-102) WILL SHUT DOWN VACUUM BLOWERS (B-101/102) AND ACTIVATE ALARM VIA CONTROL PLC
- (28) HIGH-HIGH TCE/VOC CONCENTRATION IN THE VAPOR AT THE STACK SHUTS DOWN THE VAPOR (CLOSES SV-9028) AND GROUNDWATER SYSTEMS (STOPS VACUUM BLOWERS B-101/102)
- (33) HIGH-HIGH INLET PRESSURE AT E-102 OPENS BLOWER RECYCLE VALVE PCV-1129.
- (34) HIGH-HIGH PRESSURE SHUTS DOWN VACUUM BLOWERS
- (35) VACUUM BLOWERS WILL BE SHUT DOWN IF DIFFERENTAL PRESSURE (PIT-1129 & PIT-1204) EXCEEDS 10 PSIG
- (36) HIGH-HIGH TEMPERATURE AT E-102 OUTLET SHUTS DOWN THE VACUUM BLOWERS (B-101/102)
- (37) HIGH-HIGH LEVEL IN T-108 SHUTS DOWN P-111, P-112, P-113, P-141 AND VACUUM BLOWERS B-101A, B
- (40) IF B-101/102 ARE OFF OR IF FIT 224 IS LESS THAN OR EQUAL TO 100 CFM FOR 30 SECONDS P-106 AND P-103A BOTH SHUT DOWN.

INSTRUMENT LEGEND:

- AE — INSTRUMENT MOUNTED LOCALLY OR ON SKID CONTROL PANEL
- TAH — INSTRUMENT MOUNTED ON LOCAL SKID CONTROL PANEL OR SKID PLC HMI
- AI — INSTRUMENT DISPLAY ON HMI OF CENTRAL PLC

B-101A	B-101B	E-102	P-110A, B	P-113	P-114A, B	P-141	T-110A, B	T-111
VACUUM BLOWER 100 HP	VACUUM BLOWER 100 HP	VAPOR CHILLER	VACUUM BLOWER LIQUID/VAPOR SEPARATOR	T-102 CONDENSATE PUMP ½ HP	T-110A, B CONDENSATE PUMP	E-102 CONDENSATE PUMP ½ HP	B-101A, B LIQUID/VAPOR SEPARATOR	E-102 CONDENSATE TANK

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
6	/ /	AS-BUILT - UPDATE							

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC — managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020, Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: C-400 REMEDIATION DESIGN

TITLE: SOIL VACUUM EXTRACTION AND VAPOR CONDITIONING PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A008-2 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A008-2	6

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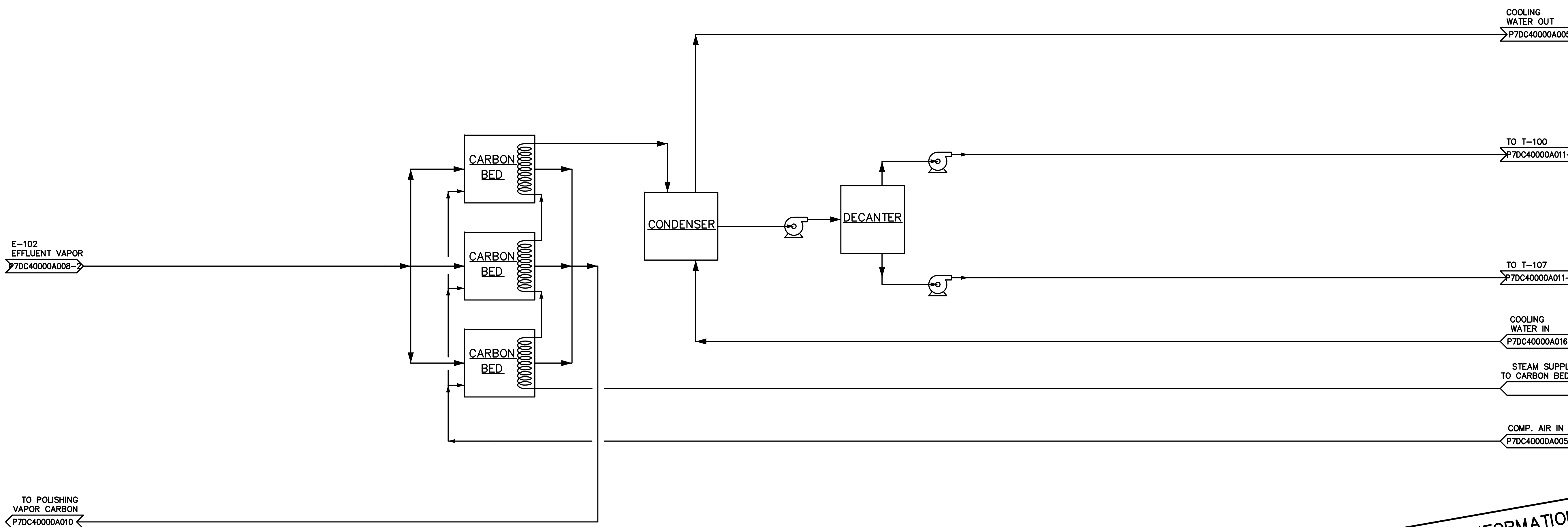


FOR INFORMATION ONLY

NOTES:

1. EQUIPMENT INSIDE "STEAM REGENERATED CARBON VENDOR PACKAGE" BOUNDARY WILL BE SUPPLIED AS A SKID-MOUNTED SYSTEM. EQUIPMENT VENDOR WILL SUPPLY A COMPLETE SYSTEM INCLUDING ALL EQUIPMENT AND INSTRUMENTATION INSIDE THE SKID LIMITS. EQUIPMENT WILL BE SUPPLIED PRE-PIPED AND PRE-WIRED WITH A CONTROL PANEL AND PLC.

2. VALVE NUMBERS FOR GEO INC SYSTEMS 3 AND 4 TO BE ASSIGNED AS PART OF THE PHASE 2 DESIGN.

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	FAC MGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	PROJ ENGR		
6		REVISED PER PHASE IIA DESIGN									
5		AS BUILT									
4		REVISED PER WALKDOWN COMMENTS	JWH	DWB							
3	2/12/10	ISSUED FOR TRAINING	JWH	DWB							
2		AS BUILT	JWH	DWB							
1	6/24/09	TITLE BLOCK REVISION ONLY	DAS	DWB		TDS					
0	4/9/09	ISSUED FOR CONSTRUCTION	JWH	DWB		TDS					
		DRAWING REVISIONS									

U.S. DEPARTMENT OF ENERGY

PORTSMOUTH/PADUCAH PROJECT OFFICE

PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020 Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:

C-400 REMEDIATION DESIGN

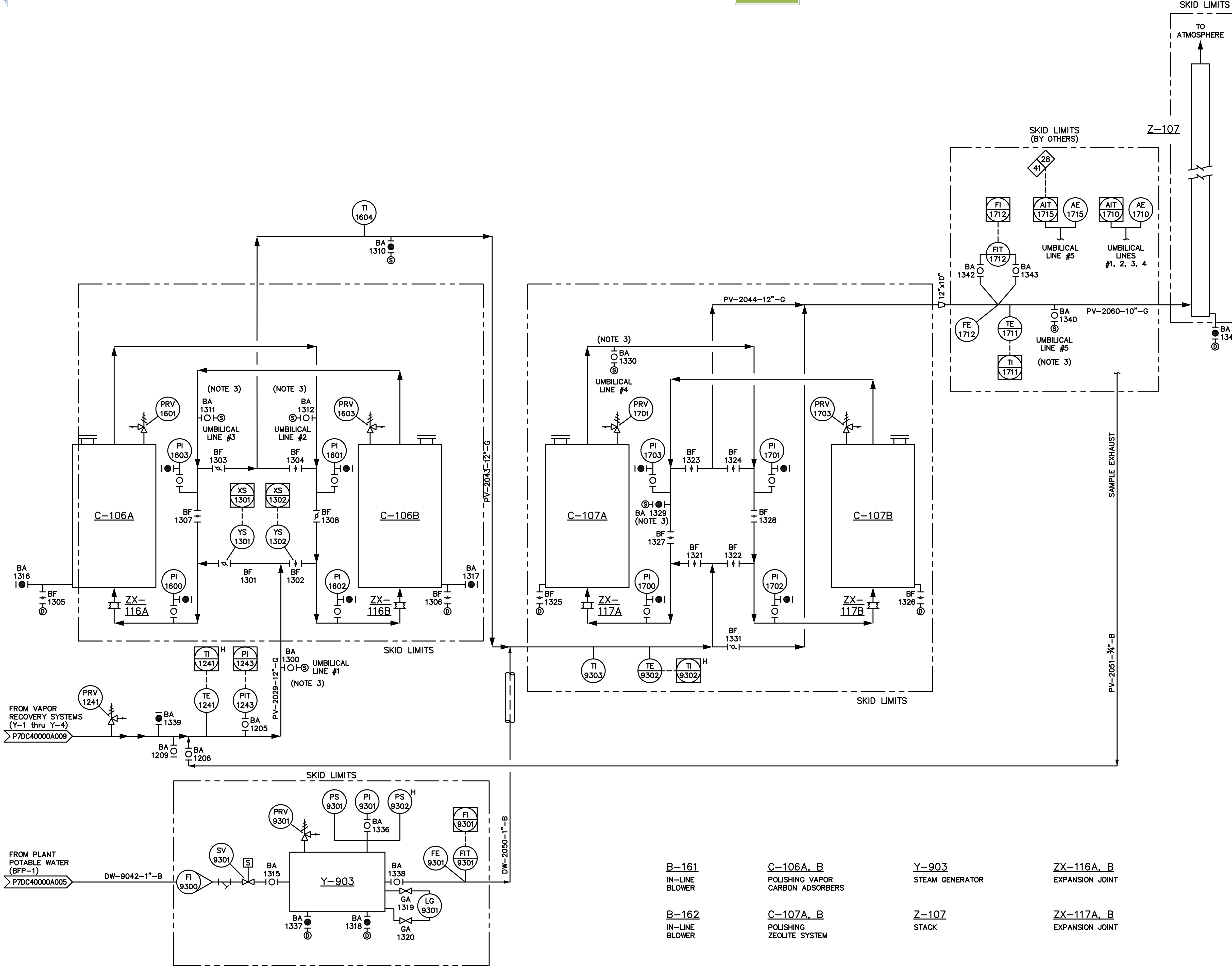
TITLE:

VAPOR TREATMENT SYSTEMS
STEAM REGENERATED CARBON ADSORPTION SYSTEM
PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A009 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A009	6

File:
XREF Files:
Plot Date/Time:
Plotted By:
IMAGE Files:



NOTES:

1. AIT-1710 AND AIT-1715 SAMPLE LOCATIONS, CONNECTED BY SAMPLE UMBILICAL LINES TO ANALYZER.

INTERLOCKS:

28 — HIGH-HIGH TCE/VOCs CONCENTRATION IN THE VAPOR WILL INITIATE SHUT DOWN OF THE VAPOR AND GROUNDWATER SYSTEMS, ACTIVATE ALARM IN CONTROL PLC AND NOTIFY TELEMANAGER.

41 — NO CHANGE IN AIT-1710 READINGS AT STACK AFTER 2.5 MINUTES TIME PERIOD SHUTS DOWN THE VAPOR SYSTEM.

INSTRUMENT LEGEND:

- AE — INSTRUMENT MOUNTED LOCALLY OR ON SKID CONTROL PANEL
- TAH — INSTRUMENT MOUNTED ON LOCAL SKID CONTROL PANEL OR SKID PLC HMI
- AI — INSTRUMENT DISPLAY ON HMI OF CENTRAL PLC

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
6		AS-BUILT – UPDATE							

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
VAPOR TREATMENT SYSTEMS
CARBON AND ZEOLITE POLISHING ADSORBERS
PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A010 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A010	6

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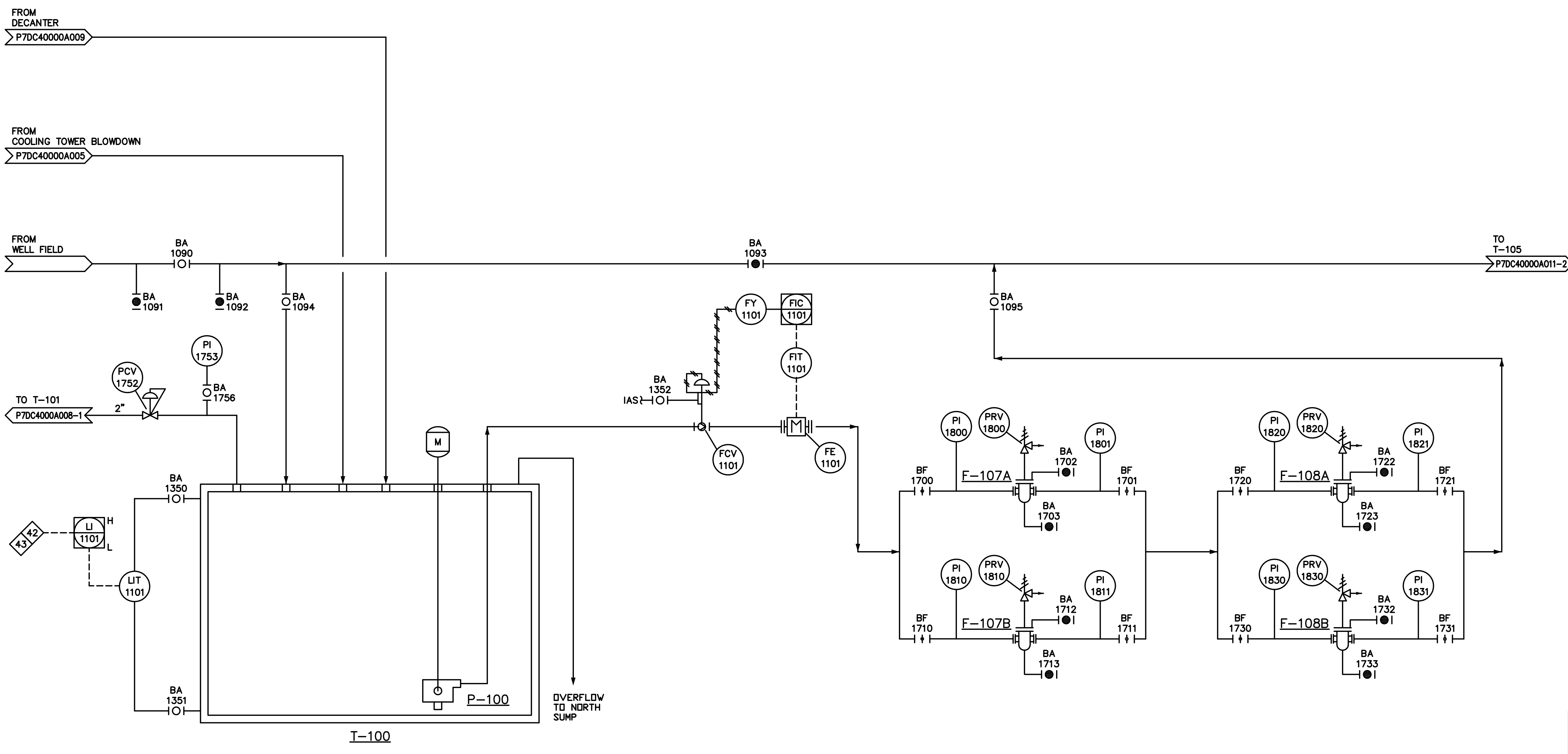


FOR INFORMATION ONLY

INTERLOCKS:

42 HIGH-HIGH LEVEL IN SURGE TANK (T-100) SHUTS DOWN AIR TO WELL PUMPS.

43 LOW-LOW LEVEL IN AIR STRIPPER FEED SURGE TANK (T-100) SHUTS DOWN SURGE TANK PUMP (P-100)

INSTRUMENT LEGEND:

AE — INSTRUMENT MOUNTED LOCALLY OR ON SKID CONTROL PANEL

TAH — INSTRUMENT MOUNTED ON LOCAL SKID CONTROL PANEL OR SKID PLC HMI

AI — INSTRUMENT DISPLAY ON HMI OF CENTRAL PLC

T-100
FEED SURGE TANK

P-100
FEED SURGE PUMP
1 HP

F-107A – 107B
BAG FILTERS

F-108A – 108B
BAG FILTERS

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/NUCL SFTY	FAC MGR	E&TS MGR
6		AS-BUILT – UPDATE							

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
ucah, Kentucky

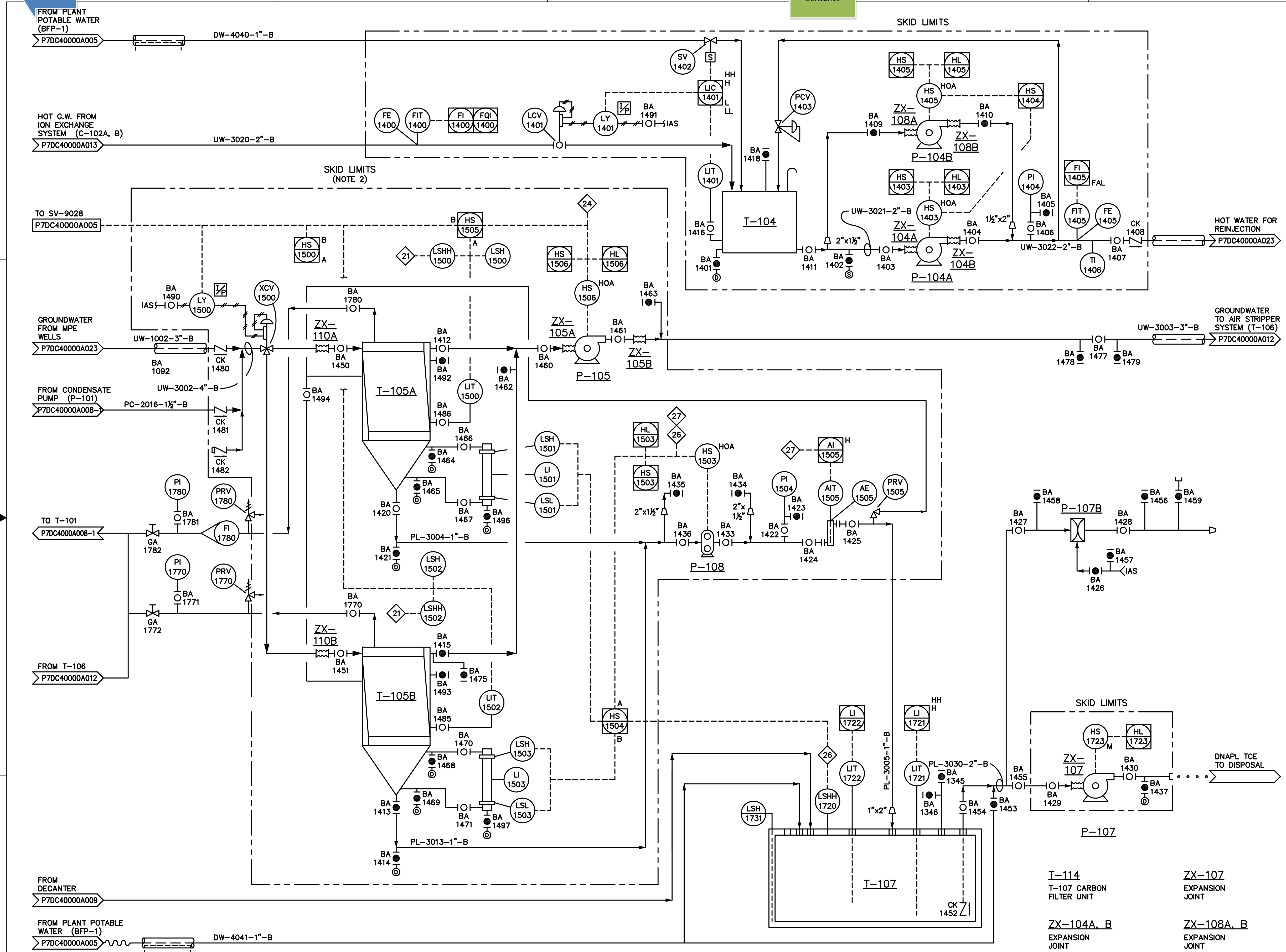
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: C-400 REMEDIATION DESIGN

TITLE: WATER TREATMENT SYSTEMS GROUNDWATER TREATMENT PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A011-1 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A011-1	6



NOTES:

1. DNAPL SEPARATOR VENDOR UNIT INCLUDES STANDBY SPARE SEPARATOR.
2. LSH-1731 ONLY MONITORS THE SECONDARY CONTAINMENT OF THE DOUBLE-WALLED TANK, T-107.

INTERLOCKS:

- (21) HIGH-HIGH LEVEL IN DNAPL SEPARATOR (T-105A, B) WILL INITIATE SHUT DOWN OF ALL WELL PUMPS AND LIQUID/VAPOR SEPARATOR PUMP (P-101), ALARM AND NOTIFY TELEMANAGER
- (24) HIGH-HIGH LEVEL IN AIR STRIPPER FEED TANK (T-106) SHUTS DOWN AIR TO WELL PUMPS AND STOPS P-105
- (26) HIGH-HIGH LEVEL IN LIQUID TCE STORAGE TANK (T-107) WILL SHUT OFF LIQUID TCE PUMP (P-108), ALARM AND NOTIFY TELEMANAGER
- (27) HIGH CONDUCTIVITY IN DNAPL SEPARATOR (T-105) UNDERFLOW WILL SHUT OFF LIQUID TCE PUMP (P-108) AND ACTIVATE ALARM IN CENTRAL PLC

INSTRUMENT LEGEND:

- (AE) INSTRUMENT MOUNTED LOCALLY OR ON SKID CONTROL PANEL
- (TAH) INSTRUMENT MOUNTED ON LOCAL SKID CONTROL PANEL OR SKID PLC HMI
- (AI) INSTRUMENT DISPLAY ON HMI OF CENTRAL PLC

P-104A, B	HOT GROUNDWATER PUMP 5 HP
P-105	SEPARATOR WATER PUMP 5 HP
P-107	TCE TRANSFER PUMP 5 HP
P-108	LIQUID TCE PUMP 1 HP
T-104	HOT GROUNDWATER TANK
T-105A, B	DNAPL SEPARATOR
T-107	LIQUID TCE STORAGE TANK (DOUBLE-WALLED) 8'ø x16' L
T-113	T-105 CARBON FILTER UNIT
T-114	T-107 CARBON FILTER UNIT
ZX-104A, B	EXPANSION JOINT
ZX-105A, B	EXPANSION JOINT
ZX-107	EXPANSION JOINT
ZX-108A, B	EXPANSION JOINT
ZX-110A, B	EXPANSION JOINT

REV.	DATE	DESCRIPTION
6		AS-BUILT – UPDATE

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS, PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC — managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020, Paducah, Kentucky

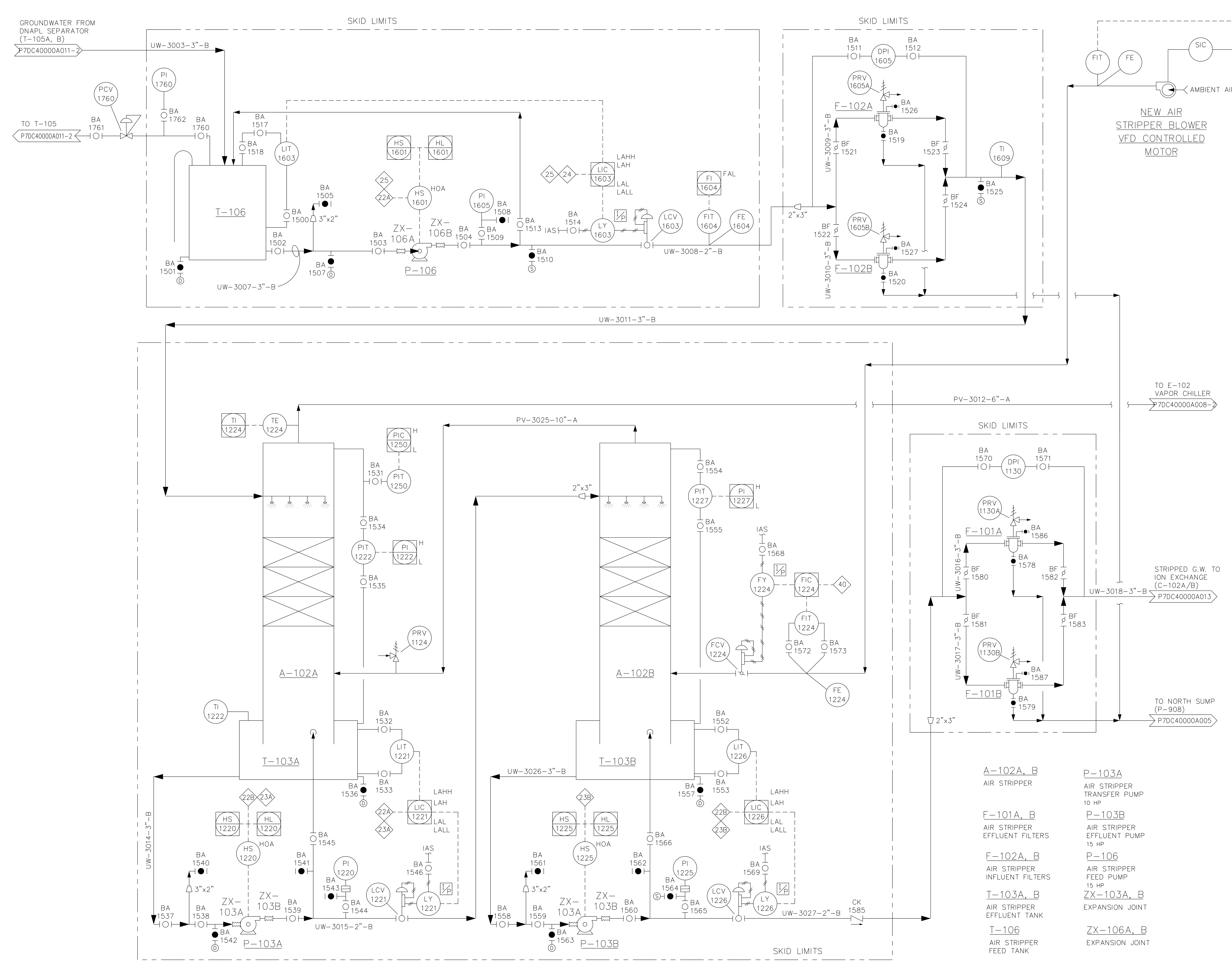
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: C-400 REMEDIATION DESIGN

TITLE: WATER TREATMENT SYSTEMS GROUNDWATER TREATMENT PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A011-2 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A011-2	6



INTERLOCKS:

22A HIGH-HIGH LEVEL IN AIR STRIPPER EFFLUENT TANK (T-103A) WILL SHUT DOWN AIR STRIPPER FEED PUMP (P-106), ACTIVATE AIR STRIPPER SKID TROUBLE ALARM IN THE CENTRAL PLC AND NOTIFY TELEMANAGER.

22B HIGH-HIGH LEVEL IN T-103B SHUTS DOWN P-103A

23A/B LOW-LOW LEVEL IN AIR STRIPPER EFFLUENT TANK (T-103A, B) WILL SHUT DOWN AIR STRIPPER EFFLUENT PUMP (P-103A, B), ACTIVATE AIR STRIPPER SKID TROUBLE ALARM IN THE CENTRAL PLC AND NOTIFY TELEMANAGER.

24 HIGH-HIGH LEVEL IN AIR STRIPPER FEED TANK (T-106) WILL INITIATE SHUT DOWN OF WELL PUMPS AND STOP P-105, ACTIVATE AIR STRIPPER SKID TROUBLE ALARM IN THE CENTRAL PLC AND NOTIFY TELEMANAGER.

25 LOW-LOW LEVEL IN AIR STRIPPER FEED TANK (T-106) WILL SHUT DOWN AIR STRIPPER FEED PUMP (P-106), ACTIVATE AIR STRIPPER SKID TROUBLE ALARM IN THE CENTRAL PLC AND NOTIFY TELEMANAGER.

40 IF B-101 A/B ARE OFF OR IF FI-1224 IS LESS THAN OR EQUAL TO 100 CFM FOR 30 SECONDS THEN P-106 AND P-103A SHUT DOWN.

INSTRUMENT LEGEND:

AE — INSTRUMENT MOUNTED LOCALLY OR ON SKID CONTROL PANEL

TAH — INSTRUMENT MOUNTED ON LOCAL SKID CONTROL PANEL OR SKID PLC HMI

AI — INSTRUMENT DISPLAY ON HMI OF CENTRAL PLC

A-102A, B — AIR STRIPPER

F-101A, B — AIR STRIPPER EFFLUENT FILTERS

F-102A, B — AIR STRIPPER INFLUENT FILTERS

T-103A, B — AIR STRIPPER EFFLUENT TANK

T-106 — AIR STRIPPER FEED TANK

P-103A — AIR STRIPPER TRANSFER PUMP 10 HP

P-103B — AIR STRIPPER EFFLUENT PUMP 15 HP

P-106 — AIR STRIPPER FEED PUMP 15 HP

ZX-103A, B — EXPANSION JOINT

ZX-106A, B — EXPANSION JOINT

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/NUCL SFTY	FAC MGR	E&TS MGR
6	/ /	AS-BUILT - UPDATE							

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS, PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC — managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020, Paducah, Kentucky

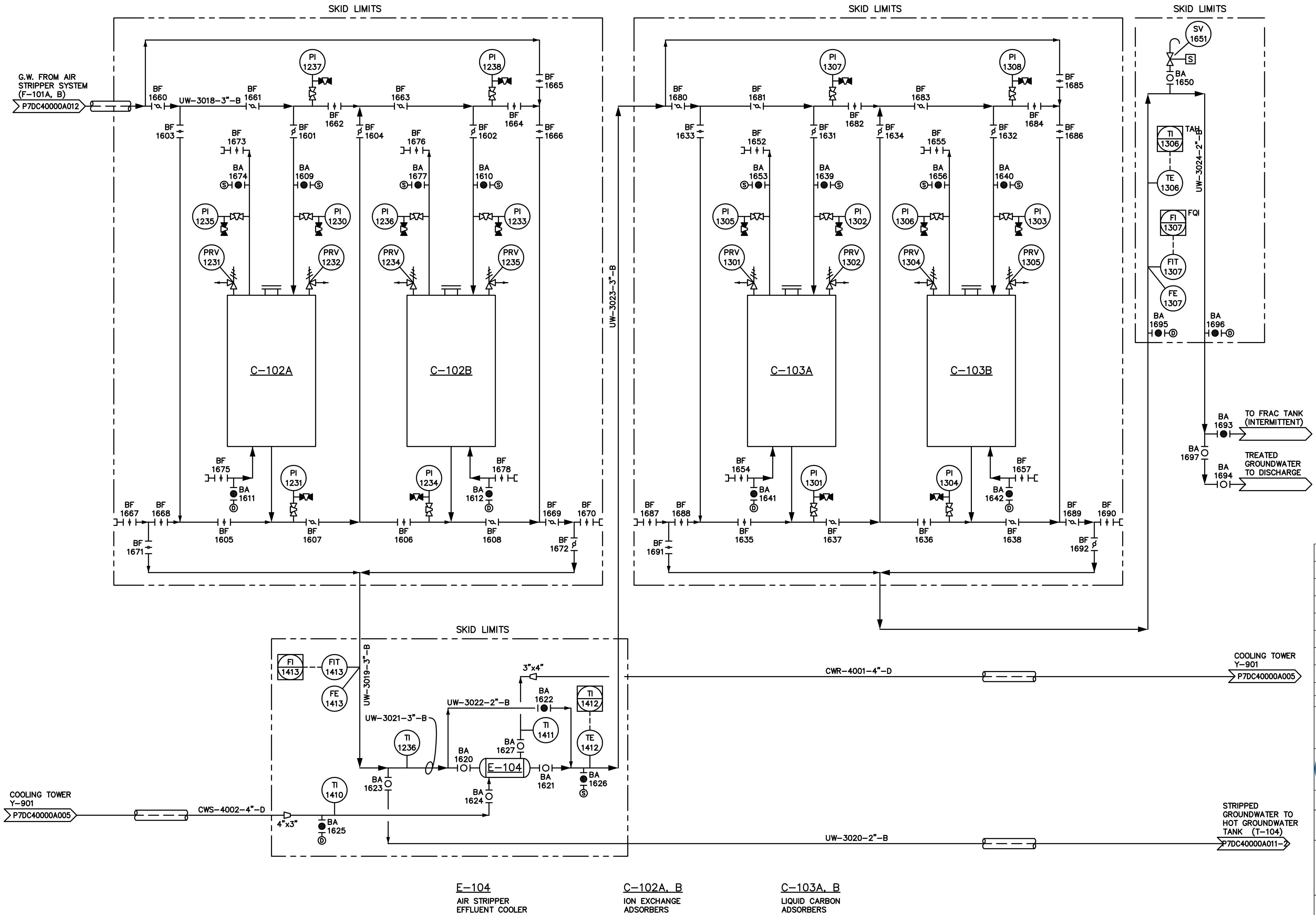
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: C-400 REMEDIATION DESIGN

TITLE: WATER TREATMENT SYSTEMS AIR STRIPPER SYSTEM PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A012 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A012	6



E-104
AIR STRIPPER EFFLUENT COOLER

C-102A, B
ION EXCHANGE ADSORBERS

C-103A, B
LIQUID CARBON ADSORBERS

NOTES:

1. CARBON AND RESIN FEEDING WILL BE GRAVITY. VACUUM TRUCK WILL BE USED TO VACUUM SPENT CARBON AND RESIN FROM THE ADSORBERS.

INSTRUMENT LEGEND:

- AE — INSTRUMENT MOUNTED LOCALLY OR ON SKID CONTROL PANEL
- TAH — INSTRUMENT MOUNTED ON LOCAL SKID CONTROL PANEL OR SKID PLC HMI
- AI — INSTRUMENT DISPLAY ON HMI OF CENTRAL PLC

REV.	DATE	DESCRIPTION
6		AS-BUILT – UPDATE

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

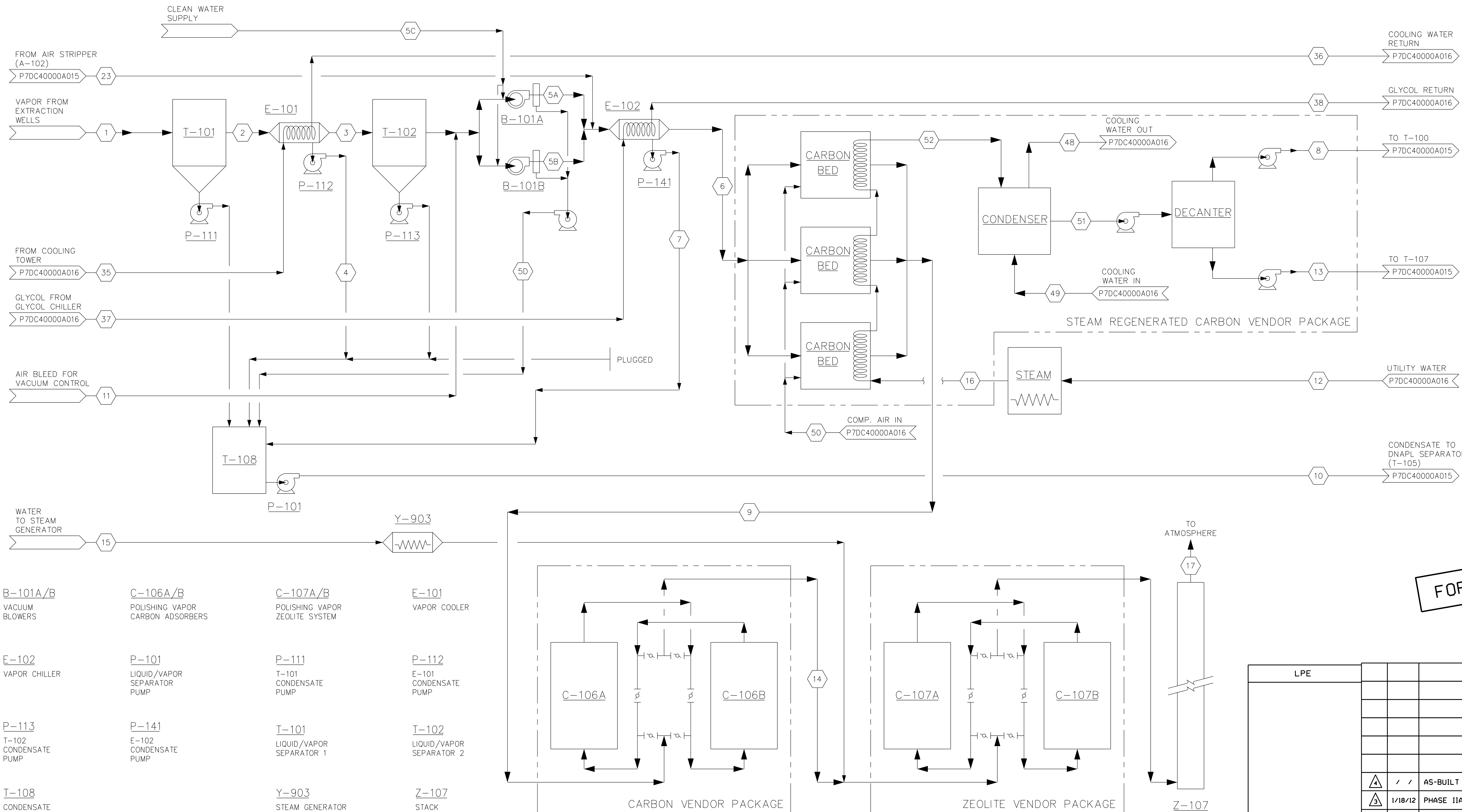
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: C-400 REMEDIATION DESIGN

TITLE: WATER TREATMENT SYSTEMS GROUNDWATER TREATMENT PROCESS PIPING & INSTRUMENTATION DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A013 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A013	6



NOTES:

1. FLOW RATES ARE BASED ON TYPICAL RUN DATA FROM PHASE I OPERATION.
2. VOC CONCENTRATIONS (ppmv) FOR VAPOR STREAMS ARE DRY AIR BASIS.
3. ALL STREAMS IDENTIFIED AS TBD WILL BE ADDRESSED IN CFC PACKAGE.
4. EQUIPMENT INSIDE "STEAM REGENERATED CARBON VENDOR PACKAGE" BOUNDARY WILL BE SUPPLIED AS A SKID-MOUNTED SYSTEM. EQUIPMENT VENDOR WILL SUPPLY A COMPLETE SYSTEM INCLUDING ALL EQUIPMENT AND INSTRUMENTATION INSIDE THE SKID LIMITS. EQUIPMENT WILL BE SUPPLIED PRE-PIPED AND PRE-WIRED WITH A CONTROL PANEL AND PLC.

FOR INFORMATION ONLY

NOTE:

FLOW RATES SHOWN ON THIS TABLE ARE INDICATIVE OF EXPECTED RUN DATA BASED ON MODELING OF McMILLAN-McGEE REPORT AND PHASE I DATA

STREAM NO. / COMPONENT	1 VAPOR FROM SVE HEADER	2 VAPOR COOLER INLET	3 VAPOR COOLER OUTLET	4 CONDENSATE FROM VAPOR COOLER	5A VAPOR FROM VACUUM BLOWER	5B VAPOR FROM VACUUM BLOWER	5C SEAL WATER BLOWER	5D SEAL WATER DRAIN	6 VAPOR FROM CHILLER	7 CONDENSATE FROM VAPOR CHILLER	8 AQUEOUS FROM DECANTER	9 CARBON OUTLET VAPOR	10 CONDENSATE FROM COOLER/CHILLER
DRY AIR lb/hr	3,099	3,099	3,099		1550	1550			4,055			3,647.292	
STEAM/WATER VAPOR lb/hr	972	880	165		221	221			62			26.94	
TOTAL VOCs (PRIMARY TCE) lb/hr	29	29	29	0.03	14.5	14.5			29	0.01		0.288	0.045
GROUNDWATER /CONDENSATE lb/hr				867						499			1,094
TOTAL STREAM FLOW lb/hr	4,100	4,008	3,293	867	1,785	1,785			4,146	499		3,674.52	1,094
GAS FLOW acfm													
LIQUID FLOW gpm				1.8			12	11		1.0	2.61		13.8
TOTAL VOCs ppmv (mg/L)	7,000	5,668.491	5,668.491	(34)						(74)			(40)
TEMPERATURE °F	203	199	105	105	138	138	85	138	70	70	50	50	101
PRESSURE psia	6.81	6.58	6.38	14.9	14.9	14.9			14.7	14.95	14.9	14.9	14.7

STREAM NO. / COMPONENT	11 AIR BLEED FOR VACUUM CONTROL	12 WATER TO STEAM BOILER	13 TCE FROM DECANTER	14 CARBON ADSORBER OUTLET	15 STEAM FOR HUMIDITY	16 STEAM TO CARBON BEDS	17 VAPOR TO STACK	23 AIR FROM STRIPPER	35 COOLING WATER TO E-101	36 E-101 COOLING WATER RETURN	37 GLYCOL TO E-102	38 E-102 GLYCOL RETURN	48 COOLING WATER RETURN FROM CONDENSER	49 COOLING WATER SUPPLY TO CONDENSER	50 COMP. AIR SUPPLY TO CARBON BEDS	51 LIQUID TO DECANTER	52 VAPOR TO CONDENSER
DRY AIR lb/hr	TBD			3,640			3,640	955.1									668
STEAM/WATER VAPOR lb/hr	TBD		3	20	107	1,200	127	137									1,200
TOTAL VOCs (PRIMARY TCE) lb/hr	TBD		28.6	0.05			0.02	0.246									28.6
GROUNDWATER /CONDENSATE lb/hr	TBD																
TOTAL STREAM FLOW lb/hr	TBD			3,660.05	107	1,200	3,767.02	1,093									1,897
GAS FLOW acfm	TBD				30										26		
LIQUID FLOW gpm	TBD	2.4	0.45						780.5	780.5	186.8	186.8	100	100		3.06	
TOTAL VOCs ppmv (mg/L)	TBD			14			5	217									
TEMPERATURE °F	TBD	80	50	50	220	298	50	139.6	90	100	45	55	80	100	50	50	
PRESSURE psia	TBD	70	14.9	14.9	14.9	64.7	14.9	14.9	50	15	50	15	50	50	104.7	14.9	

LPE

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DATE

PROFESSIONAL SEAL

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
4	/ /	AS-BUILT - UPDATE							
3	1/18/12	PHASE IIA DESIGN	HDH	DJH	MWI	JTP	SJO	JRW	RES

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY

PADUCAH, PORTSMOUTH PROJECT OPERATIONS, PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

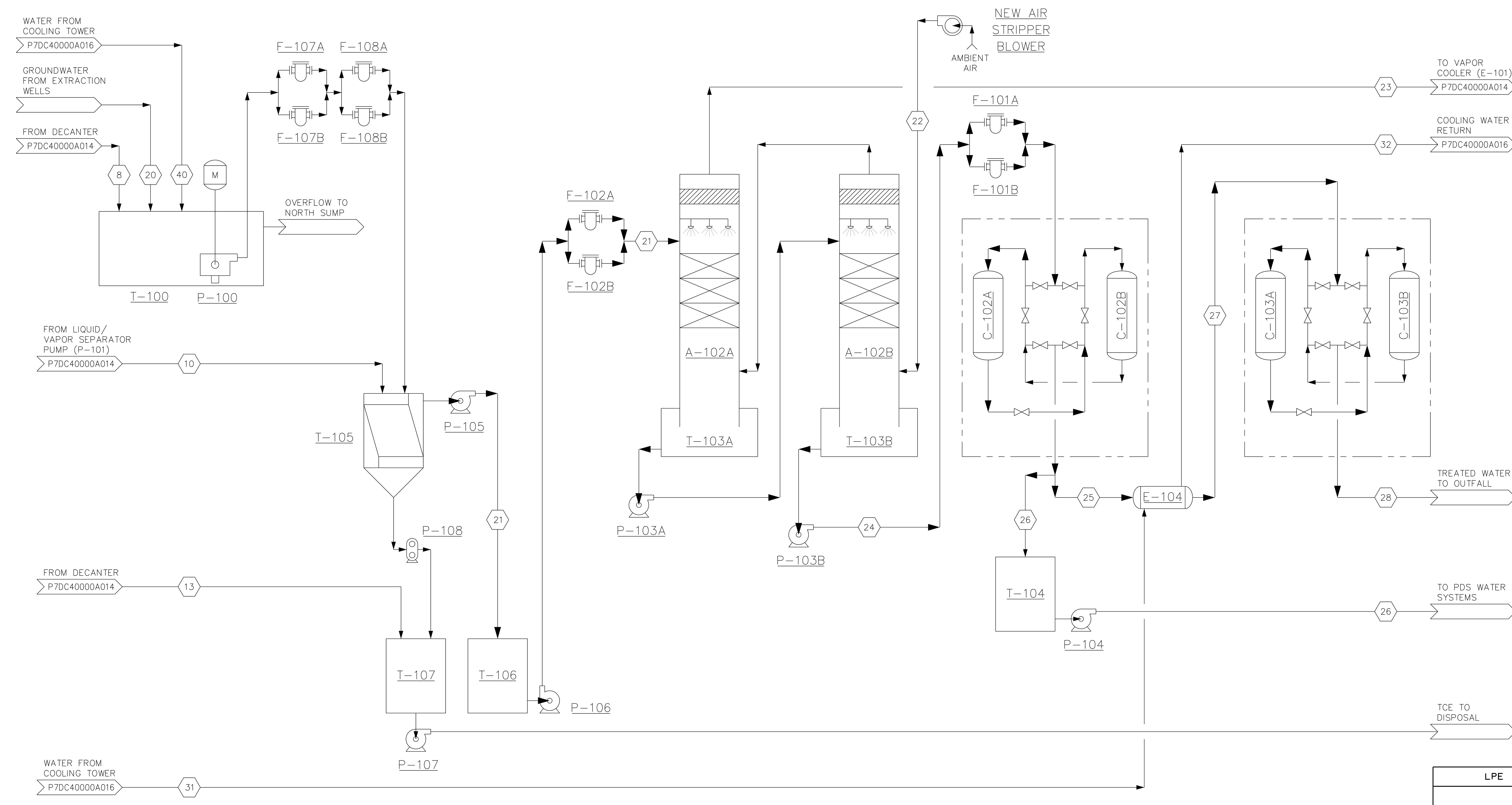
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
SOIL VAPOR TREATMENT SYSTEM PROCESS FLOW DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A014 REV 4.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A014	4



NOTES:

1. FLOW RATES ARE BASED ON TYPICAL RUN DATA FROM PHASE I OPERATION.
2. VOC CONCENTRATIONS (ppmv) FOR VAPOR STREAMS ARE DRY AIR BASIS.
3. ALL STREAMS IDENTIFIED AS TBD WILL BE ADDRESSED IN CFC PACKAGE.

FOR INFORMATION ONLY

A-102A/B — AIR STRIPPER
C-103A/B — LIQUID CARBON ADSORBERS
F-101A/B — AIR STRIPPER EFFLUENT FILTERS
F-107A/B — T-100 EFFLUENT FILTERS
P-100 — FEED SURGE PUMP
P-103B — AIR STRIPPER EFFLUENT PUMP
P-105 — SEPARATOR WATER PUMP
P-107 — TCE TRANSFER PUMP
T-100 — FEED SURGE TANK
T-104 — HOT GROUNDWATER TANK
T-106 — AIR STRIPPER FEED TANK
C-102A/B — ION EXCHANGE
E-104 — AIR STRIPPER EFFLUENT COOLER
F-102A/B — AIR STRIPPER INLUENT FILTERS
F-108A/B — T-100 EFFLUENT FILTERS
P-103A — AIR STRIPPER TRANSFER PUMP
P-104 — WATER INJECTION PUMP
P-106 — AIR STRIPPER FEED PUMP
P-108 — LIQUID TCE PUMP
T-103A/B — AIR STRIPPER EFFLUENT TANK
T-105 — DNAPL SEPARATOR
T-107 — LIQUID TCE STORAGE TANK

NOTE:
FLOW RATES SHOWN ON THIS TABLE ARE INDICATIVE OF EXPECTED RUN DATA BASED ON MODELING OF McMILLAN-McGEE REPORT AND PHASE I DATA

COMPONENT / STREAM NO.		8	10	13	20	21	22	23	24	25	26	27	28	31	32	33	34	40
		FROM DECANTER	CONDENSATE FROM COOLER/ CHILLER	TCE FROM CONDENSER	GROUNDWATER FROM MPE WELLS	AIR STRIPPER FEED	AIR TO STRIPPER	AIR FROM STRIPPER	AIR STRIPPED GROUNDWATER	GROUNDWATER TO E-104	HOT GROUNDWATER TO REINJECTION	GROUNDWATER TO C-103A/B	GROUNDWATER TO DISCHARGE	COOLING WATER TO E-104	E-104 COOLING WATER RETURN	DNAPL FROM T-105 (NOTE 1)	TCE TO DISPOSAL	COOLING TOWER BLOWDOWN
DRY AIR	lb/hr						1,454	955.1										
STEAM/WATER VAPOR	lb/hr			3				152.9										
TOTAL VOCs (PRIMARY TCE)	lb/hr		0.045	28.6	44.1	44.4		0.246	0.21	0.05	0.16	0.05					568.6	
GROUNDWATER/CONDENSATE	lb/hr		1,094		40,032	44,083			42,553	10,708	31,825	10,708	10,708					
TOTAL STREAM FLOW	lb/hr		1,094		40,076	44,128	1,454	1,108.246	42,553	10,708	31,826	10,708	10,708				568.6	
GAS FLOW	acfm																	
LIQUID FLOW	gpm	2.61	2.2	0.45	80	88			85	21.4	63.6	21.4	21.4	257.5	257.5			1.2
TOTAL VOCs	ppmv (mg/L)		(40)		(1,100)	(1,006)		217	(5)	(5)	(5)	(5)						
TEMPERATURE	°F	50	101	50	203	194	70	139.6	157	157	157	100	100	90	100	194	79	90
PRESSURE	psia	14.9	14.7	14.9	14.7	14.7	15.6	14.9	14.7	14.7	14.7	14.7	14.7	50	15	14.7	14.7	15

LPE

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DATE
PROFESSIONAL SEAL

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
4	/ /	AS-BUILT - UPDATE							
3	1/18/12	PHASE IIA DESIGN	HDH	DJH	MWI	JTP	SJD	JRW	RES

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

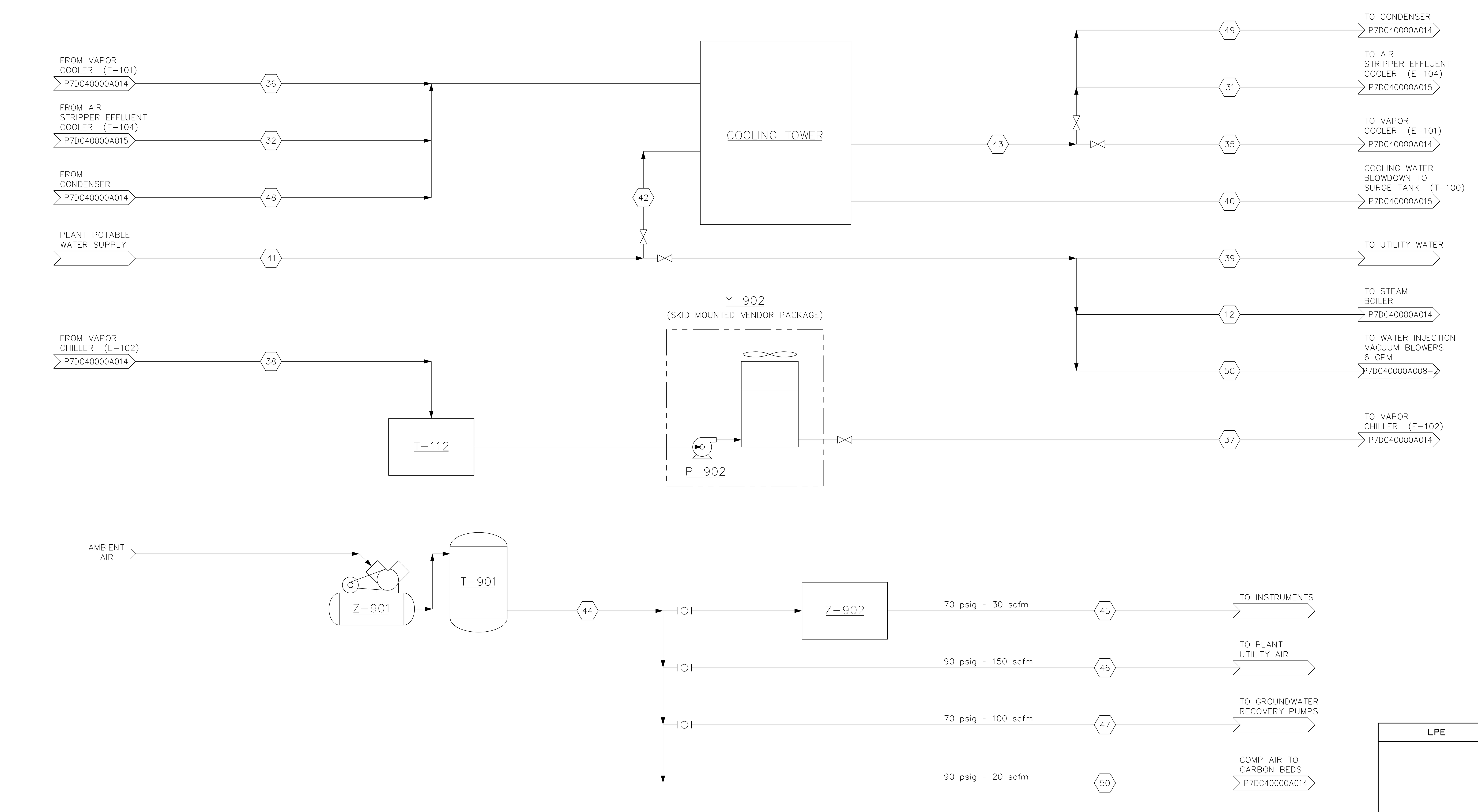
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
GROUNDWATER TREATMENT SYSTEM PROCESS FLOW DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A015 REV 4.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A015	4



NOTES:

1. FLOW RATES ARE BASED ON TYPICAL RUN DATA FROM PHASE I OPERATION.
2. ALL STREAMS IDENTIFIED AS TBD WILL BE ADDRESSED IN CFC PACKAGE.

FOR INFORMATION ONLY

P-902 CHILLER PUMP

T-901 AIR COMPRESSOR RECEIVER TANK

T-112 GLYCOL TANK

Y-902 GLYCOL CHILLER (AIR COOLED)

Z-901 UTILITY AIR COMPRESSOR

Z-902 DEHUMIDIFIER

NOTE:
FLOW RATES SHOWN ON THIS TABLE ARE INDICATIVE OF EXPECTED RUN DATA BASED ON MODELING OF McMILLAN-McGEE REPORT AND PHASE I DATA

STREAM NO. / OPERATIONAL MODES	5C	12	31	32	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
	SEAL WATER BLOWER	WATER TO STEAM BOILER	COOLING WATER TO E-104	E-104 COOLING WATER RETURN	COOLING WATER TO E-101	E-101 COOLING WATER RETURN	GLYCOL TO E-102	E-102 GLYCOL RETURN	UTILITY WATER	COOLING TOWER BLOWDOWN	TOTAL MAKE-UP WATER	COOLING TOWER MAKE-UP	WATER FROM COOLING TOWER	AIR FROM AIR COMPRESSOR	INSTRUMENT AIR	UTILITY AIR	AIR TO GROUNDWATER PUMPS	COOLING WATER RETURN FROM CONDENSER	COOLING WATER SUPPLY TO CONDENSER	COMP. AIR SUPPLY TO CARBON BEDS
AIR FLOW scfm														190	30	150	100			26 (acfm)
AIR FLOW lb/hr														921	145	485	388			
WATER FLOW gpm	12	2.4	258	258	780.5	780.5	186.8	186.8	–	1.2	9.6	9.6	1,038					100	100	
WATER FLOW lb/hr			128,800	128,800	390,600	390,600	98,600	98,600	–	601	4,806	4,806	519,400							
TEMPERATURE f°	85	80	90	100	90	100	45	55		90	70	70	90	80	70	80	80	80	100	50
PRESSURE psig		70	50	15	50	15	50	15		15	30	30	30	90	30	90	70	50	50	104.7

LPE

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DATE

PROFESSIONAL SEAL

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
4	/ /	AS-BUILT - UPDATE							
3	1/18/12	PHASE IIA DESIGN	HDH	DJH	MWI	JTP	SJD	JRW	RES

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
SOIL VAPOR AND GROUNDWATER TREATMENT SYSTEMS UTILITIES PROCESS FLOW DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A016 REV 4.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A016	4

FOR INFORMATION ONLY

T-128
CONDENSATE
COLLECTION SYSTEM
MAIN HEADER

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
4	/ /	AS-BUILT - UPDATE							

DRAWING REVISIONS

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC
managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
SOIL VAPOR EXTRACTION WELLS
PROCESS PIPING & INSTRUMENTATION DIAGRAM

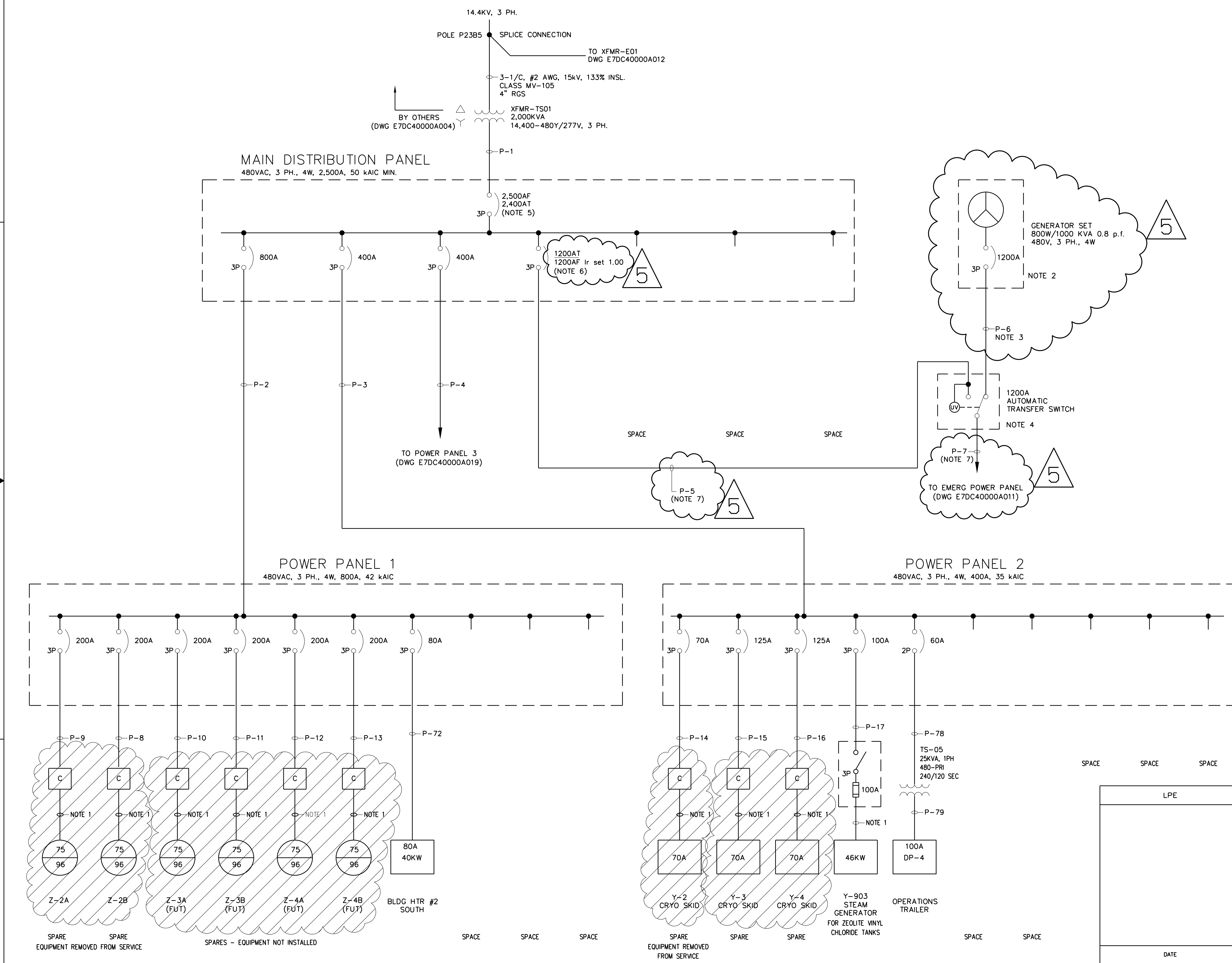
CAD FILE NAME	BUILDING	PLANT	CLASS
P7DC40000A023 REV 4.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	P7DC40000A023	4

NOTES:

1. CIRCUITS PRE-WIRED BY VENDOR.
2. GENERATOR OUTPUT BREAKER TO BE SIZED BY MANUFACTURER.
3. CABLE TO BE SIZED IN ACCORDANCE WITH GENERATOR BREAKER.
4. AUTOMATIC TRANSFER SWITCH TO BE RATED TO MATCH GENERATOR OUTPUT BREAKER.
5. ~~SET LONG TIME CURRENT TRIP @ 96% Ir.~~
6. SET LONG TIME CURRENT TRIP @ 1.00% Ir.
7. INCREASE CABLE SIZE OF P-5 & P-7. SEE DWG. E7DC40000A014

5



REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	EATS MGR
5	01/18/12	PHASE IIA DESIGN	HDH	RCS	RCS	KAS	SJD	JRW	RES
4	12/17/10	AS-BUILT - UPDATE	HDH	RCS	RCS	RCS	SBM	MEC	RES

DRAWING REVISIONS

LPE

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY

PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020
Paducah, Kentucky

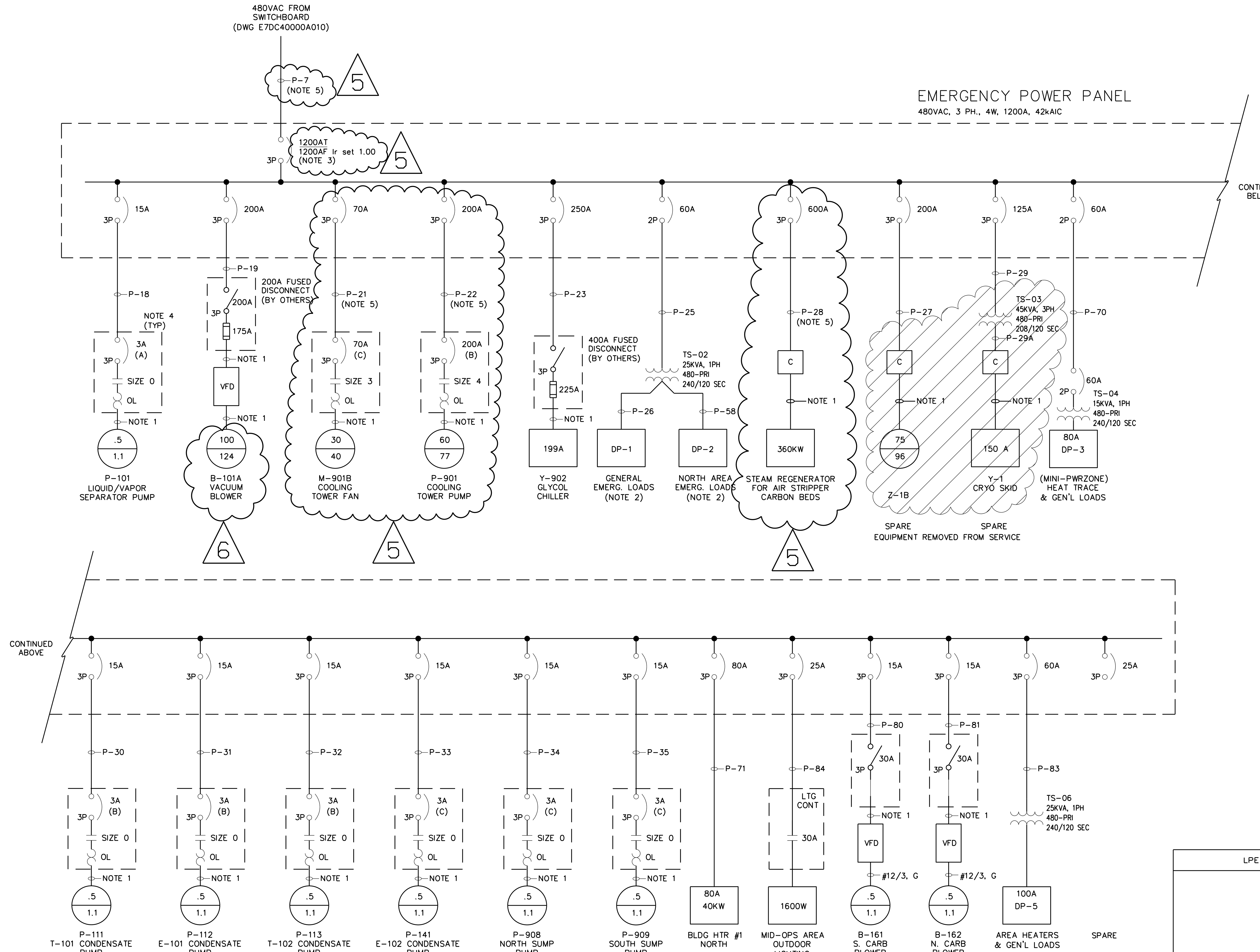
DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:
C-400 REMEDIATION DESIGN

TITLE:
GROUNDWATER/VAPOR TREATMENT SYSTEM
ELECTRICAL
TREATMENT SYSTEM ONE LINE DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
E7DC40000A010 REV 5.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	E7DC40000A010	5



NOTES:

1. CIRCUITS PRE-WIRED BY VENDOR.
2. SEE DRAWING E7DC40000A020 FOR PANEL SCHEDULE.
3. SET B-RATING PLUG @ 1.00% Ir.
4. CUTLER-HAMMER HMCP MOTOR CIRCUIT PROTECTORS UTILIZED, (X) DENOTES THE CAM (TRIP) SETTING.
5. INCREASE CABLE SIZE OF P-7, P-21, P-22, & P-28. SEE DWG. E7DC40000A014

FOR INFORMATION ONLY

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	EATS MGR
6	/ /	PHASE IIA DESIGN - UPDATE							
5	01/18/12	PHASE IIA DESIGN	HDH	RCS	RCS	KAS	SJD	JRW	RES
4	12/17/10	AS-BUILT - UPDATE	HDH	RCS	RCS	RCS	SBM	MEC	RES

DRAWING REVISIONS

LPE

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY
PADUCAH, PORTSMOUTH PROJECT OPERATIONS,
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC — managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020, Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME: C-400 REMEDIATION DESIGN

TITLE: GROUNDWATER/VAPOR TREATMENT SYSTEM ELECTRICAL TREATMENT SYSTEM ONE LINE DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
E7DC40000A011 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	E7DC40000A011	6

NOTES:

1. NOTED CIRCUITS ARE PRE-WIRED BY VENDOR.
2. CUTLER-HAMMER HMCP MOTOR CIRCUIT PROTECTORS UTILIZED, (X) DENOTES THE CAM (TRIP) SETTING.
3. INCREASE CABLE SIZE OF P-46 AS REQUIRED. SEE DWG. E7DC40000A014

FOR INFORMATION ONLY

REV.	DATE	DESCRIPTION	DRAWN BY	DRAFT CHK	PROJ ENGR	LEAD ENGR	CONF CTRL/ NUCL SFTY	FAC MGR	E&TS MGR
6	/ /	PHASE IIA DESIGN - UPDATE							
5	01/18/12	PHASE IIA DESIGN	HDH	RCS	RCS	KAS	SJD	JRW	RES
4	12/17/10	AS-BUILT - UPDATE	HDH	RCS	RCS	RCS	SBM	MEC	RES

DRAWING REVISIONS

LPE

DATE

PROFESSIONAL SEAL

U.S. DEPARTMENT OF ENERGY

PADUCAH, PORTSMOUTH PROJECT OPERATIONS, PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

managed for the DEPARTMENT OF ENERGY under U.S. GOVERNMENT contract DE-AC30-10CC40020 Paducah, Kentucky

DOE CONTRACT NO. DE-AC30-10CC40020

PROJECT NAME:

C-400 REMEDIATION DESIGN

TITLE:

GROUNDWATER/VAPOR TREATMENT SYSTEM ELECTRICAL TREATMENT SYSTEM ONE LINE DIAGRAM

CAD FILE NAME	BUILDING	PLANT	CLASS
E7DC40000A019 REV 6.DWG	C-400	PGDP	U

SCALE:	DRAWING NUMBER	REV
NONE	E7DC40000A019	6

APPENDIX G

TECHNICAL SPECIFICATIONS AND EQUIPMENT DATA SHEETS

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EQUIPMENT DATA SHEETS

Data sheets for Phase IIa components (B-102 blower, cooling tower, steam boiler, steam regenerated carbon treatment system, and emergency generator) will be finalized prior to construction.

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SPECIFICATION TABLE OF CONTENTS

SPECIFICATION TABLE OF CONTENTS

DIVISION 18 – WELDING

PROCESS EQUIPMENT DATA SHEETS

Process Flow Diagram Tag Number	Equipment Name
A-102	Air Stripper
B-101A&B	Vacuum Blower
B-102	Air Stripper Blower
C-102A&B	Ion Exchange Vessels
C-103A&B	Liquid Carbon Adsorbers
C-106A&B	Polishing Vapor Carbon Adsorbers
C-107A&B	Polishing Vapor Zeolite System
C-108A&B	Ion Exchange Vessels
E-101	Vapor Cooler
E-102	Vapor Chiller
E-104	Air Stripper Effluent Cooler
F-101A&B	Air Stripper Effluent Filters
F-102A&B	Air Stripper Influent Filter Assembly
P-101	Liquid/Vapor Separator Pump
P-103	Air Stripper Effluent Pump
P-104	Water Injection Pump
P-106	Air Stripper Feed Pump
P-108	Liquid TCE Pump
T-100	Feed Surge Tank
T-101	Liquid/Vapor Separator 1
T-102	Liquid/Vapor Separator 2
T-103	Air Stripper Effluent Tank
T-104	Hot Groundwater Tank
T-105	DNAPL Separator
T-106	Air Stripper Feed Tank
T-107	Liquid TCE Storage Tank
T-108	Condensate Sump Tank
Y-901	Cooling Tower
Y-902	Glycol Chiller
Z-901	Utility Air Compressor
Z-902	Air Dryer
N/A	Emergency Generator
N/A	Steam Boiler
N/A	Steam Regenerated Carbon Treatment System

SECTION 01050

FIELD ENGINEERING

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Field engineering for surveying, as-builts, and quantity calculations during on-site work.

1.02 DEFINITIONS

A. Surveyor: Licensed as a surveyor in the Commonwealth of Kentucky.

B. Engineer: Minimum of a Bachelor of Science Degree in Civil Engineering and licensed in the Commonwealth of Kentucky.

1.03 REFERENCES

A. Horizontal Control as Applied to Local Surveying Needs, American Congress on Surveying and Mapping.

B. Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee, 1984.

1.04 QUALITY CONTROL

A. Maintain complete, accurate log of survey work and redlined, as-built drawings during the progression of work. Changes from the design documents, which are made in the work or additional information that might be uncovered in the course of construction, shall be accurately and neatly recorded as they occur by means of details and notes.

B. Provide horizontal control for Class 3 surveys and vertical control for third-order level closures. Provide horizontal control in accordance with "Horizontal Control as Applied to Local Surveying Needs, American Congress on Surveying and Mapping S200," and vertical control in accordance with "Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee, 1984."

C. Provide as-built data to the nearest 0.01 ft horizontally and vertically.

D. Legibly record survey field notes on standardized (4-in. x 7 ¼-in.) permanent-bound, hard back, transit field books. Include title of project, name of the survey company, initials of survey party, and date of survey.

E. Either a Surveyor or Engineer shall perform layout survey and as-built documentation. Submittals shall be sealed and signed by the Surveyor or Engineer.

1.05 SUBMITTALS

A. Submit the following for information:

1. Copy of reduced field notes, calculated coordinates, elevations, and quantity calculations. Provide certification of survey accuracy by the surveyor and quantity calculations by the surveyor or engineer. Identify nonconformances upon discovery.

PART 2 PRODUCTS

Not used.

PART 3 EXECUTION

3.01 INSPECTION

A. Verify locations of survey control points before starting work. Promptly notify the Field Engineer of discrepancies.

3.02 INSTALLATION/APPLICATION/ERECTION

A. Control Points

1. Survey control points shall be as identified by the Field Engineer.

2. Protect and preserve survey control points. Do not make changes to control points unless directed in writing by the Field Engineer.

3. Survey control points damaged or destroyed shall be replaced.

4. Establish and maintain a minimum of two permanent benchmarks on the site referenced to data established by control points.

5. Record benchmark locations, with horizontal and vertical data, on project record drawings.

B. Layout Survey

1. Establish lines and levels, locate and layout by instrumentation and similar appropriate means:

a. Site improvements (including pavements).

b. Grid or axis for structures.

2. Periodically verify layouts.

B. As-Built Data

1. Provide as-built redlined drawings located by survey and documented in field books for the following:

a. Contract changes in layout and location of work.

b. Existing underground utilities that are not shown on the design documents or that are missing coordinates and elevations or deviate from design location.

END OF SECTION

SECTION 02200

EARTHWORK

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Removal and stockpiling of topsoil, excavation, and compaction of fill and backfill to grade as shown on drawings.

1.02 DEFINITION OF TERMS

A. Earth Excavation: Removal of material to lines, elevations, and dimensions shown on drawings and disposition of materials encountered in grading and excavation work.

B. Unauthorized Excavation: Excavation not required by specifications or drawings or not authorized in writing by the Project Manager or designee.

C. Fill: Earth or other material, as specified, used to bring an existing grade to a specified grade.

D. Backfill: Earth, crushed stone or other materials as specified used to replace material excavated during construction.

E. Subgrade: Compacted fill or backfill of embankments or undisturbed soil of cut sections, which supports base course and wearing surface.

F. Undercutting: Removal of soft or undesirable materials determined by Project Manager or designee encountered in undisturbed subgrade below grades specified for excavation.

G. Spot Subgrade Reinforcement: Placing accepted geosynthetic materials and fill or backfill in areas where authorized undercutting has been performed.

H. Shoring: A structure such as a metal, hydraulic, mechanical, or timber shoring system that supports sides of an excavation and which is designed to prevent cave-ins.

I. Topsoil: The term topsoil used herein shall mean that portion of the soil profile defined technically as the “A” horizon by the Soil Science Society of America. The texture shall be a sandy loam, clay loam, loam, silty clay loam, or silt loam as defined by the U.S. Department of Agriculture Soil Conservation Service Guide for Technical classification. The topsoil shall be capable of producing heavy growths of vegetation; free from subsoil, noxious weeds, stones larger than 1 inch in diameter, lime, cement, ashes, slag or other deleterious matter; well drained in its original position; free from toxic quantities of acid or alkaline elements; and free of roots and other large organic matter.

1.03 REFERENCES

A. ASTM D422 (latest version), Test Method for Particle-Size Analysis of Soils.

B. ASTM C136 (latest version), Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

C. ASTM D689 (latest version), Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort. (12,400 ft-lb/ft (600 kN-m/m))

D. ASTM D1241 (latest version), Standard Specification for Materials for Soil-Aggregate Sub-base, Base, and Surface Courses.

E. ASTM D1557 (latest version), Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort. (56,000 ft-lb/ft (2700 kN-m/m))

F. ASTM D2216 (latest version), Standard Test Method for Laboratory Determination of Water (moisture) Content of Soil and Rock.

G. ASTM D2487 (latest version), Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System).

H. ASTM D2922 (latest version), Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

I. ASTM D3017 (latest version), Standard Test Method for Water Content of Soil and Rock In-Place by Nuclear Methods (Shallow Depth).

J. ASTM D4318 (latest version), Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

K. OSHA Code of Federal Regulations 29 CFR 1926, Subpart P - Excavations, latest edition.

1.04 SUBMITTALS (Refer to Exhibit I for Requirements)

A. Not Used.

1.05 RELATED SECTIONS

A. Not Used.

PART 2 PRODUCTS

2.01 MATERIALS

A. Select Fill and Backfill Materials

1. Coarse Stone: Angular, crushed, free of shale, clay, friable materials, and debris; graded in accordance with ASTM C136 within the following limits: size No. 57 stone.

2. Sand: Natural River, bank, or manufactured sand; washed, free of silt, clay, loam, friable, or soluble materials, and organic matter; graded in accordance with ASTM D1241, Fine Aggregate.

3. Spot Subgrade Repair Materials: Number Two Road Base (RB2) or other material acceptable to the Project Manager or designee.

B. Common Fill and Backfill Materials

1. Subsoil: Reused; free of gravel larger than 3 in. size; free of material with an expansion index less than 20; no debris, roots, or vegetation. Satisfactory borrow to consist of any material classified by ASTM D2487 as GW, GP, GM, GC, SW, or SP.

2. Top Soil: Existing topsoil removed during construction will be considered adequate, if a natural, friable soil representative of productive soils and is free of subsoil, clay or impurities, plants, weeds, and roots.

2.02 EQUIPMENT

A. Maintain compaction equipment in satisfactory operating condition. Use compaction equipment capable of achieving the degree of compaction specified.

B. Power tampers for use in restricted areas shall be of a type and size suitable to perform required compaction.

PART 3 EXECUTION

3.01 PREPARATION

A. Verify that subgrade is not soft, spongy, or composed of otherwise unstable materials. If unstable materials are encountered, stop work and notify the Project Manager or designee.

B. Verify that stockpiled soil and topsoil to be reused are acceptable.

3.02 INSTALLATION/APPLICATION/ERECTION

A. Stripping and Stockpiling Topsoil

1. Erosion control measures: Install prior to stripping.

2. Stripping: Strip all vegetative matter, topsoil, sod, and rubbish from within portions of the job site to be excavated. Clean Topsoil shall be segregated and stockpiled in the Excavated Material Storage Area.

3. Stockpiling: It is the Subcontractor's responsibility to locate and construct the stockpiles of soil so as not to disturb the drainage in the area. As a minimum, all stockpiled soil from on site locations, shall be covered with a single layer of 6-mil polyethylene sheeting anchored to prevent lifting from wind. Silt fence shall be installed around the stockpiles per Section 02270, Erosion Control.

B. Excavation

1. Prior to the start of work, obtain a Trenching, Excavation, and Penetration Permit.

2. Carry excavation through whatever materials are encountered to depths shown on the design drawings. Remove all existing fill and other unsatisfactory materials within limits of excavation as indicated on drawings.

3. Dispose of excavated materials in accordance with the approved Project Waste Management Plan.

4. Backfill unauthorized excavation with clean compacted earth, sand, clay or crushed stone in accordance with the requirements of Section D, as directed by the Project Manager or designee.

5. The materials shall not obstruct proper drainage of the area.

C. Structural Excavation

1. Excavate subsoil required for building foundations, construction operations, and other work. Excavation to be in accordance with OSHA Safety Regulation 29 CFR 1926 Subpart P - Excavations, latest edition. Maintain a minimum of 2-ft working space around structure.

2. Protect excavation by shoring, bracing, sheet piling, underpinning, or other methods required to prevent cave-in or loose soil from falling into excavation. Protection to be in accordance with OSHA Safety Regulation 29 CFR 1926 Subpart P - Excavations, latest edition.

D. Backfill and Compaction

1. All areas receiving fill shall be cleared, scarified to a depth of 6 in. and compacted.

2. When existing ground surface has a density less than the density specified under compaction, break up the ground surface, pulverize, adjust moisture content to specified limits, and compact to specified density.

3. Spread soil material in lifts that shall not exceed 6 in. after compaction.

4. Compact layers by use of a sheepsfoot roller or other methods approved by the Project Manager or designee.

5. Compact locations not accessible to mechanical equipment by machine or hand-maneuvered power tamping.

6. Project Manager or designee shall accept the compaction effort. No testing is required.

7. Compact all fill not accessible to self-propelled or towed compactors by hand-operated power tampers or other accepted means to the specified density.

8. Do not place fill material when weather conditions, condition of the subgrade, or condition of the fill material precludes obtaining the specified compaction.

9. Prior to finish grading of the area, complete all backfilling. Correct any washouts or other similar irregularities.

10. Grade all exposed earth surfaces to smooth contours and in such a manner to promote positive drainage. The finish for grading shall be that degree ordinarily obtainable for either blade-grade or scraper operations or that obtainable by hand shovel operations.

11. Scarify subsoil of area to receive topsoil to a depth of 3 in.

12. Spread a uniform layer of topsoil 4 in. thick. Topsoil material to be from stockpiled material or accepted borrow. Bond to subsoil by rolling with a light roller or by tamping. Hand rake surface.

13. Topsoil shall be placed to lines and grades shown on drawings and a 2 in. layer of straw shall be placed on the topsoil if seeding operations will not begin within 2 days following topsoil placement. Seeding season and seeding requirements to conform to Section 02936, Seeding.

E. General

1. Maintain excavations free from water, and dispose of excess water by methods in accordance with approved project work plans.

2. Maintain newly graded areas until final acceptance by Project Manager or designee. Restore areas showing settlement or washes to specified grades prior to final acceptance.

3. Provide temporary shoring and bracing as necessary to safely support excavation. Remove shoring and bracing from excavation as backfilling progresses. Shoring, in accordance with OSHA 29 CFR 1926, Subpart P - Excavations, latest revision, Safety Regulations.

4. Provide erosion and sediment control to minimize erosion and transport of sediment beyond limits of the work area. Methods of control shall conform to Section 02270, Erosion Control.

5. Bind thin layers of added materials to material in place by scarifying and recompacting.

3.03 FIELD QUALITY CONTROL

A. No testing is required.

B. Top of subgrade shall be a uniformly smooth grade surface without high or low points and shall not be more than 0.20 ft above or below specified grades.

3.4 PROTECTION

A. Protect existing utility lines and structures in work area and existing roadway structures, seeded areas, and other features adjacent to work area during construction activities. Provide adequate shoring and bracing, as required, to protect and maintain the stability of previously constructed structures and facilities.

B. Obtain an excavation/penetration permit prior to the start of excavation work.

END OF SECTION

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SECTION 02225

TRENCHING

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Excavation of trenches for utilities, compaction of bedding and fill over utilities to subgrade elevation, and compaction and backfill requirements.

1.02 REFERENCES

A. ASTM D1241 (latest version), Standard Specification for Materials for Aggregate and Soil-Aggregate Subbase, Base and Surface Courses.

B. OSHA Code of Federal Regulations 29 CFR 1926 Subpart P, Excavation, latest revision.

C. Kentucky 2000 (or latest version) Transportation Cabinet/Department of Highways (KDH), Standard Specifications for Road and Bridge Construction.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Backfill: Earth for backfill shall be obtained from an offsite source. Materials for earth backfill shall be dry earth, free from clods of earth, boulders, broken rock or concrete exceeding 3 inches in the larger dimension, organic and vegetable matter, rubbish, and other unsuitable material.

B. Sand: natural sand or crushed stone passing a No. 10 sieve and conforming to gradation requirements of ASTM D-1241.

C. Backfill Materials Under Roads and Structures: Mineral aggregate base to limit settlement. Dense Grade Aggregate base shall conform to Sect. 02505, Dense Grade Aggregate Base.

D. Bedding materials for sanitary water piping shall be sand in accordance with KDH, Section 804.

E. Top Soil: in accordance with Sect. 02200, Earthwork.

PART 3 - EXECUTION

3.01 PREPARATION

A. Verify fill materials are acceptable. Do not use frozen material.

B. Verify areas to be backfilled are free of debris, snow, ice, or water and that the surfaces are not frozen.

C. Identify required lines, levels, contours, and datum.

3.02 INSTALLATION/APPLICATION/ERECTION

A. Excavation

1. Excavate trenches to a width necessary for proper installation of pipe or other utility to be accommodated. Excavation to be in accordance with OSHA Safety Regulation, 29 CFR 1926.650 and 1926.651. Clearance between pipe and trench walls, except where otherwise specified or indicated on the drawings, shall be 6 in. for trenches less than 2 ft deep and 12 in. for trenches more than 2 ft deep. Obtain an excavation permit prior to starting excavation activities.

2. Remove excavated materials from the work area to an approved spoils area.

3. Grade excavation top perimeter to prevent surface water runoff into excavation. Keep trench bottom free of standing water.

4. Grade bottom of trench to provide uniform bearing and support for utility either on undisturbed soil or properly compacted backfill throughout the length of the utility except where necessary to hand excavate for bell or coupling for proper sealing of pipe joints.

5. Hand excavate for bell and spigot after trench has been fine graded to ensure uniform bearing is provided for pipe.

6. Remove soft, spongy, or otherwise unstable materials encountered at elevation of pipe, which will not provide a firm foundation for the pipe.

B. Bedding/Backfill

1. Promptly backfill utility trenches and around utility structures after utilities have been accepted by Field Engineer.

2. Deposit bedding material in 6-in. layers, and carefully ram or tamp until utility has a cover of not less than 1 ft. The remainder of the backfill shall be placed in horizontal layers 12 in. in depth and compacted by mounted equipment or hand-maneuvered power compaction tools. Bedding material shall be in accordance with KDH 701.02.04.

3. Remove temporary blocking or cribbing material used to support utility before backfilling.

C. General

1. Notify the Project Manager or designee of unexpected subsurface conditions, and discontinue work in affected area until notification to resume work.

2. Do not excavate in the vicinity of buildings and structures below the existing foundation until underpinning and shoring have been installed. Protect or replace existing structures, piping, or foundations.

3. In areas where paving, top soiling, or sodding is to be done, stop fill or backfill the required distance below finish grade to permit installation of these items.

4. Support pipe during placement and compaction of bedding fill.

5. Mineral aggregate base shall begin 2.5 ft from facility or road cut and end 2.5 ft from facility or road cut and shall be compacted in 6-in.-deep horizontal layers using hand-maneuvered power compacting tools.

3.03 FIELD QUALITY CONTROL

A. Testing

1. No testing is required. Field Engineer will inspect compaction effort.

B. Top of subgrade shall be a uniformly smooth grade surface without high or low points and shall not be more than 0.20 ft above or below specified grades. Bind thin layers of added materials to material in place by scarifying and recompacting.

3.04 PROTECTION

A. Protect excavation by shoring, bracing, sheet piling, underpinning, or other methods required to prevent cave-in of loose soil from falling into excavation. Protection shall be in accordance with OSHA 29 CFR 1926 Subpart P, Excavations, latest revision.

1. Trenches more than 5 ft in depth shall be shored or laid back to a stable slope or provided with some other equivalent means of protection.

2. Refer to OSHA 29 CFR 1926 Subpart P, Excavations, Appendices A and B, as a guide to minimum requirements for slopes that are laid back.

3. Refer to OSHA 29 CFR 1926 Subpart P, Excavations, Appendices C through E, as a guide to minimum requirements for shoring or bracing.

4. Trenches less than 4 ft in depth shall also be effectively protected when examination of ground indicates hazardous ground movement may be expected.

5. Trenches 4 ft deep or more shall have a means of exit requiring no more than 25 ft of lateral travel.

END OF SECTION

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SECTION 02270

EROSION CONTROL

PART 1 GENERAL

1.01 SECTION INCLUDES

A. Temporary control measures for slope protection and controls to reduce erosion, sedimentation, and water pollution through the use of erosion control devices.

1.02 REFERENCES

A. ASTM D4355-92, Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).

B. ASTM D4491-92, Standard Test Methods for Water Permeability of Geotextiles by Permittivity.

C. ASTM D4632-91, Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.

D. ASTM D4751-93, Standard Test Method for Determining Opening Size of a Geotextile.

1.03 SUBMITTALS

A. Submit for acceptance the manufacturer’s data for silt fence.

1.04 PROJECT/SITE CONDITIONS

A. Coordinate temporary pollution control provisions with permanent erosion control features to assure economical, effective, and continuous erosion control throughout construction and post construction periods.

1.05 RELATED SECTIONS

A. Section 02225, Trenching

PART 2 PRODUCTS

2.01 MATERIALS

A. Silt Fences

1. Geotextile Filter Fabric: A non-woven fabric consisting of pervious sheets of propylene, nylon, polyester, or ethylene yarn. Certify material by manufacturer to meet the following requirements.

Physical Requirements for Fabric Silt Fence

Property	Test Method	Requirement
Minimum Tensile Strength	ASTM D4632	90 lb
Maximum Elongation at 45 lb	ASTM D4632	50% max
Apparent Opening Size	ASTM D4751	AOS < 0.84 mm
Minimum Permittivity	ASTM D4491	1 X 10^{-2} SEC^{-1}
Ultraviolet Exposure Strength Retention	ASTM D4355	70% @ 500 h

2. Posts: Wood and a minimum 5 ft long. Wood posts shall be at least 4 in. diameter or nominal 2 X 2 in.

3. Preassembled silt fencing may be substituted if it meets the above requirements.

B. Mulching Material

1. Oat, wheat, barley, or rye straw, or excelsior wood fibers, free from weeds, foreign matter detrimental to plant life, and dry. Hay or chopped cornstalks are not acceptable. Straw shall be suitable for spreading with standard mulch blower equipment.

C. Straw Bale Barriers

1. Baled hay or straw containing 5 ft^3 or more of material. Securely bind bales with wire or nylon.

PART 3 EXECUTION

3.01 PREPARATION

A. Site Preparation: Prepare site in accordance with good engineering practices for installation of surface erosion control features. Compact surface and remove and replace pockets of soft soil with compacted earth material to provide a consistently uniform and stable surface.

3.02 INSTALLATION/APPLICATION/ERECTION

A. General

1. Control surface water runoff on-site and provide temporary soil stabilization measures as required to prevent removal of soil by action of either water or wind, more commonly known as erosion. Protect land areas adjacent to work site from sedimentation by installation of erosion and sediment control measures. Provide, as a first step in construction operation, sediment basins and traps, perimeter barriers, and other measures intended to deter erosion and transport of sediment associated with construction activities before upslope land disturbance takes place.

2. Seed and mulch within 15 days of installation of earthen structures, such as dams, berms, and diversions.

B. Silt Fences

1. Install silt fence to reduce the quantity of sediment and reduce sheet flows and low-to-moderate level channel velocities to downstream areas.

2. Silt fences shall be anchored in a trench not less that 6-in. in depth. Refer to attachment “A”.

C. Straw Bale Barriers

1. Obtain an excavation permit and confirm that no underground utilities will be encountered before driving stakes. Install straw or hay bale barriers in accordance with Attachment A and B of this specification. These entrenched and anchored bales are placed in a row to reduce the quantity of sediment and flow velocities to downstream areas.

2. String-tie bales. Install bales so that bindings are oriented around the sides rather than along tops and bottoms of bales in order to prevent deterioration of bindings. Excavate a trench the width of bale and a length of proposed barrier to a minimum depth of 4 in. Place bales in the trench and fill the gaps with loose straw to prevent water from escaping between the bales. Anchor bales with at least two wooden stakes driven through bales to a depth of 1.5 to 2 ft in ground. Drive first stake in each bale toward previously laid bale to force the bales together. After bales are staked and chinked, backfill excavated soil against barrier. Backfill soil shall conform to ground level on downhill side and shall be built up to 4 in. against uphill side of the barrier.

   a. Channel Flow: Place bales at locations indicated, in a single row, lengthwise, oriented parallel to contour, with ends of adjacent bales tightly abutting one another. Extend barrier to such a length that bottoms of end bales are higher in elevation than top of lowest middle bale to assure that sediment-laden runoff will flow either through or over barrier, but not around it.

   b. Sheet Flow: Place bales at locations indicated, in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.

3.03 MAINTENANCE

A. Silt Fences

1. All erosion and sediment control measures will be checked and repaired as necessary weekly during dry periods and within 24 h after 0.5 in. or more of rainfall. During prolonged rainfall, checks and repairs will be made within a 24-h period on all control devices. Should fabric decompose or become ineffective and still be necessary, replace fabric promptly. As a minimum, remove sediment when deposits reach approximately one-third the height of barrier.

B. Straw Bale Barriers

1. All erosion and sediment control measures will be checked and repaired as necessary weekly during dry periods and within 24 h after 0.5 in. or more of rainfall. During prolonged rainfall, checks and repairs will be made within a 24-h period on all control devices. Repair damaged bales, end runs, and undercutting beneath bales. Accomplish necessary repairs to barriers or replacement of bales promptly. Remove sediment when level of deposition reaches approximately one-third the height of lowest point of barrier.

END OF SECTION

ATTACHMENT A

ENGINEERING STANDARD

OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY

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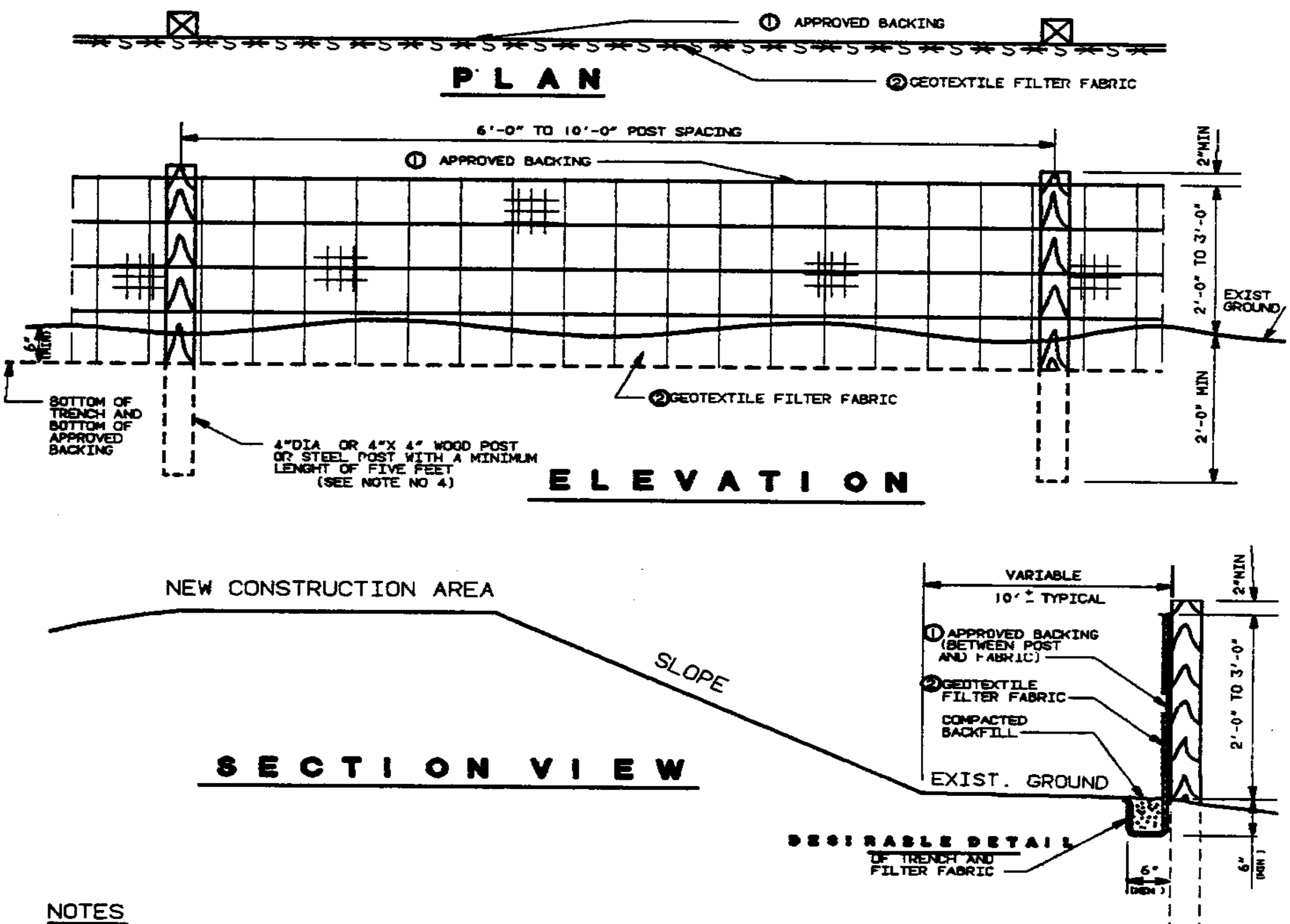
REVISED	
PAGE	1 OF 1

TEMPORARY SILT FENCE



NOTES

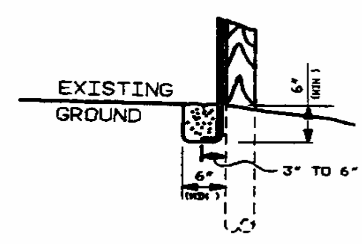
① GEOTEXTILE FILTER FABRIC SHALL HAVE APPROVED BACKING SUCH AS WIRE MESH FENCE, OR A REINFORCED STRUCTURE AS RECOMMENDED BY THE MANUFACTURER TO SUPPORT THE FILTER FABRIC WIRE FENCE SHALL BE LIVESTOCK TYPE WIRE, AT LEAST 14-GAGE, A MINIMUM OF 36 INCHES IN HEIGHT, AND HAVE A MAXIMUM SPACING OF 6 INCHES.

② GEOTEXTILE FILTER FABRIC SHALL MEET THE REQUIREMENTS OF FABRIC MANUFACTURED FOR THE SPECIFIC PURPOSE OF SILT CONTROL.

③ ACCEPTABLE SILT FENCE FABRICS INCLUDE AMOCO SILTSTOP, MIRAFI 100X AND TREVIRA 1115.

④ A PREASSEMBLED SILT FENCE MEETING THE REQUIREMENTS OF THIS DRAWING IS ACCEPTABLE IN LIEU OF A FIELD CONSTRUCTED SILT FENCE.

⑤ SILT FENCE SHALL BE MAINTAINED IN A SATISFACTORY CONDITION FOR THE DURATION OF THE PROJECT.

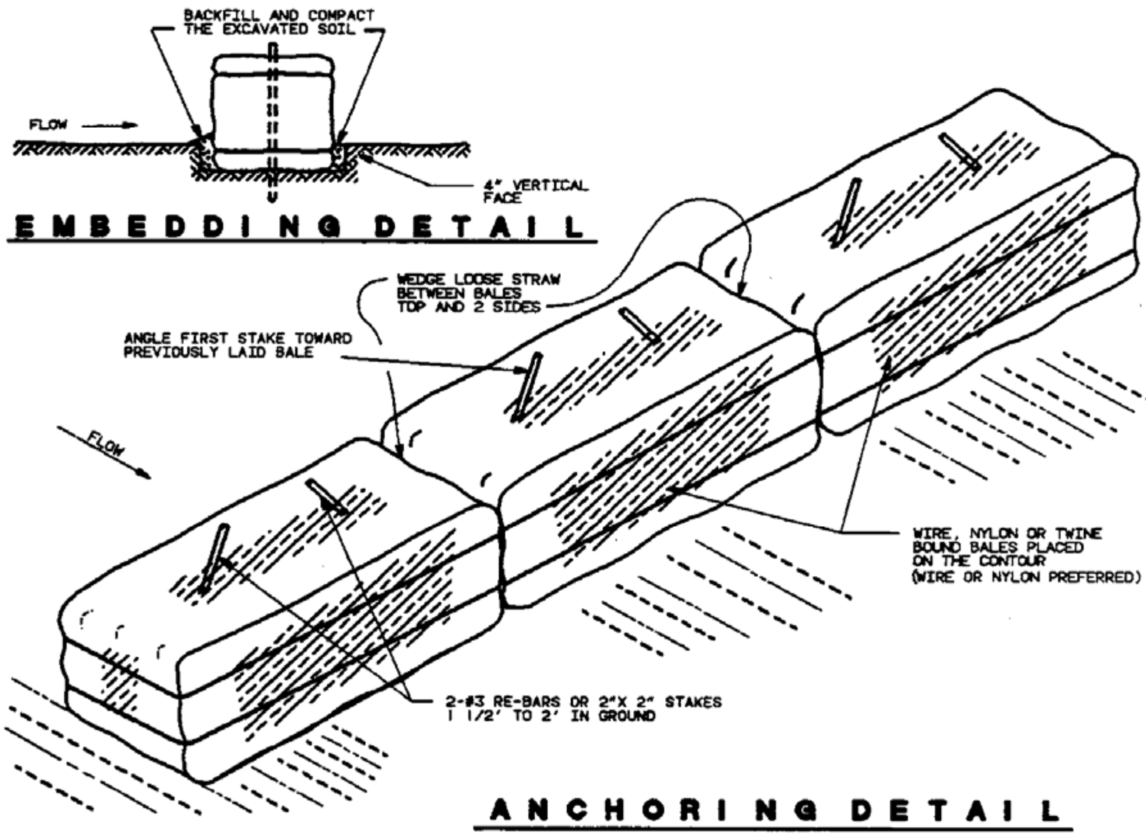


ALTERNATE DETAIL OF TRENCH AND FILTER FABRIC

EROSION CONTROL PLAN LEGEND: →← S →← S →← S →← (TEMP. SILT FENCE)

ATTACHMENT B

ENGINEERING STANDARD	NUMBER ES-7.16-2
OAK RIDGE, TENNESSEE - PADUCAH, KENTUCKY	DATE 10-3-88
	REVISED
STRAW BALE BARRIERS	PAGE 1 OF 1



CONSTRUCTION SPECIFICATIONS

1. BALES SHALL BE PLACED IN A ROW WITH ENDS TIGHTLY ABUTTING ADJACENT BALES.
2. EACH BALE SHALL BE EMBEDDED IN THE SOIL A MINIMUM OF 4".
3. BALES SHALL BE SECURELY ANCHORED IN PLACE BY STAKES OR RE-BARS DRIVEN THROUGH THE BALES, THE FIRST STAKE IN EACH BALE SHALL BE ANGLED TOWARD PREVIOUSLY LAID BALE TO FORCE BALES TOGETHER.
4. TRENCH ON EACH SIDE OF BALES SHALL BE BACKFILLED AND COMPACTED WITH THE EXCAVATED SOIL TO PREVENT PIPING.
5. INSPECTION SHALL BE FREQUENT AND REPAIR OR REPLACEMENT SHALL BE MADE PROMPTLY AS NEEDED.
6. BALES SHALL BE REMOVED WHEN THEY HAVE SERVED THEIR USEFULNESS SO AS NOT TO BLOCK OR IMPEDE STORM FLOW OR DRAINAGE.

STANDARD SYMBOL —— SBB ——

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SECTION 02505

DENSE GRADE AGGREGATE BASE (DGA)

PART 1 - GENERAL

1.01 DESCRIPTION

A. This work includes the compaction and installation requirements of dense grade aggregate base (DGA).

1.02 DEFINITIONS

1. Dense Grade Aggregate Base (DGA): Aggregate base course shall consist of crushed stone and water and is compacted in layers on a previously prepared subgrade to a finished thickness and in areas specified on the drawings.

2. Crushed Stone: An aggregate mixture conforming to Kentucky Department of Highways (KDH), Standard Specifications for Road and Bridges, Division 300.

1.03 RELATED WORK

1. Section 02200, Earthwork.

1.04 REFERENCES

A. KDH "Standard Specifications for Road and Bridge Construction," Division 300 and Section 805.

PART 2 - PRODUCTS

2.01 MATERIALS

A. In accordance with the KDH "Standard Specifications for Road and Bridge Construction," Section 805, Material Certifications.

PART 3 - EXECUTION

3.01 INSPECTION

A. Verify the grades and elevations are correct.

B. Verify the subgrade is not soft, spongy, or composed of otherwise unstable materials. If unstable materials are encountered, stop work and notify the Project Manager or designee.

3.02 INSTALLATION

A. The method of construction and workmanship shall be in accordance with the KDH "Standard Specifications for Road and Bridge Construction," Division 300.

B. Prepare the subgrade according to Section 02200, Earthwork.

C. Place and compact aggregate in 4" loose lifts maximum. The compaction effort shall be a minimum four passes with mechanical compaction equipment accepted by the Project Manager or designee. Additional compaction effort may be required at the discretion of the Project Manager or designee.

3.03 FIELD QUALITY CONTROL

A. Compact each layer to an average dry density of not less than 100% of the theoretical density based upon 83% of the solid volume. No individual test shall be less than 97% of the theoretical density. The density determination will be based on the bulk specific gravity in accordance with KDH Specifications approved by the Contractor. Maximum density determination and in-place density tests shall be performed by the Subcontractor. Perform one test for each layer placed.

B. The surface of the (DGA) layer shall be ½ inch of the required elevation.

END OF SECTION

SECTION 02510

ASPHALT PAVING

PART 1 - GENERAL

1.01 DESCRIPTION

A. Construction of hot mixed, hot-laid asphalt pavement on prepared base or existing pavement course.

1.02 REFERENCES

A. Kentucky 2000 Transportation Cabinet/Department of Highways (KDH), Standard Specifications for Road and Bridge Construction.

1.03 SUBMITTALS

A. None Required.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Trucks shall have tight, clean, smooth metal beds, which have been coated to prevent the mixture from adhering to the beds. Cover trucks to protect mixture from weather.

B. Deliver mixture to site at the specified temperature.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Bituminous Concrete Base, Surface, and Binder: KDH Section 403 – Production and Placement of Asphalt Mixtures.

B. Prime and Tack Coat: KDH Section 406 – Asphalt Curing Seal and Asphalt Prime and Tack Coats.

C. Traffic Marking Paint: KDH Section 713 – Permanent Pavement Striping.

2.02 EQUIPMENT

A. Mixing Plant: KDH Section 401 – Asphalt Plant Requirements.

B. Pavers and Rollers: KDH Section 403 – Production and Placement of Asphalt Mixtures.

PART 3 - EXECUTION

3.01 PREPARATION

A. Verify that the subgrade is in accordance with Section 02505, Dense Graded Aggregate Base (DGA).

B. Erect adequate barricades, signs, flagmen, warning lights, and other devices to protect others from ongoing work, paving equipment, and stored materials.

3.02 INSTALLATION/APPLICATION/ERECTION

A. Prime Coat

1. Apply prime coat to Dense Grade Aggregate Base at a rate of 0.50 gal/yd^2.

2. Apply by means of a pressure distributor at a uniform, continuous spread to the whole width of the area to be primed.

3. Application temperature shall be between 60–120 °F for Primer L.

4. Correct any areas containing an excess or deficiency of material.

B. Tack Coat

1. Use tack coat on existing bituminous or where traffic or other conditions have injured bonded qualities of base course.

2. Apply means of pressure distributor at a rate not to exceed 0.05 gal/ yd^2.

3. Application temperature shall be within the ranges set below:

Asphalt	Temperature range (°F)
SS-1, SS-1h, CSS-1, CSS-1h	70 – 160 °F
RS-1, RS-2	70 – 140 °F
CRS-1	120 – 185 °F

4. Allow tacked surfaces to dry until it is in a proper condition to receive the next course.

5. Apply tack coat only so far in advance of the paving operations as is necessary to obtain the proper condition of tackiness.

6. Protect tack coat from damage until the next course is placed.

C. Bituminous Plant Mix Base (Hot Mix)

1. Install Bituminous Hot-Mix Base 3 inches thick after compaction on prepared base.

2. Subbase and surface shall be free of excess moisture and cleaned of loose particles.

3. Air temperature or surface temperature, whichever is less, shall be equal to or greater than 35

°F for compacted asphaltic concrete base and binder.

4. Compact base to an average of 90% of the maximum theoretical density.

3.03 PROTECTION

A. Protect existing surfaces of roads and seeded areas adjacent to the job site and repair damaged areas.

END OF SECTION

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SECTION 02936

SEEDING

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Seeding, mulching, fertilizing, and liming.

1.02 SUBMITTALS

A. None required.

1.03 QUALITY ASSURANCE

A. Provide seed mixture in containers showing percentage of seed mix, year of production, net weight, date of packaging, and location of packaging.

1.04 REFERENCES

A. Kentucky Transportation Cabinet/Department of Highways (KDH), Standard Specifications for Road and Bridge Construction, 2000 edition (or latest version).

1. Permanent Seeding and Protection: KDH Specification Section 212.03.03.
2. Seed: KDH Specification Section 827.04.
3. Fertilizer: KDH Specification Section 827.03.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver grass seed mixture in sealed containers. Seed in damaged packaging is not acceptable.

B. Deliver fertilizer in waterproof bags showing weight, chemical analysis, and name of manufacturer.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Seed Mixture in accordance with requirements of KDH Specification Section 212.03.03.

1. All seed shall meet the applicable minimum purity and actual germination specified in KDH Specification Section 827.04.
2. No seed shall contain more than 1.0- percent weed seed by weight. No seed shall contain more than 18 noxious weed seeds or bulblets per ounce.

3. Seed mixtures shall be special mixture as follows:

   a. Mixture No. 1: 65% Kentucky 31 Fescue
      10% Creeping Red Fescue
      10% Red Top
      5% White Dutch Clover
      10% Ryegrass, perennial

   b. Mixture No. 2. 50% Kentucky Bluegrass
      25% Creeping Red Fescue
      10% Red Top
      5% White Dutch Clover
      10% Ryegrass, perennial

   c. Mixture No. 3. 45% Korean Lespedeza
      41% Ryegrass, Annual
      14% Switch Grass

   d. Mixture No. 4. 42% Korean Lespedeza
      38.5% Ryegrass, annual
      6.5% Big Bluestem
      6.5% Little Bluestem
      6.5% Indian Grass

B. Topsoil

1. Topsoil: In accordance with Sect. 02200, Earthwork.

C. Accessories

1. Mulch: Shall conform to KDH Specification Section 827.05.

2. Fertilizer:

   a. Inside security fence: Standard commercial fertilizer conforming to requirements of KDH Specification, Subsection 827.03 with guarantee of analysis conforming to a 10-10-10 formula. Fertilizer shall be uniform in composition, free flowing, and suitable for application with approved equipment.

   b. Outside security fence: Perform soil test to determine the fertilizer proportions and rates of application.

3. Agricultural Limestone: Agricultural Limestone shall contain not less than 85% of calcium carbonate and magnesium carbonate combined and be crushed so that at least 85% will pass No. 10 mesh sieve and 50% through a 40 mesh sieve.

4. Water: Clean, fresh, and free of substances or matter that could inhibit vigorous growth of grass.

PART 3 - EXECUTION

3.01 PREPARATION

A. Verify that prepared soil base is ready to receive work of this section and that final dressing is within reasonably close conformity to lines, grades, and cross-sections.

3.02 INSTALLATION/APPLICATION/ERECTION

A. Fertilizing and Liming

1. (Inside Security Fence) Apply commercial Grade 10-10-10 fertilizer at a rate of not less than 20 lb/1000 ft^2 and agricultural limestone at a rate of not less than 75 lb/1000 ft^2.

2. (Outside Security Fence) Apply fertilizer of the type and grade determined by soil testing.

3. Apply after smooth raking of topsoil.

4. Do not apply fertilizer at same time or with same machine used to apply seed.

5. Uniformly incorporate into soil for a depth of approximately 1/2 in.

6. Lightly water to aid the dissipation of fertilizer.

B. Seeding and Mulching

1. (Inside Security Fence) Apply Mixture 1 or 2 seed at a rate of 3 lb pls/1000 ft^2 evenly in two, intersecting directions. Rake in lightly. Do not seed area in excess of that which can be mulched on same day.

2. (Outside the Security Fence) Apply Mixture 3 within ditch banks at a rate of 29 lbs pls/acre. Apply Mixture 4 to all other disturbed areas outside the security fence at a rate of 31 lbs pls/acre.

3. Do not sow immediately following rain, when ground is too dry, or during windy periods.

4. Roll seeded area with an approved roller.

5. Immediately following seeding and rolling, apply erosion control matting or mulch at a rate of 100 lb/1000 ft^2 as directed by the design drawings. Maintain clear of shrubs and trees.

6. Apply water with a fine spray immediately after each area has been mulched. Saturate to 2 in. of soil.

7. Mulch is not required on areas to receive erosion control matting.

C. Seed Protection

1. Cover seeded slopes where grade is 3:1 or greater or other areas at locations shown on plans with excelsior matting.

2. Place and secure excelsior matting on previously shaped and seeded channels, slopes, or other areas and locations shown on plans or as required by the Project Manager or designee.

D. Maintenance

1. Maintain newly graded and topsoiled and seeded areas until final acceptance. Restore areas showing settlement of wash to specified grades. Newly seeded areas shall be watered as necessary or reseeded at the Subcontractor's expense until an acceptable stand of grass has been achieved. An acceptable stand of grass is defined as follows:

   a. No bare spots larger than 3 ft^2.

   b. No more than 10% of total area with bare spots larger than 1 ft^2.

   c. No more than 15% of total area with bare spots larger than 6 $in.^2$.

END OF SECTION

SECTION 03000

CONCRETE

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Requirements for placing reinforced concrete with minimal inspection.

1.02 REFERENCES

A. AASHTO M 154 (latest version), Standard Specification for Air-Entraining Admixtures for Concrete.

B. AASHTO M 240 (latest version), Blended Hydraulic Cements.

C. AASHTO M 302 (latest version), Ground Granulated Blast Furnace Slag for Use in Concrete and Mortars.

D. ACI 226.1R (latest version), Ground Granulated Blast Furnace Slag as a Cementitious Constituent in Concrete.

E. ACI 226.3R (latest version), Use of Fly Ash in Concrete.

F.ACI 302.1R (latest version), Guide for Concrete Floor and Slab Construction.

G. ACI 304R (latest version), Guide for Measuring, Mixing, Transporting, and Placing Concrete.

H. ACI 305R (latest version), Standard Specification for Hot Weather Concreting.

I. ACI 306.1-90, Standard Specification for Cold Weather Concreting.

J. ACI 318-95/318R (latest version), Building Code Requirements for Structural Concrete.

K. ASTM A185-A-90, Standard Specification for Steel Welded Wire Fabric Plain for Concrete Reinforcement.

L. ASTM A615/A615MB-95, Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.

M. ASTM C31-91, Standard Practice for Making and Curing Concrete Test Specimens in the Field.

N. ASTM C33-94, Standard Specification for Concrete Aggregates.

O. ASTM C39A-93, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.

P. ASTM C94-94, Standard Specification for Ready-Mixed Concrete.

Q. ASTM C143A-90, Standard Test Method for Slump of Hydraulic Cement Concrete.

R. ASTM C150A-94, Standard Specification for Portland Cement.

S.ASTM C172-90, Standard Practice for Sampling Freshly Mixed Concrete.

T. ASTM C231B-91, Air Content of Freshly Mixed Concrete by the Pressure Method.

U. ASTM C260-95, Standard Specification for Air-Entraining Admixtures for Concrete.

V. ASTM C309-95, Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.

W. ASTM C311B-94, Standard Methods of Sampling and Testing Fly Ash and Natural Pozzolans for Use as a Mineral Admixture in Portland Cement Concrete.

X. ASTM C494-92, Standard Specification for Chemical Admixture for Concrete.

Y. ASTM C595-94, Standard Specification for Blended Hydraulic Cements.

Z. ASTM C618-95, Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Minimeral Admixture in Portland Cement.

AA. ASTM C989-93, Ground Granulated Blast Furnace Slag for Use in Concrete and Mortars.

BB. Kentucky 2000 (or latest version) Transportation Cabinet/Department of Highways Standard Specifications for Road and Bridge Construction

1.03 SUBMITTALS

A. Submit for acceptance: Concrete Mix Design (including air content, slump, cylinder break strengths) and reinforcement drawings.

B. Submit method for concrete repair for acceptance as required by Part 3.04 of this section.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Cement: Portland cement per ASTM C150, normal - Type I or II.

B. Aggregates: ASTM C33.

1. Fine Aggregates: Natural sand or sand prepared from stone.
2. Coarse Aggregates: Crushed, No. 57 washed limestone only.

C. Water: Clean and free from injurious amounts of oil, alkali, organic matter, or other deleterious material.

D. Air Entrainment (for all exterior exposed concrete): ASTM C260 or AASHTO M-154. Add air-entraining admixture to the mixer in the amount necessary to produce the specified air content.

E. Water-Reducing, Set-Controlling Admixtures: ASTM C494, Type A, water-reducing or Type D, water-reducing and retarding. Add water-reducing admixtures at the mixer separately from air-entraining admixtures in accordance with manufacturer's printed instructions.

F. Concrete Admixtures: Coal fly ash per ACI 226.3R, ASTM C311, and/or ASTM C618. GGBF slag per AASHTO M 302, ACI 226.1R, and/or ASTM C989.

G. Curing Compounds: ASTM C309.

2.02 REINFORCEMENT

A. Reinforcing Steel: ASTM A615, 60 kpsi yield strength; deformed billet steel bars; plain finish, free of detrimental rust and oils.

B. Tie Wire: Minimum 16 gage annealed type.

2.03 CONCRETE MIX

A. Use ready-mix concrete per ASTM C94 containing either coal fly ash per ACI 226.3R and/or GGBF slag per ACI 226.1R.

B. Mix and proportion to produce minimum 4000-psi concrete at 28 d with slump of 4 in. ± 1 in. and 5 1/2% ± 1 1/2% air entrainment, ASTM C94.

C. Use accelerating admixture in cold weather only when acceptable to Project Manager or designee. Use of admixtures shall not relax cold-weather placement requirements. Do not use calcium chloride.

D. Use set-retarding admixtures during hot-weather concrete placement.

2.04 SEALANT

A. Polyurethane sealant: FS TT-S-00230C, Type II, Class A, one component sealant such as Sonneborne NP1 Gun-Grade sealant or accepted alternate.

B. Primer: Recommended by sealant manufacturer to suit application.

C. Cleaner: Non-corrosive type recommended by sealant manufacturer; compatible with adjacent materials.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine the subgrade to verify that rough grading elevations are correct.

3.02 CONSTRUCTION

A. Subgrade Preparation

1. Fill soft spots and hollows with additional fill to meet required elevations.

2. Level and compact subgrade to receive concrete to the minimum required dry density compaction of 95% modified procter.

3. Maintain bench marks, monuments, and survey control references.

B. Forming

1. Forms: Use clean forms, free from warp, tight enough to prevent leakage of mortar, and substantial enough to maintain their shape and position without springing or settlement when concrete is placed or vibrated.

2. For exposed surfaces, provide a smooth, even finish without fins or board marks.

3. All exposed edges shall have a 3/4-in. chamfer.

4. Set forms for slabs on ground at exact finished grade. Check for line and grade and correct immediately before concreting. Provide uniform bearing.

C. Reinforcement

1. Reinforcement shall be accurately installed to the dimensions given on the drawings and shop drawings. It shall be securely tied to prevent displacement during concrete placement.

D. Placing Concrete

1. In accordance with ACI 304. Rotate drum a minimum of ten revolutions at mixing speed immediately prior to discharge.

2. Place concrete on a moist compacted subgrade or base, free from loose material. Do not place concrete on a muddy or frozen subgrade.

3. Spade concrete thoroughly along forms and expansion joints, and work carefully into corners and around reinforcement. Tamp and screed to a dense mass. Consolidate concrete by means of a mechanical vibrator.

4. Time in Transit: Maximum 90 minutes between loading concrete on truck and placing in final position.

5. Retempering: Do not add water after the concrete has been placed on truck unless authorized by Project Manager or designee.

6. Weather Conditions: Do not mix or place concrete when the air temperature is below freezing. If temperature may be expected to fall below 40°F within 24 hours after concrete is placed, heat water and aggregate to bring the temperature of concrete mix to at least 55°F. In addition to ACI 302, comply with the following:

   a. Cold Weather: ACI 306.

   b. Hot Weather: ACI 305.

7. Protection: Do not remove forms for 24 hours after placing concrete. Protect concrete from traffic for a period of 7 days after placing.

E. Finishing Concrete

1. General: Strike-off, consolidate, and finish concrete with mechanical equipment. No finishing operations shall be performed in the presence of bleed water.

2. Hand Finishing: Permitted in narrow widths, areas of irregular dimensions and in event of breakdown of the mechanical equipment to finish the concrete already deposited on grade.

3. Final Surface Finish: Broomed or burlap drag finish providing a uniform, skid-resistant texture for exterior slabs.

F. Curing Concrete

1. Option 1: After finishing operations have been completed, coat and seal surface of slab with a uniform layer of membrane curing compound as recommended by the manufacturer.

   a. Respray curing compound on areas where the curing membrane is damaged within 3 days.

   b. The curing compound shall not react with the concrete or alter its natural color. Keep workmen, equipment, and materials off the membrane for 3 days after applying.

2. Option 2: Continuous curing under wet burlap. Apply wet burlap after finishing operations are complete and as soon as marring of concrete surface will not occur. Maintain moisture continuously for a period of 7 days when ambient temperatures are above 40°F. Use burlap free of substances that may harm concrete or cause discoloration.

3. Cold Weather Protection: Whenever the air temperature may be expected to reach the freezing point, spread straw or other blanketing material to sufficient depth to keep concrete from freezing or provide enclosure and heating device capable of maintaining concrete temperature to at least 50°F. Maintain such protection for at least 5 days.

4. Remove and replace any concrete injured by frost action.

5. Saw cut control joints within 24 hours of placement.

G. Concrete Headwalls

1. Construct all precast head walls in accordance with Section 710 of the KDH Standard Specifications and Standard Drawings.

2. Construct all cast-in-place head wall in accordance with Section 609 of the KDH Standard Specifications and Standard Drawings.

3.03 INSPECTION

A. If the concrete being placed is suspect, the Project Manager or designee may employ an independent testing laboratory to test the concrete during placement.

3.04 CONCRETE REPAIRS

A. Bring concrete areas determined inadequate, honeycombed, defective, porous, contaminated, or deteriorated to the attention of the Project Manager or designee.

B. Match color and texture of repairs on exposed surfaces.

3.05 PROTECTION

A. Protect the finished concrete during the remainder of the job. Do not use the structure for miscellaneous workstations or loading areas without approval from the Project Manager or designee.

END OF SECTION

SECTION 13121

METAL BUILDING SYSTEM

PART 1 - GENERAL

1.01 SECTION INCLUDES:

Requirements necessary for the design, fabrication, and furnishing of metal building structures. Includes framing, flashing, insulation, roofing, siding, painting, anchor bolt design, and drawings as required for a complete building.

1.02 REFERENCES

The latest revision of the following references shall be used:

A. AISC Code of Standard Practice for Steel Buildings and Bridges.

B. AISC Allowable Stress Design Specification for Structural Joints Using ASTM A325 or ASTM A490 Bolts.

C. AISC Specification for Structural Steel Buildings, Allowable Stress Design and Plastic Design with Commentary.

D. AISI Publication SG-673, Part I: Specification for the Design of Cold-Formed Steel Structural Members, August 19, 1986, and Addendum: Cold-Formed Steel Design Manual, December 11, 1989.

E. Aluminum Association Publication 30-86, Specification for Aluminum Structures.

F. ASCE 7: Minimum Design Loads for Buildings and Other Structures.

G. ASTM A36/A36M, Standard Specification for Carbon Structural Steel.

H. ASTM A307, Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.

I. ASTM A325, Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength.

J. ASTM A446, Standard Specification for Steel Sheet, Zinc Coated (Galvanized) by the Hot-Dip Process, Structural (Physical) Quality.

K. ASTM A563, Standard Specification for Carbon and Alloy Steel Nuts.

L. ASTM A572, Standard Specification for High Strength, Low Alloy Columbium - Vanadium Structural Steel.

M. ASTM A607, Standard Specification for Steel, Sheet and Strip, High Strength, Low Alloy, Columbium or Vanadium, or Both, Hot Rolled and Cold Rolled.

N. ASTM A611, Standard Specification for Steel Sheet, Carbon, Cold-Rolled, Structural Quality.

O. ASTM A653/A653M, Standard Specification for Steel Sheet, Zinc Coated (Galvanized) or Zinc - Iron Alloy - Coated (Galvannealed) by the Hot-Dip Process.

P. ASTM A792/A792M, Standard Specification for Steel Sheet, 55% Aluminum - Zinc Alloy - Coated by the Hop-Dip Process.

Q. ASTM C236, Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box.

R. ASTM F436, Standard Specification for Hardened Steel Washers.

S. AWS Publications:

1. AWS D1.1, Structural Welding Code-Steel.
2. AWS D1.3, Structural Welding Code-Sheet Steel.

T. FS HH-I-558C, Insulation, Blocks, Boards, Blankets, Felts, Sleeving (Pipe and Tube Covering), and Pipe Fitting Covering Thermal (Mineral Fiber Industrial Type), January 7, 1992.

U. FS TT-S-00230C, Sealant, February 2, 1970, and Amendment 2, October 9, 1970.

V. International Conference of Building Officials, UBC.

W. MBMA Publication: Low Rise Building Systems Manual.

X. 40 CFR 247: Comprehensive Procurement Guideline For Products Containing Recovered Materials.

Y. SMACNA: Architectural Sheet Metal Manual.

Z. UL Building Materials Directory.

AA. 2002 Kentucky Building Code.

1.03 SUBMITTALS

A. Submit detailed shop drawings for approval showing the arrangement of all parts and details for shop fabrication. Prepare shop drawings under direct supervision of a professional engineer licensed in the state of Kentucky with all drawings, bearing engineer's seal and signature. Show the following as a minimum.

1. Framing layout, diagonal bracing, door subframes, member sizes, connections and fastener or bolt sizes, type, material composition, and spacing.
2. Erection drawings for the structure framing.
3. Drawings for anchor bolt details, locations, and column base reactions.

4. Location and length of siding, roofing, and liner panels including splice details for roofing.

5. Shop drawings of panel erection, fasteners, trim, and flashings.

6. Wall air intake/exhaust framings and flashing.

7. Fascia details.

8. Canopy framing and details.

9. Details of roof curbs, roof jacks, and items penetrating roof.

10. Materials, finishes, and construction/installation details.

11. Other pertinent information required for fabrication, assembly, and erection of watertight metal building system.

B. Submit design calculations for approval showing assumptions, loads and pressures, load combinations and applications, stress analysis and values, identification of allowable stresses and basis of determination, frame and component deflections, and column base reactions. Prepare by, or under direct supervision of, a professional engineer registered in the state of Kentucky with calculations bearing engineer's seal and signature.

C. Submit for approval standard specifications and installation instructions clearly marked to identify only applicable sections that pertain to these buildings.

D. Submit product data for approval showing color of metal siding panels proposed for use.

E. Submit letter of certification for approval, attesting to the following:

1. The building is the design of a manufacturer engaged in the fabrication of Metal Building Systems conforming to the recommendations of the Metal Building Manufacturers Association (MBMA) Manual,

2. The manufacturer has at least 15-years' experience in manufacture of Metal Building Systems,

3. The manufacturer is a member of Metal Building Manufacturing Association (MBMA), and

4. The manufacturer is an AISC Quality Certified Fabricator of Metal Building Systems.

F. Submit complete roof panel product data for information covering the materials, load/span/deflection charts, paint and/or coating types with weathering test results, recommended seam sealing techniques and required equipment, recommended structural fasteners, and installation instructions.

G. Submit proposed repair methods for approval if required.

H. Submit Certified Material Test Reports (CMTRs) of each size of high strength bolt that will be furnished for the erection of the metal building.

I. Submit wall and roof insulation product data for information covering material specifications, conformance to standards, certification of recovered material content, and installation instructions.

1.04 DESIGN REQUIREMENTS

A. All required loads (wind, seismic, snow, live, dead, etc.) shall be determined in accordance with the requirements of the 2002 Kentucky Building Code and applicable supplements.

B. Load Combinations: In accordance with the requirements of the 2002 Kentucky Building Code.

C. Provide anchor bolt design and layout for the building foundation. Size anchor bolts to resist shear, bearing, and uplift based on ASTM A307 material.

D. Size bracing connections to transfer 1.25 times the member force without using the one-third stress increase.

E. Provide sufficient bracing to transfer wind and seismic forces to the footings. Bracing shall utilize steel rods placed diagonally in the roof and walls. Cable bracing shall be prohibited.

F. Design and construct the building column bases for shear transfer only.

G. Design roofing and wall systems for a deflection not exceeding 1/180 of the span between supports. Roofing Systems: (UL) Class 90 requirements for uplift.

1.05 QUALITY ASSURANCE

A. Building Design: By a manufacturer engaged in the fabrication of Metal Building Systems conforming to the recommendations of the MBMA Manual, not less than 15 years' experience in manufacture of Metal Building Systems, and a member of MBMA.

B. Fabricators: Certified in Metal Building Systems through the AISC Quality Certification Program.

C. Builders and Erectors: Not less than 5-years' experience in erecting buildings similar to those required for this project and members of the Systems Builders Association (SBA).

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver material to the site in an undamaged condition. Return material bent or damaged during delivery to the manufacturer for repair or replacement.

B. Deliver roof panels in protective containers with panel separating material to protect the finish.

C. Store materials at the job site on blockage aboveground.

D. Do not deliver insulation and metal siding and roofing panels to the work site until immediately prior to installation.

E. Deliver and store insulation in water-resistant plastic containers. Do not wet insulation.

F. Handle insulation in a manner to prevent damaging the vapor barrier or the insulation. Do not install damaged insulation.

G. Protect stored metal siding and roofing panels from precipitation and dust. Store panels on blocking aboveground, uniformly supported to prevent permanent deformation, and on edge in their shipping containers. Handle panels during installation using softeners and protect panels to prevent deformation or damage to interlocking edges or finish.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Structural Steel Rolled Shapes, Plates, and Bars: ASTM A36.

B. Machine Bolts: ASTM A307.

C. High Strength Bolts, Nuts, and Washers: ASTM A325.

D. Structural Steel Built-Up Members: ASTM A572, minimum yield strength 50 ksi.

E. Cold-Formed Structural Steel: ASTM A607, Grade 55.

2.02 COMPONENTS

A. Wall, Canopy, and Facia Panels: ASTM A446, Grade A (33,000 psi yield) galvanized steel, continuous roll-formed sections.

1. Panels: Architectural-faced panels of not less than 24 gage, galvanized to ASTM A653, G-90, 1.25-oz./ft^2 zinc-coated (galvanized) steel.

2. Panel Finish: 1 mil min dry thickness, factory applied, baked fluoropolymer resin enamel finish on the exposed side.

3. Panel Description: Supplied in maximum lengths to minimize end laps, complete with all required trim, flashings, panel closures, and other components required for an airtight and moisture-tight wall system.

4. Form Exterior Wall Panels: 36-in.-wide with minimum 1 3/8-in.-high ribs at 12 in. on center with two intermediate, longitudinal stiffening grooves, and overlapping caulked side flanges designed for exposed fastening.

5. Form Interior Wall (Liner) Panels: 12-in.-wide X 1 3/8-in.-deep (min) flat panels; two intermediate, longitudinal stiffening grooves; and interlocking side flanges designed for concealed fastening.

6. Interior Liner Panels: Minimum 26-gage wall panels, full wall height around building perimeter.

B. Roof Panels: ASTM A792 (50,000 psi yield) galvanized-aluminized steel, continuous roll-formed sections.

1. Roofing: Architectural-faced panels of not less than 24 gage, coated with 0.5-oz./ft^2 aluminum-zinc alloy-coating, designation AZ 55. Approximately 24-in.-wide flat, with or without intermediate longitudinal stiffening grooves. Use interlocking standing seam side joints and a minimum finished height of 2 1/2 in.

2. Provide in maximum possible length to minimize number of end joints. Complete with start and finish panels, ridge covers, and gable and eave trim.

3. Mount the panels with clips bolted to the structural steel for a concealed floating anchorage, permitting expansion along the full length of the panel.

4. Furnish roof panels with mounting anchors, matching closure flashings, fillers, and sealants required for an airtight and moisture-tight roof system.

5. The Roof Panel Side Joint: Provide a factory-installed sealant gasket in interlocking standing seams to ensure an airtight and watertight joint.

C. Panel Design: Determine wall siding and roof section properties in accordance with the AISI Cold-Formed Steel Design Manual.

D. Fasteners: Secure the sheet-metal wall panels with stainless steel self-drilling, self-tapping screws with plated steel washers and neoprene weather seals. Size and space fasteners to sustain the design loads and allow for expansion. Fasteners and washers to be color coated to match the siding.

E. Gutters, downspouts, and flashing: Use same type materials, finish, and color as the siding and roofing (min 26 gage). Install gutters and downspouts that comply with SMACNA Architectural Sheet Metal Manual for a storm of 5-min duration that is exceeded only once in 10 years. Discharge downspouts on grade to concrete slash blocks.

F. Factory Installed Side Joint Caulking Sealant: Butyl rubber or polysulfide base compound complying with FS TT-S-00230. Design and install to remain flexible while sealing the surface materials under exterior exposure.

G. Wall and Roof Insulation: FS HH-I-558B, Type I, Class A flame spread $\leq$25 and smoke $\leq$50, vinyl-foil-scrim faced fiberglass insulation R-11 for walls and R-19 for roof, maximum water vapor transmission value of 0.2 perm, white facing with a light reflectance of 72%, 60 in. wide, as needed.

1. Fiberglass shall contain, as a minimum, the percentage of recovered materials required in 40 CFR 247.

2. Use seam tape, nonstaining adhesives, staples, wall and roof trim strips, and accessories recommended by the insulation manufacturer.

3. Do not use foamed plastic materials.

4. Install insulation over the purlins and girts prior to installation of the panels with the vapor barrier turned toward the inside of building. Use insulation with 2-in. folded, stapled, and tucked tabs.

H. Provide a stock entrance canopy over all 3-ft X 7-ft exterior doors. Canopy: Overhang of 4 ft 4 in. and a width of 6 ft 0 in. Construction and finish to match building.

I. Mount roof exhaust fans on a factory-supplied roof curb. Match the curb flashing tie-ins of the standing seam roof to the standing seam roof panel profile. Show all curbs and flashing on shop drawings, provided or approved by the roof-panel manufacturer. Mount wall louvers on a factory-supplied subframe.

2.03 FABRICATION

A. Building: Includes all structural framing, metal roofing, siding, gutters and downspouts, flashing, trim and closures, filler strips, door subframes, overhead door framing, hardware, fasteners, shop and factory painting, insulation as needed, and all other component parts of the building. Design and shop fabricate the building steel to permit bolted assembly of parts.

B. Conform to the dimensions and roof slopes shown on the accompanying drawings.

C. All structural steel shop connections shall be welded and inspected in accordance with AWS D1.1 and D1.3 using certified welders and welding procedures.

D. All Members: Free of twists or bends and true to length so that assembly may be done without use of fillers.

E. Building Columns: 1-in. grout allowance for leveling.

F. Design and fabricate the building to allow for the wind and seismic bracing to be placed diagonally in the roof and walls. Install flange brace angles as required. Do not use steel cables for primary bracing.

G. Make all primary (rigid frames of shop-welded steel plate columns and rafters) field-bolted connections with high-strength bolts. Use machine bolts for secondary (purlins, girts, struts, flange braces, base angles, base trim angles, and door frames) bolted connections. Tighten all bolted connections by the AISC turn-of-the-nut method.

H. Fabricate framed openings for overhead doors using structural channel material of sufficient size to carry all design loads including dead weight and wind.

2.04 FINISHES

A. The color of all building components receiving factory-applied finish shall be selected from the building manufacturer's standard color chart. Prime and paint steel surfaces not receiving factory-applied finish, such as structural framing, frames, etc.

2.05 SOURCE QUALITY CONTROL

A. The Project Manager or designee may conduct inspections at the Subcontractor's facility where fabrication of the steel building frame and all associated components to be erected will be done. The inspection will confirm that the parts being fabricated, tested, and inspected are in accordance with contractual requirements and this specification. Inspection may include either witnessing the operation or reviewing the results/data, or both. Inspections may be conducted at Contractor's discretion. Specific activities under the surveillance program are as follows:

1. Verify the material used for fabricating the steel framing, siding, and roofing panels of the metal building.

2. Verify certification of the nuts and bolts.

3. Verify dimensional inspection.

4. Verify hole placement for bolt connections.

5. Verify joint welding procedures meet AWS D1.1 and D1.3 requirements.

6. Verify and observe welding procedure specification requirements.

7. Verify AWS welder qualifications.

8. Verify and observe the inspection of welding, weld sizing, and inspection for any unacceptable weld conditions before accepting fabricated section.

9. Verify that the painting has been completed on all sections, prior to stacking of material.

10. Review vendor manufacturing data of welding inspection completed by subcontractors to the Contractor.

11. Verify all data has been reviewed prior to shipment.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Prior to erection, examine foundations and anchors to ascertain that the work is done.

B. During roof installation, examine the fastener and standing seam closures for completeness and defects occurring that would effect the weathertightness or wind-resistance capability of the completed enclosure.

C. Prior to the start of the metal panel erection, examine the installed insulation and structural steel for the accuracy of erection, the proper installation of the girts and/or purlins, and readiness for the structure to receive the metal panels. Report any defects that would effect the installation and propose repair methods.

D. Examine the area which is to receive the roofing, noting the completeness of the structural steel and fasteners, and the condition of the roof insulation. Correct defects in the structural steel and the insulation prior to starting the roofing installation.

E. Examine concealed fasteners for the correct type, number, and proper engagement with the structural support and the siding.

F. Prior to insulation installation, examine the structural steel to ascertain the work is properly and completely done in the area to be insulated.

G. Examine the completed siding panel installation. Clean and repair soiled or abraded areas. Seal gaps or loose edges of trim and flashings by caulking and adding screws to bring the parts into alignment. Remove protective removable film, if provided on the panels.

H. Prior to the final acceptance, examine the insulation installation, cleaning any soiled vapor barrier, and repairing any punctures or torn areas with matching vapor barrier materials. Examine seams for gaps or incomplete closures and seal with matching tape or adhesive.

I. Examine the finished roofing installation. Repair any defects and refinish any abraded or scratched areas in the roof panel finish to match the finish. Clean the panels of all dust, dirt, or debris. Replace warped, bent, or unrepairable panels.

3.02 PREPARATION

A. Coordinate the insulation installation with the roof deck and wall panel installation to ensure the insulation is covered and protected from precipitation immediately after installation.

B. Do not start installation until all materials required for the roof deck and wall panel installation are at the job site.

C. Limit the amount of unbundled siding and roofing panels to the amount for immediate installation.

3.03 ERECTION/INSTALLATION

A. Erect a weathertight, steel building. Follow manufacturer's instructions and comply with details and requirements shown on approved shop drawings.

B. Erect structural frames true to line, level and plumb, rigid and secure. Level base plates to true even plane with full bearing to supporting structure. Install diagonal bracing, purlins, girts, struts, and other secondary framing.

C. Provide shapes of proper design and size to reinforce openings and to carry loads and vibrations imposed, including equipment furnished under mechanical or electrical work.

D. Do not install insulation during periods of inclement weather.

E. Apply roof insulation in succeeding widths from eave to eave allowing an overhang of 6 to 8 in. Extend the vapor barrier beyond the insulation to form a continuous edge tab for folding, stapling, taping, and sealing with adhesive.

F. Field erect wall panels in accordance with approved shop drawings and the manufacturer's instructions. Place and erect the panels plumb, true, and level.

G. Install adequate temporary guys and bracing as construction proceeds to resist wind and seismic forces as specified in Articles 1.05A and 1.05B. Guys and bracing shall be in accordance with the MBMA Manual.

H. Inspect fasteners that will be concealed for the correct type, numbers, and proper engagement with structural support.

I. Install flashings, closures, and trim as shown on the shop and design drawings. Caulk and seal joints weathertight. Closely follow siding installation with the flashings, trim, and closure installation to protect the insulation from precipitation.

J. Fasteners for Exterior and Liner Wall Panels to the Structural Steel: Minimum No. 10 screws at 12 in. on center.

K. Eave and Rake Flashings at Start and Finish Wall Panels and Ridge Panels: No. 14 minimum screws with neoprene washers at 12 in. on centers.

L. Corner Flashings: Fasten with No. 14 minimum screws with neoprene washers at 8 in. on center max.

M. Coordinate insulation installation with wall and roof panel installation.

N. Apply wall insulation in succeeding widths and in full height lengths of the wall from top to bottom. Extend the vapor barrier beyond the insulation to form a continuous edge tab for folding, stapling, taping, and sealing with adhesive.

O. Install insulation only when remaining construction operations will not damage the installed insulation.

P. Place insulation widths smooth over purlins and girts to remove wrinkles and creases in the vapor barrier. Make joints between widths stapled, taped, and/or applied with adhesive as specified by the approved insulation manufacturer's instructions. Provide a continuous thermal and vapor barrier over the entire roof and wall area. Install insulation on the cold or weather side of electrical outlets, ducts, pipes, or other utility items.

Q. Perform roofing installation using a qualified, experienced erector approved by the roof panel manufacturer. Use seam closure equipment approved by the roof panel manufacturer.

R. Install concealed standoff clips using a minimum of two, No. 12 min, screws through the thermal break spacer block into the structural roof purlins.

S. Install roofing panels over concealed standoff clips.

T. Install roofing panels with accessories and sealants as recommended by the manufacturer to ensure a rigid-water and airtight enclosure.

U. Install roofing panel flashings and trim.

3.04 PROTECTION

A. At the completion of each work period, secure loose unfastened panels and flashings to prevent being wind borne from the stored location.

B. Protect the installed insulation from construction damage and exposure to precipitation.

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SECTION 13405

PROCESS CONTROL AND INSTRUMENTATION

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

A. AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1	(2001) Electric Meters Code for Electricity Metering
ANSI INCITS 154	(1988; R 1999) Office Machines and Supplies - Alphanumeric Machines-Keyboard Arrangement
ANSI X3.64	(1979; R 1990) Additional Controls For Use With the American National Standard Code for Information Interchange

B. AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE Fundamentals Handbook	(2005) Fundamentals Handbook

C. AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C606	(2004) Grooved and Shouldered Joints

D. ASME INTERNATIONAL (ASME)

ASME B31.8	(2003) Gas Transmission and Distribution Piping Systems
ASME BPVC SEC VIII D1	(2004) Boiler and Pressure Vessel Code; Section VIII, Pressure Vessels Division 1 - Basic Coverage
ASME FED	(1971; Sixth Edition) Fluid Meters Their Theory and Application

E. ASTM INTERNATIONAL (ASTM)

ASTM A 536	(1984; R 2004) Ductile Iron Castings
ASTM B 88	(2003) Seamless Copper Water Tube
ASTM B 88M	(2003) Seamless Copper Water Tube (Metric)
ASTM D 1238	(2004b) Melt Flow Rates of Thermoplastics by Extrusion Plastometer

ASTM D 1693	(2005) Environmental Stress-Cracking of Ethylene Plastics
ASTM D 2000	(2005) Rubber Products in Automotive Applications
ASTM D 635	(2003) Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
ASTM D 638	(2003) Tensile Properties of Plastics
ASTM D 792	(2000) Density and Specific Gravity (Relative Density) of Plastics by Displacement

F. ELECTRONIC INDUSTRIES ALLIANCE (EIA)

EIA ANSI/EIA/TIA-232-F	(2002) Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange

G. INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C37.90	(1994) Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.90.1	(2002) Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C62.41	(1991; R 1995) Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits
IEEE Std 100	(2000) The Authoritave Dictionary of IEEE Standards Terms
IEEE Std 142	(1992) Recommended Practice for Grounding of Industrial and Commercial Power Systems - Green Book
IEEE Std 802.3	(2002) Information Technology - Telecommunications and Information Exchange Between Systems LAN/MAN - Specific Requirements - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications

H. INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 61131-3	(2003) Programmable Controllers - Part 3: Programming Languages

I. INTERNATIONAL TELECOMMUNICATION UNION (ITU)

ITU V.34	(1998) Data Communication Over the Telephone Network: A Modem Operating at Data Signaling Rates of up to 33,600 bits for use on the General Switched Telephone Network and on Leased Point-to-Point Two-Wire Telephone Type Circuits
ITU V.42 bis	(1990) Data Communication over the Telephone Network: Data Compression Procedures for Data Circuit Terminating Equipment (DCE) Using Error Correction Procedures

J. ISA - THE INSTRUMENTATION, SYSTEMS AND AUTOMATION SOCIETY (ISA)

ISA MC96.1	(1982) Temperature Measurement Thermocouples
ISA S7.0.01	(1996) Quality Standard for Instrument Air

K. NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2003) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ICS 1	(2000; R 2005) Industrial Control and Systems: General Requirements
NEMA ICS 2	(1996; R 2004) Standard for Industrial Control and Systems: Controllers, Contractors, and Overload Relays Rated Not More than 2000 Volts AC or 750 Volts DC: Part 8 - Disconnect Devices for Use in Industrial Control Equipment
NEMA ICS 3	(2005) Industrial Control and Systems: Medium Voltage Controllers Rated 2001 to 7200 Volts AC
NEMA ICS 4	(2000) Industrial Control and Systems: Terminal Blocks

L. NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2005) National Electrical Code

M. NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST SP 250	(1998) Calibration Services Users Guide

N. U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

40 CFR 60	Standards of Performance for New Stationary Sources
47 CFR 15	Radio Frequency Devices
47 CFR 68	Connection of Terminal Equipment to the Telephone Network

O. UNDERWRITERS LABORATORIES (UL)

UL 1059	(2001; Rev thru Mar 2004) Terminal Blocks
UL 508	(1999; Rev thru Dec 2003) Industrial Control Equipment
UL 94	(1996; Rev thru Dec 2003) Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

1.2 CONTROL SYSTEM DESCRIPTION

The process instrumentation and control system shall be used to monitor and control the operation of process equipment as specified and in accordance with the sequence of control and control schematics shown on the drawings. The control system shall provide for operator interaction, overall control system supervision, and process equipment control and monitoring. The Subcontractor shall provide hardware configured and sized to support expansion as specified and shown on the drawings.

1.2.2 Control System Operation

The control system provided under this specification shall operate using direct digital control (DDC) algorithms or ladder logic type and supervisory control to provide the required sequences of operation. Input data to the controller shall be obtained by using instruments and controls interfaced to mechanical, electrical, utility systems and other systems as shown and specified. All required setpoints, settings, alarm limits, and sequences of operation shall be as identified in the piping and instrumentation drawings, electrical schematics, interlock tables and the process control description. The number and location of control panels shown on drawings shall be provided as a minimum.

1.2.3 Control System Points

Inputs to and outputs from the control system shall be in accordance with the Input/Output (I/O) Summary Table shown on the drawings. Each connected analog output (AO), analog input (AI), digital output (DO), digital input (DI), pulse accumulator (PA) input and other input or output device connected to the control system shall represent a "point" where referred to in this specification.

1.2.4 Symbols, Definitions, and Abbreviations

Symbols, definitions, and engineering unit abbreviations shall conform to IEEE Std 100, as applicable.

1.3 ENVIRONMENTAL CONDITIONS

Capacity and design of the air moving equipment and accessories shall be suitable for 24-hour full load service and shall meet the following criteria.

A. Location: Paducah, Kentucky (Seismic design to KY Zone E)

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. The following shall be submitted:

- Shop Drawings
- Installation
- Wiring

Detail drawings containing complete piping, wiring, schematic, flow diagrams and any other details required to demonstrate that the system has been coordinated and will properly function as a unit. Piping and Instrumentation (P&ID) drawings will be prepared using industry recognized device symbols, clearly defined and describing piping designations to define the service and materials of individual pipe segments and instrument tags employing Instrument Society of America suggested identifiers. Drawings shall include, as appropriate: product specific catalog cuts; a drawing index; a list of symbols; a series of drawings for each control system using abbreviations, symbols, nomenclature and identifiers as shown; valve schedules; compressed instrument air station schematics, and ASME air storage tank certificates for each type and make of compressed instrument air station.

Product Data

Compressed Air Stations

Instrumentation compressed-air station schematic diagram showing equipment utilized, including compressor with motor output and voltage; starter; isolators; manual bypasses; tubing sizes; drain piping and drain traps; reducing valves; air-dryer; and data on manufacturer's names and model numbers, mounting, access, and clearance requirements. Air-compressor and air-dryer data shall include calculations of the air consumption of current-to-pneumatic transducers (IPs), pneumatic control valves and of other control system devices to be connected to the compressed-air station; the number of starts per hour, the running time for the unit selected; and the compressed air-supply dewpoint temperature at 80 psig.

Instrumentation and Control System

Manufacturer's descriptive and technical literature, performance charts and installation instructions. Product specific catalog cuts shall be in booklet form, indexed to the unique identifiers, and shall consist of data sheets that document compliance with the specification. Where multiple components are shown on a catalog cut, the application specific component shall be marked.

Sensors and Meters

Manufacturer's descriptive and technical literature, catalog cuts, performance charts and installation instructions.

Training Manual

Instruction manual within 60 days of Notice to Proceed.

Performance Verification Test (PVT)

The performance verification test procedure; it shall refer to the actions and expected results to demonstrate that the control system performs in accordance with the sequence of control. A list of the equipment to be used during the testing shall be included. The list shall also include manufacturer's name, model number, equipment function, the date of the latest calibration and the results of the latest calibration.

Factory Test Procedure

Documentation containing factory test methods and procedures.

Test Reports

- Factory Test Report
- Testing, Adjusting and Commissioning
- Performance Verification Test (PVT)
- Endurance Test

Test results in report format.

- Insertion Turbine Flowmeter
- Calibration test data.
- Certificates
- Control and Sensor Wiring
- Certified test results for surge protection.
- Ground Rods
- Certification stating that the test was performed in accordance with IEEE Std 142.
- Operation and Maintenance Data
- Instrumentation and Control System

Operating instructions outlining the step-by-step procedures required for system startup, operation and shutdown. The instructions shall include layout, wiring and control diagrams of the system as installed. The instructions shall include the manufacturer's name, model number, service manual, parts list and a brief description of all equipment and their basic operating features.

Maintenance instructions listing routine maintenance procedures, possible breakdowns and repairs and trouble shooting guides.

1.5 EQUIPMENT REQUIREMENTS

1.5.1 Materials and Equipment

Materials and equipment shall be standard unmodified products of a manufacturer regularly engaged in the manufacturing of such products. Units of the same type of equipment shall be products of a single manufacturer. Items of the same type and purpose shall be identical and supplied by the same manufacturer, unless replaced by a new version approved by the Project Manager or designee.

1.5.2 Nameplates

Each major component of equipment shall have the manufacturer's name and address, and the model and serial number in a conspicuous place. Laminated plastic nameplates shall be provided for equipment devices and panels furnished. Each nameplate shall identify the device, such as pump "P-1" or valve "VLV-402". Labels shall be coordinated with the schedules and the process and instrumentation drawings. Laminated plastic shall be 1/8 inch thick, white with black center core. Nameplates shall be a minimum of 1 by 3 inches with minimum 1/4 inch high engraved block lettering. Nameplates for devices smaller than 1 by 3 inches shall be attached by a nonferrous metal chain. All other nameplates shall be attached to the device.

PART 2 PRODUCTS

2.1 GENERAL REQUIREMENTS

Equipment located outdoors, not provided with climate controlled enclosure, shall be capable of operating in the ambient temperature range indicated in paragraph ENVIRONMENTAL CONDITIONS, unless otherwise specified. Electrical equipment will conform to Specification. Equipment and wiring must be in accordance with NFPA 70, with proper consideration given to environmental conditions such as moisture, dirt, corrosive agents, and hazardous area classification.

2.2 MONITORING AND CONTROL PARAMETERS

The control system shall be complete including sensors, field preamplifiers, signal conditioners, offset and span adjustments, amplifiers, transducers, transmitters, control devices, engineering units conversions and algorithms for the applications; and shall maintain the specified end-to-end process control loop accuracy from sensor to display and final control element. Control equipment shall be powered by a 120 vAC, single phase, 60 Hz power source, with local transformers included as needed for signal transmission and subsystem operation. Connecting conductors shall be suitable for installed service. Enclosures shall be rated for NEMA ICS 4.

2.2.1 Transmitter

Unless indicated otherwise, each sensor shall be provided with a transmitter, selected to match the sensor. Except where specifically indicated otherwise on the drawings, the transmitter shall be provided with a four digit or analog visual display of the measured parameter and shall provide a 4 to 20 mA DC output signal proportional to the level of the measured parameter. Accuracy shall be plus or minus 5 percent of full scale reading with output error not exceeding plus or minus 0.5 percent of the calibrated measurement. Transmitter shall be located where indicated, mounted integrally with the sensor, pipe mounted, wall mounted or installed in the control panel. The distance between the sensor and transmitter shall not exceed the manufacturer's recommendation. Field preamplifiers and signal conditioners shall be included when necessary to maintain the accuracy from sensor to the programmable logic controller or recorder.

2.2.2 Off-Gas or Vapor Service

Sensors and meters in vapor service shall be rated for continuous duty service and meet the following additional requirements:

Type – Photoacoustic field gas monitor (as specified below or equivalent):

a. Innova Photoacoustic Field Gas Monitor, Model 1412 including optical filters for trichloroethene, vinyl chloride, *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, and 1,1-dichlorethene .
b. Calibration Kit, standard span gas calibration and special span gas calibration with *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, and 1,1-dichlorethene.

Operation:

a. To measure a continuous sample of the off-gas for detection of VOCs (trichloroethene, vinyl chloride, *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, 1,1-dichlorethene with local gas concentration read out and indication on the local control panel recorder.

Process:

a. Fluid – Off-Gas VOC

Physical:

a. Housing, 6.9"H x 15.6"W x 11.8"D
b. Power – 120 vAC 60 Hz

Performance:

a. Linear dynamic range of 5 orders of magnitude
b. Accuracy – typically +/- detection limit
c. Detection limit (minimum):
   - trichloroethene – 4 ppm
   - vinyl chloride – 2 ppm
   - *cis*-1,2-dichloroethene – 2 ppm
   - *trans*-1,2-dichloroethene – 2 ppm
   - 1,1-dichlorethene – 2 ppm
d. Failsafe self diagnostic – coded to display
e. Output – local display of gas mg/m3, g/m3, u/m3 ppm, vol%, or ppb

2.2.3 Liquid Service

Sensors and meters in liquid service shall be rated for continuous duty service at fluid approach velocities from 0.327 ft/s to 10 ft/s with correspondingly higher constriction velocities over a fluid temperature range from 32^0 F to 250^0 F at pressures up to 150 psig.

2.2.4 Flow Sensor

Liquid flow indication shall be provided in gpm. Vapor flow indication shall be provided in cubic feet per minute (cfm). Pressure taps shall incorporate appropriate snubbers. Unless indicated otherwise, the flow transmitter shall produce a signal that is proportional to the volumetric flow rate, compensated for fluid temperature, and shall have an accuracy of plus or minus 3 percent of full flow. Flow transmitter shall be located within 15 feet of the flow element. The flow transmitter shall include a digital readout of the volumetric flow rate to 3 significant figures. The controller shall be provided with a minimum of three alarm lights. The first alarm light shall indicate when the lower (warning) detection level has been exceeded. The second alarm light shall indicate when the upper (alarm) detection level has been exceeded. The third alarm light shall indicate a controller malfunction, including loss of power or loss of sensor input. The controller shall be provided with a minimum of three sets of dry contacts rated in accordance with NEMA ICS 1. The first set of contacts shall close when the lower (warning) detection level has been exceeded. The second set of contacts shall close when the upper (alarm) detection level has been exceeded. The third set of contacts shall close when a controller malfunction has occurred, including loss of power or loss of sensor input. The alarm levels shall be individually adjustable. The controller shall be provided with an audible warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller shall provide a 4-20 mA DC output signal to the programmable logic controller, proportional to the measured parameter. The controller shall be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost. Flow rate shall be controlled to within plus or minus 5 percent of the design flow.

2.2.4.1 Flow Nozzle

Flow nozzle shall be made of austenitic stainless steel. The inlet nozzle form shall be elliptical and the nozzle throat shall be the quadrant of an ellipse. The thickness of the nozzle wall and flange shall be such that the accuracy will not be degraded by distortion of the nozzle throat from strains caused by the pipeline temperature and pressure, flange bolting, or other methods of installing the nozzle in the pipeline. The outside diameter of the nozzle flange or the design of the flange facing shall be such that the nozzle throat shall be centered accurately in the pipe.

2.2.4.2 Flow Switch

Flow switch shall have a repetitive accuracy of plus or minus 10 percent of actual flow setting. Switch actuation shall be adjustable over the operating flow range. Flow switch for use in contaminated groundwater, vapor and or hot gas system shall be rated for use and constructed of suitable materials for installation in the environment encountered. The flow switch shall have non flexible paddle with Form C snap action contacts, rated in accordance with NEMA ICS 1.

2.2.4.3 Magnetic Flowmeter

Magnetic flowmeter shall be non-intrusive and shall measure fluid flow through the use of a self generated magnetic field. The magnetic flow element shall be encapsulated in type 300 stainless steel. Flowmeter shall be capable of measuring clean or dirty flow up to a maximum flow velocity 10 fps. The metering tube shall be constructed of material compatible with the fluid being measured. The maximum pressure drop across the meter and appurtenances shall be 5 psi at the maximum flow rate.

2.2.4.4 Natural Gas or Propane Flow Meter

Flowmeter for natural gas or propane flows, corrected to standard conditions, of up to 2500 cfh shall be of the positive displacement diaphragm or bellows type and for flows above 2500 cfh, shall be of the axial flow turbine type. Meters shall be designed specifically for natural gas or propane supply metering and rated for the pressure, temperature and flow rates of the installation. Permanent meters shall be suitable for operation in conjunction with an energy monitoring and control system. Meter body shall be constructed of 316 stainless steel. Meter shall have a minimum turndown ratio of 10 to 1 with an accuracy of plus or minus 1percent of actual flow rate. The meter index shall include a direct reading mechanical totalizing register and electrical impulse dry contact output for remote monitoring. The electrical impulse dry contact output shall provide not less than 1 pulse per 2.8 cubic meters (100 cubic feet) of gas and shall require no field adjustment or calibration. The highest electrical impulse rate available from the manufacturer, not exceeding 10 pulses per second, for the installed application shall be provided.

2.2.4.5 Orifice Plate

Orifice plate shall be made of 304 series stainless steel sheet. The outlet side of the bore shall be beveled at a 45 degree angle. The thickness of the cylindrical face of the orifice shall not exceed one-fiftieth of the pipe inside diameter or one-eighth of the orifice bore, whichever is smaller. The orifice plate shall be flat within 20 mils. The orifice surface roughness shall not exceed 0.02 mils. Orifice plates shall be concentric plates with a square and sharp upstream edge of the orifice. Orifice bore shall be designed to match the operating parameters stated in the drawings. Plate shall be permanently identified with line size, flange rating, orifice bore diameter, plate thickness and material.

2.2.4.6 Paddle Type Flowmeter

Sensor accuracy shall be plus or minus 5 percent of rate of flow, minimum operating flow velocity shall be 1.0 fps. Sensor repeatability and linearity shall be plus or minus 1 percent. Sensor shall be non-magnetic, with forward curved impeller blades designed for water containing debris. Wetted materials shall be made from non-corrosive materials and shall not contaminate water. The sensor shall be provided with isolation valves.

2.2.4.7 Pitot Tube

The velocity sensing element shall be of the pitot tube type. Each transmitter shall have a low range differential pressure sensing element and a square root extractor. Sensing element accuracy shall be plus or minus 1 percent of full scale. Transmitter accuracy shall be plus or minus 0.25 percent of the calibrated measurement. Overall accuracy shall be plus or minus 5 percent over a range of 500 to 2500 fpm scaled to air volume. The resistance to air flow shall not exceed 0.08 inch water at an air flow of 2000 fpm.

2.2.4.8 Annular Pitot Tube

Sensor shall have an accuracy of plus or minus 2 percent of full flow and a repeatability of plus or minus 0.5 percent of measured value. Annular pitot tube shall be averaging type differential pressure sensors with four total head pressure ports and one static port made of austenitic stainless steel. The total head pressure ports shall extend diametrically across the entire pipe.

2.2.4.9 Positive Displacement Flowmeter

Output accuracy shall be plus or minus 2 percent of the flow range. The flow meter shall be a direct reading, gerotor, nutating disk or vane type displacement device rated for liquid service. A counter shall be mounted on top of the meter, and shall consist of a non-resettable mechanical totalizer for local reading, and a pulse transmitter for remote reading. The totalizer shall have a six digit register to indicate the volume passed through the meter in gallons. A sweep-hand dial will indicate down to 1 gallon. The pulse transmitter shall have a hermetically sealed reed switch which is activated by magnets fixed on gears of the counter. The meter shall have a bronze body with threaded or flanged connections as required for the application. The maximum pressure drop at full flow shall be 5 psig.

2.2.4.10 Turbine Meters

Turbine meters shall be series 300 stainless steel with an accuracy of plus or minus 1 percent from 30 percent to 100 percent of actual flow.

2.2.4.11 Insertion Turbine Flowmeter

Design of the flowmeter probe assembly shall incorporate integral flow, temperature, and pressure monitoring. The meter flow sensing element shall operate over the temperature range with a pressure loss limited to 2 percent of operating pressure at maximum flow rate. The internal temperature transmitter shall monitor the full temperature range of the fluid. The integral pressure transmitter shall monitor the pressure range with end limits of 0 psi to 300 psig. The flowmeter electronics shall be scaled and rescaled in the field when application data changes. The flowmeter shall be designed for installation in pipe sizes of 3 inches and larger to accommodate maximum probe insertion depths up to 44 inches. The retractor assembly shall have a rotor depth gage having graduations of 0.1 inches to determine exact position of turbine rotor in the pipe. The meter retractor assembly and the turbine rotor assembly shall be constructed of Series 300 stainless steel with polytetrafluoroethylene (PTFE) seals. The meter retractor assembly shall be designed to protect the turbine rotor during insertion into the pipeline. Retraction of the turbine rotor shall be accomplished by using a hand wheel. The retractor assembly shall include an isolation valve providing a means of removal of the meter from service to allow for field maintenance and field replacement of the rotor assembly or parts. The turbine rotor shall be designed to allow compensation for bearing wear without affecting rotor calibration. The turbine rotor shall have an over range operating capacity of 150 percent of maximum flow for up to 5 seconds. The rotor shall be calibrated at the factory in an actual flow of similar fluid over the flow range performed on test equipment with accuracy traceable to the National Institute of Standards and Technology (NIST). A copy of the calibration test data, including all of the physical parameters under which the calibration tests were performed, shall be provided with each turbine rotor. Calibration test data shall be analyzed to determine the rotor's arithmetic average "K" factor, the best line fit and the plus or minus deviation from these figures. Turbine flowmeter accuracy shall be plus or minus 1 percent of reading for a minimum turndown ratio of 1:1 through a maximum turndown ratio of 50:1. Repeatability shall be plus or minus 0.25 percent of reading. Accuracy of the transmitter shall be plus or minus 0.25 percent over the calibrated span. The turbine rotor response time from minimum to maximum flow shall be less than 10 milliseconds.

2.2.4.12 Ultrasonic Flowmeter

Ultrasonic flowmeter shall utilize high frequency Doppler shift or transit-time transducer. Flowmeter shall be capable of measuring flow up to a maximum flow rate of 15 fps.

2.2.4.13 Variable Area Flowmeter

Meters shall have an accuracy of plus or minus 5 percent of full scale. The flowmeter body shall be clear acrylic plastic or glass with stainless steel end fittings. The float shall be glass or stainless steel. The metering tube shall be tapered and shall be provided with a direct reading flow scale engraved on the meter body.

2.2.4.14 Venturi Tube

Venturi tube shall be made of cast iron or cast steel. The throat section shall be lined with austenitic stainless steel. Thermal expansion characteristics of the lining shall be the same as that of the throat casting material. The surface of the throat lining shall be machined to a plus or minus 1.2 micron (50 mils) finish, including the short curvature leading from the converging entrance section into the throat. The metering tube shall be rated for continuous duty service at minimum pressure of 100 psig.

2.2.4.15 Vortex Shedding Flowmeter

The accuracy shall be within plus or minus 2 percent of the actual volumetric flow. The flow meter body shall be made of austenitic stainless steel. Flowmeter shall be rated for continuous duty service at minimum pressure of 100 psig. The vortex shedding flowmeter body shall not require removal from the piping in order to replace the shedding sensor.

2.2.5 Level Instrumentation

Pressure taps shall incorporate appropriate snubbers. Relays and housing shall be intrinsically safe or explosion proof as required by the NFPA hazard rating for compatibility with the contents of the tank or sump. The controller shall be provided with a minimum of three sets of dry contacts rated in accordance with NEMA ICS 1. The first set of contacts shall close when the lower (warning) detection level has been exceeded. The second set of contacts shall close when the upper (alarm) detection level has been exceeded. The third set of contacts shall close when a controller malfunction has occurred, including loss of power or loss of sensor input. The alarm levels shall be individually adjustable. The controller shall be provided with an audible warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller shall provide a 4-20 mA DC output signal to the programmable logic controller, proportional to the measured parameter. The controller shall be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost.

2.2.5.1 Bubble Type Level Sensor

Bubbler type liquid level sensor shall be of the hydrostatic balance type, operating from compressed air. Each gauging system shall contain the following: an air set including connection to plant air, compressed air pressure regulating valve, air filter and moisture trap; a sight feed bubbler with built-in adjusting needle valve; a tank entry gland with air supply and equalized pilot signal connections; a 1/2 inch standard weight 316 stainless steel dip tube; a direct reading circular gauge 300 mm (12 inch) in diameter calibrated for the connected tank and tank liquid; connections to the circular gauge and to the pressure transducer for zero setting and calibration check; a connecting bubbler supply and equalized pilot signal stainless tubing with minimum field made joints; and a pressure transmitter, selected to correspond to the range required to gauge the connected tank.

2.2.5.2 Capacitance Type Level Sensor

Liquid level sensor shall produce a signal that is proportional to the measured level. Sensor shall be capacitance type. The transmitter shall have non-interacting zero and span adjustments, and shall have an accuracy of plus or minus 1 percent of calibrated span. Assemblies shall include wall bracket or mounting plate, austenitic stainless steel rods, stainless steel bolts and corrosion-resistant housing.

2.2.5.3 Conductivity Switch

The switch shall detect the presence of a fluid by measuring the electrical resistance between a sensor and a ground electrode. Electrodes shall be constructed of 316 stainless steel. Electrodes shall be fully clad using polytetrafluoroethylene (PTFE). The conductivity switch shall be capable of 4 separate level set points. The switch shall be provided with a ground electrode. Electrode lengths shall be as necessary, based on the application and to meet the requirements of the control sequence. A relay switching point shall be provided for each sensor. Contacts shall be rated for a maximum of 240 vAC, 5 A. Switch shall have a maximum response time of 2 seconds. Assembly shall be flange mounted and suitable for the indicated environment.

2.2.5.4 Displacement Type Level Switch

Liquid level switch shall be displacement type, having a minimum of two tandem floats with each float independently activating a set of Form C contacts at two different level settings. Each switch shall have a narrow differential band. The mounting connections shall be threaded, flanged or surface mounted to suit the application. All surfaces in contact with the tank contents shall be austenitic stainless steel. The switch enclosure shall be explosion proof for use in a hazardous environment, complete with a sealed water tight junction box, terminal block, and mounting plate. Each set of contacts shall be snap action, dry contact type with one normally open and one normally closed, contact rated in accordance with NEMA ICS 1. The switch shall be actuated by a magnetically equipped stainless steel displacer. Repetitive accuracy shall be plus or minus 6 mm (1/4 inch) of actual displacer setting.

2.2.5.5 Float Switch

Float switch assemblies for use in liquid systems shall consist of wall bracket or mounting plate, galvanized steel rods, stainless steel bolts, explosion proof and corrosion resistant housing, and intrinsically safe relays. Each switch shall consist of two normally open switches. The float casing shall be polypropylene. The switch cable shall be oil resistant thermoplastic cable with 4 No. 18 gauge stranded copper conductors, rated for 600 Volt application.

2.2.5.6 Reed Sensor

Sensor shall consist of a transmitter tube with a reed strip located inside. The tube length shall be of sufficient length to permit adjustment of switch actuation within process parameters. A float containing a permanent magnet shall fit over the transmitter tube and shall move up and down with the liquid level. The transmitter tube and sliding float assembly shall be as required for the application as shown on the drawings. Wetted parts shall be suitable for the installed service indicated. Assembly shall be flange mounted.

2.2.5.7 Ultrasonic Sensor

The sensor shall be microprocessor-based and shall provide continuous, non-contact level measurement of liquids and solids utilizing microwave pulsed time of flight measurement method. The sensor shall operate in a frequency band approved for industrial use. The sensor shall be capable of measuring in a range of 0 to 10 feet, with an accuracy of plus or minus 1 percent of full scale. The sensor shall be capable of distinguishing between real echoes, reflections and background noise. The sensor shall automatically compensate for temperature changes. Assembly shall be flange mounted, of sufficient size to eliminate echoing, and suitable for the installed environment indicated. Mounting assembly shall be suitable for service without requiring entry or drainage of the vessel or sump where level is being measured.

2.2.5.8 Leak Detection

Double walled containment system leak detectors shall use electrodes mounted in the interstices of double walled containment systems. Leak detectors for open systems shall be mounted at slab or floor level. Detector shall have a contact rating of 1.0 amps resistive or 200 mA inductive at 28 vDC. Leak detector panel shall indicate the location and detector causing the alarmed state. The indicator shall be manual reset type. A framed, non-fading half-size as-built location map in laminated plastic shall be provided for the cable leak detection system in double containment piping systems indicating the as installed system configuration; sensing string layout shall be furnished. Marks in feet along the length of pipeline interstitial cable shall be provided as references to locate leaks.

2.2.6 Pressure Instrumentation

Pressure taps shall incorporate appropriate snubbers. The controller shall be provided with a minimum of three sets of dry contacts rated in accordance with NEMA ICS 1. The first set of contacts shall close when the lower (warning) detection level has been exceeded. The second set of contacts shall close when the upper (alarm) detection level has been exceeded. The third set of contacts shall close when a controller malfunction has occurred, including loss of power or loss of sensor input. The alarm levels shall be individually adjustable. The controller shall be provided with an audible warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller shall provide a 4-20 mA DC output signal to the programmable logic controller, proportional to the measured parameter. The controller shall be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost. Pressures shall be controlled to within plus or minus 5 percent of design pressures.

2.2.6.1 Pressure Sensor

The sensing element shall be either capsule, diaphragm, bellows, Bourdon tube, or solid state as applicable for the installation. The pressure transducer shall withstand up to 300 percent of rated pressure, with an accuracy of plus or minus 5 percent of full scale selected to put the design range of the measured pressure in the middle third of the transducer's range. Pressure shall be measured in psig with a range, plus or minus 10 percent of design range, and shall be furnished with display to the nearest 0.5 psi.

2.2.6.2 Pressure Switch

Sensors shall be diaphragm or Bourdon tube and shall be constructed of 316 stainless steel. Pressure switch shall have a repetitive accuracy of plus or minus 5.0 percent of the operating range and shall withstand up to 150 percent of rated pressure. Switch actuation set point shall be adjustable over the operating pressure range with a differential adjustment span of 20 to 40 percent of the range of the switch. The switch shall have Form C snap-action contacts rated in accordance with NEMA ICS 1.

2.2.6.3 Differential Pressure

The sensor/transmitter assembly accuracy shall be plus or minus 5 percent of full scale. The over pressure rating shall be a minimum of 300 percent of the operating pressure. Transmitter shall be suitable for installation with the low pressure connection removed.

2.2.6.4 Differential Pressure Switch

Each switch shall be an adjustable diaphragm, or bellows operated device, with taps for sensing lines for connection of pressure fittings designed to sense fluid pressure. For measuring air, gas or vapor stream differential pressure, these fittings shall be of the angled-tip type with tips pointing into the air stream. The adjustable differential range shall be a maximum of 0.5 inches water at the low end to a minimum of 6.0 inches water at the high end. Two Form C contacts rated in accordance with NEMA ICS 1 shall be provided.

2.2.6.5 Pneumatic to Electric (PE) Switch

Each switch shall have an adjustable set point range of 3.0 to 20 psig and an adjustable differential from 2.0 to 6.0psi. Contacts shall be Form C rated in accordance with NEMA ICS 1.

2.2.7 Temperature Instrumentation

The controller shall be provided with a minimum of three sets of dry contacts rated in accordance with NEMA ICS 1. The first set of contacts shall close when the lower (warning) detection level has been exceeded. The second set of contacts shall close when the upper (alarm) detection level has been exceeded. The third set of contacts shall close when a controller malfunction has occurred, including loss of power or loss of sensor input. The alarm levels shall be individually adjustable. The controller shall be provided with an audible warning horn that sounds when the upper detection level has been exceeded, and a warning horn silence button. The controller shall provide a 4-20 mA DC output signal to the programmable logic controller, proportional to the measured parameter. The controller shall be provided with an internal battery to maintain operation for a minimum of 12 hours if power is lost.

2.2.7.1 Fluid Temperature Range

All devices shall be suitable for process temperatures, which define the exposure of the element, and are described in the table on the drawings. Mercury shall not be used in thermometers.

a. Type A shall be bimetal thermometer: Direct reading, hermetically sealed, suitable for external adjustment. Accurate within 1 percent of full range. Stainless steel construction. Complete with thermowell.

b. Type B shall be remote reading gas/vapor thermometer: Direct reading, stainless steel case designed for panel mounting, complete with armor cable, bulb and ancillary components for complete system. Movement-less design, resistant to shock and vibration and free from error created by elevation. Provided with gas operated molecular sieve. Accurate within 1 percent over full range.

2.2.7.2 Resistance Temperature Detector (RTD)

RTD shall be platinum, with an accuracy of plus or minus 1 percent at 32^0 F. RTD shall be encapsulated in stainless steel Series 300.

2.2.7.3 Continuous Averaging RTD

Continuous averaging RTD shall have an accuracy of plus or minus 2^0 F at the reference temperature, and shall be of sufficient length to ensure that the resistance represents an average over the cross-section in which it is installed. The sensor shall have a bendable copper sheath.

2.2.7.4 Infrared Temperature Sensor

Infrared temperature sensor shall be encapsulated in series 300 stainless steel or anodized aluminum. Sensor shall have an accuracy of plus or minus 1 percent of temperature measured.

2.2.7.5 Temperature Switch

All devices shall be suitable for process temperatures, which define the exposure of the element, and as described in the table shown on the drawings. Temperature switch shall have a repetitive accuracy of plus or minus 1 percent of the operating ranges shown. Switch actuation shall be adjustable over the operating temperature range. The switch shall have Form C snap action contacts, rated in accordance with NEMA ICS 1.

2.2.7.6 Thermocouple

Thermocouple shall be factory assembled with Series 300 stainless steel sheathing. Wiring insulation shall be magnesium oxide. Minimum insulation resistance wire to wire or wire to sheath shall be 1.5 megaohm at 500 V DC. Thermocouple shall be Type E, Type K or Type J. Thermocouple error shall not exceed that specified in ISA MC96.1. All wire/cable from thermocouple to transmitter shall be of the type necessary to match the thermocouple used. Transmitter selected shall match the type of thermocouple provided. The transmitter shall include automatic cold junction reference compensation with span and offset adjustments, and upscale open thermocouple detection.

2.2.7.7 Thermowell

Thermowell shall be monel, brass, or copper for use in water lines; wrought iron for measuring flue gases; and austenitic stainless steel for other applications. Calibrated thermowells shall be provided with threaded plug and chain, 2 inch lagging neck and inside diameter insertion neck as required for the application. The thermowell shall include a connection box, sized to accommodate the temperature sensing devise.

2.2.8 Process Analytical Instrumentation

Probes shall be easily removable without interrupting service. Sampling pumps shall be included where necessary or applicable to the sensing device. For sensors integral to the electronic controller the sample may be drawn directly into the sensor or may be drawn through a sample tube. For sensors remotely located the sample may be drawn through a sample tube. Outdoor sample tubes shall be heat traced. Sensor and controller construction shall be suitable for operation in the monitored medium. Systems requiring automated zero and calibration gas or reagents shall be provided with 14 days supply of calibration gas or reagent.

2.2.9 Electrical Instrumentation

Electrical power measurements with a range for the specific application, plus or minus 1.0 percent of range (display and print to nearest kWh and kW).

2.2.9.1 Hour Meter

Hour meter shall provide a totalized readout of the number of hours of operation for the equipment monitored. Meter shall provide readout with a minimum of 6 digits including 1 decimal place. The display shall be non-resettable. The meter shall be driven by a 120 vAC synchronous motor.

2.2.9.2 Watt-Hour Meter

Watt-hour meters shall be in accordance with ANSI C12.1 and shall have pulse initiators for remote monitoring of watt-hour consumption. Meter sockets shall be in accordance with ANSI C12.1. Pulse initiator shall consist of Form C contacts with a current rating not to exceed 2 amperes and voltage not to exceed 500 V, with combinations of VA not to exceed 10 VA, and a life rating of one billion operations.

2.3 COMPRESSED AIR STATIONS

2.3.1 Air Compressor Assembly

The air compressor shall be a high-pressure compressing unit with electric motor. The compressor shall be equipped with a motor with totally enclosed belt guard, an operating-pressure switch, safety relief valves, gauges, intake filter and intake silencer and combination type magnetic starter with under voltage protection and thermal overload protection for each phase, and shall be supported by a steel base mounted on an air storage tank. The air compressor shall provide the compressed air required for control operation while operating not more than one-third of the time. The tank shall be of sufficient volume so that no more than six compressor starts per hour are required with the starting pressure switch differential set at 20 psig. The air storage tank shall be fabricated for a working pressure of not less than 200 psig and constructed and certified in accordance with ASME BPVC SEC VIII D1. The tank shall be provided with an automatic condensate drain trap with manual override feature.

2.3.2 Compressed Air Station Specialties

2.3.2.1 Refrigerated Dryer, Filters and Pressure Regulator

A refrigerated dryer shall be provided in the air outlet line of the air storage tank. The dryer shall be of the size required for the full air requirement of the control system. The air shall be dried at a pressure of not less than 70 psig to a temperature not greater than 35^0 F. The dryer shall be provided with an automatic condensate drain trap with manual override feature. The refrigerant used in the dryer shall be one of the fluorocarbon gases and have an ozone depletion potential of not more than 0.05. A 5 micron prefilter and coalescing-type oil removal filter with shut-off valves shall be provided in the dryer discharge. Each filter bowl shall be rated for 150 psig maximum working pressure. A pressure regulator with high side and low side pressure gauges and a safety valve shall be provided downstream of the filter. Pressure regulators of the relieving type shall not be used.

2.3.2.2 Coalescing Filter

A coalescing prefilter, together with an automatic drain valve, shall be provided for removal of liquids. The flow through the prefilter shall be from inside to outside and reduce an entrained quantity of 50 ppmv oil to 0.0013 ppmv effluent liquid oil and water and remove all particulates greater than 0.6 micron absolute. The prefilter housing shall be fitted with a drain port to eliminate collected liquids and provide sufficient sump volume to prevent liquid re-entrainment, and an automatic drain valve with adjustable cycle and drain times. Prefilter pressure drop shall be less than 3 psi saturated. A particulate after filter, outside to inside flow, designed to remove desiccant fines shall be provided. The after filter cartridge shall have a particulate removal rating of 0.5 micron absolute. Both prefilter and after filter housings shall allow for service of elements without removing the entire assembly from the system. Filter life shall be stated and guaranteed by the vendor.

2.3.2.3 Flexible Pipe Connections

The flexible pipe connectors shall be designed for 150 psig and 250^0 F service and shall be constructed of rubber, polytetrafluoroethylene (PTFE) resin or braided corrosion-resistant steel, bronze, monel or galvanized steel. The connectors shall be suitable for the service intended and may have threaded or soldered ends. The length of the connectors shall be as recommended by the manufacturer for the service intended.

2.3.2.4 Vibration Isolation Units

The vibration isolation units shall be standard products with published loading ratings and shall be single rubber-in-shear, double rubber-in-shear or spring type.

2.3.2.5 Compressed Air Piping

Control air delivered to the system shall conform to ISA S7.0.01. Air lines for pneumatic controls shall be seamless copper tubing or nonmetallic tubing. Nonmetallic tubing shall be compounded from polyethylene. Air lines concealed in walls shall be hard-drawn copper tubing or nonmetallic tubing in rigid conduit. Terminal single lines shall be hard-drawn copper tubing except when the run is less than 12 inches in length, flexible polyethylene may be used. Nonmetallic tubing will not be used for applications where the tubing could be subjected to a temperature of 130^0 F. Fittings for nonmetallic tubing shall be for instrument service and may be brass or acetyl resin of the compression or barbed push-on type. Tubing shall be as follows:

a. Copper tubing shall conform to ASTM B 88M (ASTM B 88) and shall have sweat fittings and valves. Exposed tubing shall be hard drawn in exposed areas and hard-drawn or annealed in concealed areas. Only tool made bends shall be used. Fittings for copper tubing shall be brass or copper solder joint type except at connections to the apparatus, where fittings shall be brass compression type. Grooved mechanical joints and fittings shall be designed for not less than 125 psig service and shall be the product of the same manufacturer. Grooved fittings and mechanical coupling housing shall be ductile conforming to ASTM A 536. Gaskets for use in grooved joints shall be molded synthetic polymer of pressure responsive design and shall conform to ASTM D 2000 for circulating medium up to 230^0 F. Grooved joints shall conform to AWWA C606. Tubing shall be rack mounted where multiple tubes run in parallel. Multiple tubes may be bundled when concealed.

b. Tubing shall be flame resistant, multiple polyethylene tubing in an extruded PVC protective sheath, or unsheathed polyethylene tubing in rigid metal, intermediate metal, or electrical metallic tubing conduit for areas where tubing is exposed. Tubing shall have barbed fittings and valves, and shall conform to the following: Burst pressure shall be 550 psig at 75^0 F to 175 psig at 150^0 F, minimum. Stress crack resistance in accordance with ASTM D 1693 shall be 200 hours, minimum. Tensile strength in accordance with ASTM D 638 shall be 2000 psi, minimum. Average density in accordance with ASTM D 792 shall be 920 kg/m3. Average flow rate in accordance with ASTM D 1238 shall be 0.30 decigram per minute.

c. Plastic tubing shall have the burning characteristics of linear low density polyethylene tubing, shall be self extinguishing when tested in accordance with ASTM D 635, shall have UL 94 V-2 flammability classification, and shall withstand stress cracking when tested in accordance with ASTM D 1693. Polyethylene tubing shall not be used for smoke removal systems.

2.3.3 Barrier Jacket

Plastic tubing bundles shall be provided with mylar barrier and flame retardant polyethylene jacket. Each tube shall be numbered.

2.4 PROGRAMMABLE LOGIC CONTROLLER (PLC)

2.4.1 PLC General Requirements

PLCs shall be micro-processor based, capable of receiving discrete and analog inputs and, through programming, shall be able to control discrete and analog output functions, perform data handling operations and communicate with external devices. PLCs shall meet the requirements of Class A computing devices, and shall be labeled as set forth in 47 CFR 15 and shall be able to withstand conducted susceptibility test as outlined in NEMA ICS 1, NEMA ICS 2, NEMA ICS 3, and or IEEE C37.90.1. PLCs shall function properly at temperatures between 32 and 122^0 F at 5 to 95 percent relative humidity non-condensing, and shall tolerate storage temperatures between minus 40 and plus 40 and plus 140^0 F at 5 to 95 percent relative humidity non-condensing.

2.4.2 Modular PLC

PLCs shall be based on a modular, field expandable design allowing the system to be tailored to the process control application. The system shall be expandable through the use of additional hardware and/or user software. As a minimum, the PLC shall include a mounting backplate, power supply module, central processing unit (CPU) module, communications module, and input/output (I/O) module. The modules shall be grouped together in a mounting rack or cabinet. The mounting rack backplane shall provide the communications mechanism to fully integrate the individual modules located within the rack. Modules shall plug directly into the backplane. The use of wire connectors between modules will not be allowed. The rack size shall be as needed to hold the equipment necessary while performing the required control functions. The system configuration shall allow for the removal and/or installation of modules under power.

2.4.2.1 Central Processing Unit (CPU) Module

The CPU module shall be a self contained, microprocessor based unit that provides time of day, scanning, application (ladder rung logic) program execution, storage of application programs, storage of numerical values related to the application process and logic, I/O bus traffic control, peripheral and external device communications and self diagnostics.

2.4.2.2 Communications Module

The communications module shall allow peer-to-peer communication with other PLCs and shall allow the PLC to communicate with the central station, or workstation. The communication module shall utilize the manufacturer's standard communication architecture and protocol, ethernet architecture and protocol or a combination of these. The communication module shall allow programming of the PLC to be done locally through the use of a laptop computer or from the central station or remote workstation.

2.4.2.3 Power Supply Module

One or more power supply modules shall be provided as necessary to power other modules installed in the same cabinet. Power supply modules shall plug directly into the backplane. Auxiliary power supplies may be used to supply power to remote cabinets or modules.

a. Power supply modules shall use AC power with a nominal voltage of 120 vAC plus or minus 5 percent. The power supply module shall monitor the incoming line voltage level and shall provide over current and over voltage protection. If the voltage level is detected as being out of range the power supply module shall continue to provide power for an adequate amount of time to allow for a safe and orderly shutdown. Power supply modules shall be capable of withstanding a power loss for a minimum of 20 milliseconds while still remaining in operation and providing adequate power to all connected modules.

b. Each power supply module shall be provided with an on-off switch integral to the module. If the manufacturer's standard power supply module is not provided with an on-off switch, a miniature toggle type switch shall be installed near the PLC and shall be clearly labeled as to its function.

c. Power supply modules shall be provided with an indicating light which shall be lit when the module is operating properly.

2.4.2.4 Input/Output (I/O) Modules

Modules shall be self contained, microprocessor based units that provide an interface to field devices. The module shall be located in the same mounting rack as the other PLC components. The unit shall plug directly into the backplane of the mounting rack. Each module shall contain visual indication to display the on-off status of individual inputs or outputs.

2.4.3 Loop PLC

PLCs shall be single or multiple loop controllers depending on the control system requirements. Controllers shall be self contained and shall include a central processing unit (CPU), program memory, power supply, input/output capability, network communications capability and display/keyboard. The controller shall have a scaleable process variable for each loop. Analog input signals shall be based on the use of proportional, integral and derivative (PID) control logic. Analog outputs shall be configured as direct acting or reverse acting. The controller shall have keyboard, display, auto/manual selection for control of each loop output, remote setpoint, adjustment/local setpoint adjustment selection with adjustable high-end and low-end limits, ratio and bias adjustment on remote setpoint input, operator-initiated self-tune/manual-tune selection and anti-reset wind-up feature. Controller shall power analog output loops to 20 mAdc when connected to a load of 600 ohms.

2.4.3.1 Central Processing Unit (CPU)

The central processing unit shall be microprocessor based and shall provide time of day, scanning, application program (ladder rung logic) execution, storage of application programs, storage of numerical values related to the applications process and logic, I/O bus traffic control, peripheral and external device communications and self diagnostics.

2.4.3.2 Power Requirements

Each controller shall be powered by 120 vAC. Power consumption shall not exceed 25 watts. Controller shall provide electrical noise isolation between the AC power line and the process variable inputs, remote setpoint inputs and output signals of not less than 100 dB at 60 Hertz common mode rejection ration and not less than 60 dB at 60 hertz normal-mode rejection ration.

2.4.3.3 On-Off Switch

Each controller shall be provided with an integral on-off switch. If the controller is not provided with a manufacturer's standard on-off switch, a miniature toggle type switch shall be installed near the controller and shall be clearly labeled as to its function.

2.4.3.4 Parameter Input and Display

Control parameters shall be entered and displayed directly, in the correct engineering units, through a series of keystrokes on a front panel display with decimal point and polarity indication. Display shall be in metric or English units as selected by the operator.

2.4.3.5 Self Tuning

Controllers shall be provided with self-tuning operation which shall apply to proportional, integral and derivative modes of control and shall modify the mode constants as required. Self-tuning shall only be in operation when selected from the front panel.

2.4.3.6 Manual Tuning

Controllers shall be provided with manual tuning operation which shall apply to proportional, integral and derivative modes of control, by means of individually adjustable mode constants. These adjustments shall be set for the appropriate value if a particular control mode action is required or to zero if that particular mode is not desired. The proportional mode constant shall be adjustable from 0 to 200 percent of the input signal range. The integral mode constant shall be adjustable from 0 to 20 repeats per minute. The derivative mode constant shall be adjustable from 0 to 5 minutes.

2.4.4 Program Storage/Memory Requirements

The CPU shall utilize the manufacturer's standard non-volatile memory for the operating system. The controller shall have electronically erasable, programmable, read only memory (EEPROM) for storage of user programs and battery backed RAM for application memory. The EEPROM shall be loaded through the controller keypad, central station or through the use of a laptop computer. The CPU memory capacity shall be based on the system's control requirements. The memory capacity shall be sized such that, when the system is completely programmed and functional, no more than 50 percent of the memory allocated for these purposes is used.

2.4.5 Input/Output Characteristics

Each controller shall allow for analog input, analog output, discrete input and discrete output. The number and type of inputs and outputs for the system shall be as shown on the drawings and shall comply with the sequence of control. The system capacity shall include a minimum of 20 percent spare input and output points (no less than two points) for each point type provided. During normal operation, a malfunction in any input/output channel shall affect the operation of that channel only and shall not affect the operation of the CPU or any other channel. Analog input circuits shall be available in 4-20 mA. Discrete input circuits shall be available in 79-132 vAC. All input circuits shall have a minimum optical isolation of 1500 VRMS and shall be filtered to guard against high voltage transients from the externally connected devices. Analog output circuits shall be available in 4-20 mA. Discrete output circuits shall be available in 79-132 vAC. All output circuits shall have a minimum optical isolation of 1500 VRMS and shall be filtered to guard against high voltage transients from the externally connected devices.

2.4.6 Wiring Connections

Wiring connections shall be heavy duty, self lifting, pressure type screw terminals to provide easy wire insertion and secure connections. The terminals shall accept two #14 AWG wires. A hinged protective cover shall be provided over the wiring connections. The cover shall have write-on areas for identification of the external circuits.

2.4.7 On-Off Switch

Each controller shall be provided with an integral on-off power switch. If the controller is not provided with a manufacturer's standard on-off switch, a miniature toggle type switch shall be installed in the control panel near the controller and shall be clearly labeled as to its function.

2.4.8 Diagnostics

Each PLC shall have diagnostic routines implemented in firmware. The CPU shall continuously perform self-diagnostic routines that will provide information on the configuration and status of the CPU, memory, communications and input/output. The diagnostic routines shall be regularly performed during normal system operation. A portion of the scan time of the controller shall be dedicated to performing these housekeeping functions. In addition, a more extensive diagnostic routine shall be performed at power up and during normal system shutdown. The CPU shall log input/output and system faults in fault tables which shall be accessible for display. When a fault affects input/output or communications modules the CPU shall shut down only the hardware affected and continue operation by utilizing the healthy system components. Diagnostic software shall be useable in conjunction with the portable tester.

2.4.9 Accuracy

Controllers shall have an accuracy of plus or minus 0.25 percent of input span.

2.5 PLC SOFTWARE

All PLC software described in this specification shall be furnished as part of the complete control system.

2.5.1 Operating System

Each PLC shall be provided with the manufacturer's standard operating system software package. The PLC shall maintain a point database in its memory that includes all parameters, constraints and the latest value or status of all points connected to the PLC. Execution of the PLC application programs shall use the data in memory resident files. The operating system shall support a full compliment of process control functions. It shall be possible to define these functions using a mix of function blocks, ladder logic diagrams, sequential function charts and text programming. Programming methods and interactions shall be based on IEC 61131-3. A combination of the programming methods shall be possible within a single controller. The operating system shall allow loading of software locally or from the central station and data files from the portable tester. It shall also support data entry and diagnostics using an operator interface panel attached directly to the PLC. Each PLC shall be capable of operating in stand alone mode.

2.5.1.1 Startup

The PLC shall have startup software that causes automatic commencement of operation without human intervention, including startup of all connected I/O functions. A PLC restart program based on detection of power failure at the PLC shall be included in the PLC software. The restart program shall include start time delays between successive commands to prevent demand surges or overload trips.

2.5.1.2 Failure Mode

Upon failure for any reason, each PLC shall perform an orderly shutdown and force all PLC outputs to a predetermined (failure mode) state, consistent with the failure modes shown and the associated control device.

2.5.2 Functions

The controller operating system shall be able to scan inputs, control outputs, and read and write to its internal memory in order to perform the required control as indicated in the sequence of control on the drawings. The controller shall periodically perform self diagnostics to verify that it is functioning properly.

2.5.2.1 Analog Monitoring

The system shall measure and transmit all analog values including calculated analog points.

2.5.2.2 Logic (Virtual)

Logic (virtual) points shall be software points entered in the point database which are not directly associated with a physical I/O function. Logic (virtual) points shall be analog or digital points created by calculation from any combination of digital and analog points, or other data having all the properties of real points, including alarms, without the associated hardware. Logic (virtual) points shall be defined or calculated and entered into the database by the Subcontractor. The calculated analog point shall have point identification in the same format as any other analog point.

2.5.2.3 State Variables

If an analog point represents more than two (up to 8) specific states, each state shall be nameable. For example, a level sensor shall be displayed at its measured engineering units plus a state variable with named states usable in programs or for display such as low alarm/low/normal/high/high alarm.

2.5.2.4 Analog Totalization

Any analog point shall be operator assignable to the totalization program. Up to eight analog values shall be totalized within a selectable time period.

2.5.2.5 Trending

Any analog or calculated point shall be operator assignable to the trend program. Up to eight points shall be sampled at individually assigned intervals, selectable between 1 minute and 2 hours. A minimum of the most recent 128 samples of each trended point shall be stored. The sample intervals shall be able to be defined, modified, or deleted online.

2.5.3 Alarm Processing

Each PLC shall have alarm processing software for AI, DI, and PA alarms for all real and virtual points connected to that PLC.

2.5.3.1 Digital Alarms

Digital alarms are those abnormal conditions indicated by DIs as specified and shown. The system shall automatically suppress analog alarm reporting associated with a digital point when that point is turned off.

2.5.3.2 Analog Alarms

Analog alarms are those conditions higher or lower than a defined value, as measured by an AI. Analog readings shall be compared to predefined high and low limits, and alarmed each time a value enters or returns from a limit condition. Unique high and low limits shall be assigned to each analog point in the system. In control point adjustment (CPA) applications, key the limit to a finite deviation traveling with the setpoint. The system shall automatically suppress analog alarm reporting associated with an analog point when that analog point is turned off.

2.5.3.3 Pulse Accumulator (PA) Alarms

Pulse accumulator alarms are those conditions calculated from totalized values of accumulator inputs or PA input rates that are outside defined limits as specified and shown. PA totalized values shall be compared to predefined limits and alarmed each time a value enters a limit condition. Unique limits shall be assigned to each PA point in the system.

2.5.4 Constraints

2.5.4.1 Equipment Constraints Definitions

Each control point in the database shall have PLC resident constraints defined and entered by the Subcontractor, including as applicable: maximum starts (cycles) per hour; minimum off time; minimum on time; high limit (value in engineering units); and low limit (value in engineering units).

2.5.4.2 Constraints Checks

All control devices connected to the system shall have the PLC constraints checked and passed before each command is issued. Each command point shall have unique constraints assigned. High and low "reasonableness" values or one differential "rate-of-change" value shall be assigned to each AI. Each individual point shall be capable of being selectively disabled by the operator from the central station.

2.5.5 Control Sequences and Control Loops

Specific functions to be implemented are defined in individual system control sequences and database tables shown on the drawings, and shall include, as applicable, the following functions: PI control shall provide proportional control and proportional plus integral control; two position control shall provide control for a two state device by comparing a set point against a process variable and an established dead band; floating point control shall exercise control when an error signal exceeds a selected dead band, and shall maintain control until the error is within the dead band limits; signal selection shall allow the selection of the highest or lowest analog value from a group of analog values as the basis of control and shall include the ability to cascade analog values so that large numbers of inputs can be reduced to one or two outputs; signal averaging shall allow the mathematical calculation of the average analog value from a group of analog values as the basis of control and shall include the ability to "weight" the individual analog values so that the function output can be biased as necessary to achieve proper control; reset function shall develop an AO based on up to two AIs and one operator specified reset schedule.

2.5.6 Command Priorities

A scheme of priority levels shall be provided to prevent interaction of a command of low priority with a command of higher priority. Override commands entered by the operator shall have higher priority than those emanating from applications programs.

2.5.7 Resident Application Software

The Subcontractor shall provide resident applications programs developed in accordance with paragraph Graphical Object Oriented Programming to achieve the sequences of operation, parameters, constraints, and interlocks necessary to provide control of the process systems connected to the control system. All application programs shall be resident in the PLC and shall execute in the PLC, and shall coordinate with each other, to insure that no conflicts or contentions remain unresolved.

2.5.7.1 Program Inputs and Outputs

The Subcontractor shall use program inputs listed for each application program to calculate the required program outputs. Where specific program inputs are not available, a "default" value or virtual point appropriate for the equipment being controlled and the proposed sequence of operation shall be provided to replace the missing input, thus allowing the application program to operate.

2.5.7.2 Failure Mode

In the event of a PLC failure, the controlled equipment shall continue to function in the failure mode shown on the drawings.

2.6 CONTROL PANELS

2.6.1 Components

2.6.1.1 Enclosures

The enclosure for each control panel shall conform to the requirements of NEMA 250 for the types specified. Finish color shall be the manufacturer's standard, unless otherwise indicated. Damaged surfaces shall be repaired and refinished using original type finish. Enclosures shall be as specified or shown. Enclosures for equipment installed outdoors shall be Type 4 or as shown. Enclosures for installation in a corrosive environment shall be Type 4X and shall be constructed of stainless steel, fiberglass or polymer plastic. Painted steel shall not be allowed for use in a corrosive environment. Enclosure shall be provided with a single, continuously hinged exterior door with print pocket, 3-point latching mechanism and key lock and a single, continuously hinged interior door.

2.6.1.2 Controllers

Controllers shall be in accordance with paragraph Programmable Logic Controller (PLC).

2.6.1.3 Standard Indicator Light

Indicator lights shall comply with NEMA ICS 1, NEMA ICS 2 and UL 508. Lights shall be heavy duty, round and shall mount in a 0.875 inch mounting hole. Indicator lights shall be LED type and shall operate at 120 vAC or 24 vDC. Long life bulbs shall be used. Indicator light shall be provided with a legend plate labeled as shown on the drawings. Lens color shall be as indicated on the drawings. Lights shall be push to test (lamp) type.

2.6.1.4 Selector Switches

Selector switches shall comply with NEMA ICS 1, NEMA ICS 2 and UL 508. Selector switches shall be heavy duty, round and shall mount in a 0.875 inch mounting hole. The number of positions shall be as indicated on the drawings. Switches shall be as indicted of the drawings. Switches shall be rated for 600 volts, 10 amperes continuous. Selector switches shall be provided with a legend plate labeled as shown on the drawings. Where indicated or required, dual auxiliary contacts shall be provided for the automatic position to provide position sensing at the central station or workstation. Auxiliary contacts shall be rated for 120 vAC, 1A as a minimum. Where indicated on the drawings, switches shall be key operated. All keys shall be identical.

2.6.1.5 Push Buttons

Push buttons shall comply with NEMA ICS 1, NEMA ICS 2 and UL 508. Push buttons shall be heavy duty, round and shall mount in a 0.875 inch mounting hole. The number and type of contacts shall be as indicated on the drawings or required by the Sequence of Control. Push buttons shall be rated for 600 volts, 10 amperes continuous. Push buttons shall be provided with a legend plate labeled as shown on the drawings.

2.6.1.6 Relays

Relays shall comply with IEEE C37.90.1 and derated for altitude above 1,500 m. Relays shall be as required by the Sequence of Control. Relay coil shall be 20 vAC or 24 vDC and shall be provided with matching mounting socket. Power consumption shall not be greater than 3 watts.

2.6.1.7 Terminal Blocks

Terminal blocks shall comply with NEMA ICS 4 and UL 1059. Terminal blocks for conductors exiting control panels shall be two-way type with double terminals, one for internal wiring connections and the other for external wiring connections. Terminal blocks shall be made of bakelite or other suitable insulating material with full deep barriers between each pair of terminals. A terminal identification strip shall form part of the terminal block and each terminal shall be identified by a number in accordance with the numbering scheme on the approved wiring diagrams.

2.6.1.8 Autodialer

Autodialer shall be a self contained, programmable device capable of automatic operation. The unit shall automatically dial preprogrammed number(s) to report alarm(s) or other specified conditions. The autodialer shall automatically redial upon receipt of a busy signal. The number of redials shall be an operator definable parameter. The unit shall be capable of dialing a minimum of three phone numbers. The unit shall communicate over voice grade phone lines.

2.6.1.11 Alarm Horns

Alarm horns shall be provided where indicated on the drawings. Horns shall be vibrating type and shall comply with UL 508. Horns shall provide 100 dB at 10 feet. Exterior mounted horns shall be weather proof by design or shall be mounted in a weather proof enclosure that does not reduce the effectiveness of the horn.

2.6.2 Panel Assembly

Control panels shall be factory assembled and shipped to the jobsite as a single unit. Panels shall be fabricated as indicated and devices shall be mounted as shown or required.

2.6.3 Electrical Requirements

Each panel shall be powered by a dedicated 120 volts AC circuit, with a fuse, sized as recommended by the equipment manufacturer, and a disconnect switch located inside the panel. Wiring shall terminate inside the panel on terminal blocks. Electrical work shall be as specified in and as shown on the drawings.

2.6.4 Power Line Conditioner

Each control panel shall be provided with a power line conditioner to provide both voltage regulation and noise rejection. The power line conditioner shall be of the ferro-resonant design, with no moving parts and no tap switching, while electrically isolating the secondary from the power line side. The power line conditioner shall be sized for 125 percent of the actual connected kva load. Characteristics of the power line conditioner shall be as follows:

2.6.4.1 85 Percent Load

At 85 percent load, the output voltage shall not deviate by more than plus or minus 1 percent of nominal voltage when the input voltage fluctuates between minus 20 percent to plus 10 percent of nominal voltage.

2.6.4.2 Load Changes

During load changes of zero to full load, the output voltage shall not deviate by more than plus or minus 3 percent of nominal voltage. Full correction of load switching disturbances shall be accomplished within 5 cycles, and 95 percent correction shall be accomplished within 2 cycles of the onset of the disturbance.

2.6.5 Grounding

Control panel enclosures shall be equipped with a solid copper ground bus or equivalent. The ground bus shall be securely anchored to the enclosure so as to effectively ground the entire structure. Clamp-type terminals sized large enough to carry the maximum expected current shall be provided on the ground bus for grounding cables. Where a definite circuit ground is required, a single wire not less than #10 AWG shall run independently to the panel ground bus and shall be fastened to the ground bus with a bolted terminal lug. Cases of instruments, relays and other devices shall be effectively grounded through the enclosures steel structure unless otherwise indicated. Insulated wiring having a continuous rated current of not less than the circuit fuse rating shall be used for grounding. Grounding terminals of power receptacles shall be solidly grounded to the panel enclosure.

2.6.6 Convenience Outlet

A 120 vAC, 20 amp, ground fault interruption (GFI) type duplex convenience outlet shall be provided inside the panel. The outlet circuit shall be separate from the panel power circuit.

2.6.7 Panel Interior Light

Where indicated control panels shall be provided with a light. The light shall be operated by a manual on-off switch mounted on the interior door of the enclosure. The light shall be powered by the same circuit as the convenience outlet.

2.6.8 Ventilation System

Where indicated control panels shall be provided with two single phase, 120 vAC ventilation fans. Each fan shall supply a minimum of 100 cfm of ventilation air through the enclosure. Each fan shall be provided with a line voltage thermostat. Thermostat setpoints shall be adjustable in a range of 70 to 140° F as a minimum. Each supply and exhaust grille shall contain a filter that is easily removed for cleaning or replacement.

2.7 CENTRAL STATION AND OPERATORS WORKSTATION EQUIPMENT

This section not used.

2.8 CENTRAL STATION SOFTWARE

This section not used.

2.9 DATA COMMUNICATION REQUIREMENTS

Control system data communications shall support the specified functions and control system configuration shown on the drawings.

2.9.1 Central Station/Workstation

Each workstation shall be able to communicate with the central station as a virtual terminal. The workstation shall be able to initiate uploads or downloads of programs and resident data, including parameters of connected systems PLCs and devices, constraints and programs in the central station.

2.9.2 Central Station/PLC

The central station shall be able to initiate an upload or download of PLC data programs.

2.9.3 Modem Communication

Communication with other computer systems shall be accomplished using a modem and dialup circuit. The central station or workstation shall be able to initiate upload or download of data files; however, answering incoming calls shall not be possible for system security reasons.

2.9.4 Error Detection and Retransmission

Asynchronous transmission system shall use cyclic code error detection methods. The predicted undetected error rate shall not exceed 1 bit in 1 billion. A message shall be in error if one bit is received incorrectly. The system shall retransmit messages with detected errors. Where a LAN is not utilized for data transmission, a 2-digit decimal number shall be operator assignable to each communication link representing the number of retransmission attempts. When the number of consecutive retransmission attempts equals the assigned quantity, the central station shall close down transmission to that particular device, and print an alarm message. The operator shall manually reopen any communications line after automatic closedown, subject to the same error checking and automatic closedown procedures in effect before the first automatic closedown. The system shall monitor the frequency of data transmission errors for display and logging.

PART 3 EXECUTION

3.1 EQUIPMENT INSTALLATION REQUIREMENTS

3.1.1 Installation

The Subcontractor shall install system components and appurtenances in accordance with the manufacturer's instructions and shall provide necessary interconnections, services, and adjustments required for a complete and operable system. Instrumentation and communication equipment and cable grounding shall be installed as necessary to preclude ground loops, noise, and surges from adversely affecting system operation. The Subcontractor shall adjust or replace devices not conforming to the required accuracies. Factory sealed devices shall be replaced (rather than adjusted). Wiring in exposed areas, including low voltage wiring, shall be installed in metallic raceways or EMT conduit as specified. Wiring in air plenum areas installed without conduit shall be plenum-rated per NFPA 70.

3.1.1.1 Isolation, Penetrations of Buildings and Clearance from Equipment

Dielectric isolation shall be provided where dissimilar metals are used for connection and support. Penetrations through and mounting holes in the building exteriors shall be made watertight. Holes in concrete, brick, steel and wood walls shall be drilled or core drilled with proper equipment; conduits installed through openings shall be sealed with materials which are compatible with existing materials. Openings shall be sealed with materials which meet the requirements of NFPA 70. Installation shall provide clearance for control-system maintenance. Control system installation shall not interfere with the clearance requirements for mechanical and electrical system maintenance.

3.1.1.2 Device Mounting

Devices shall be installed in accordance with manufacturers' recommendations and as shown. Control devices to be installed in piping shall be provided with required gaskets, flanges, thermal compounds, insulation, piping, fittings, and manual valves for shutoff, equalization, purging, and calibration. Any deviations shall be documented by the Subcontractor and submitted to the Government for approval prior to mounting. Damaged insulation shall be replaced or repaired after devices are installed to match existing work. Damaged galvanized surfaces shall be repaired by touching up with zinc paint.

3.1.1.3 Pneumatic Tubing

Tubing shall be concealed in finished areas. Tubing may be run exposed in unfinished areas, such as mechanical equipment rooms. For tubing to be enclosed in concrete, rigid metal or intermediate metal conduit shall be provided. Tubing shall be installed parallel or perpendicular to building walls throughout. Maximum spacing between tubing supports shall be 5 feet. Each tubing system shall be tested pneumatically at 1.5 times the working pressure for 24 hours, with a maximum pressure drop of 1.0 psig with compressed air supply turned off. Joint leaks shall be corrected by remaking the joint. Caulking of joints will not be permitted. Tubing and two insulated copper phone wires for installation checkout may be run in the same conduit. Tubing and electrical power conductors shall not be run in the same conduit; however, control circuit conductors may be run in the same conduit as polyethylene tubing.

3.1.1.4 Grooved Mechanical Joints

Grooves shall be prepared according to the coupling manufacturer's instructions. Grooved fittings, couplings, and grooving tools shall be the products of the same manufacturer. Pipe and groove dimensions shall comply with the tolerances specified by the coupling manufacturer. The diameter of grooves made in the field shall be measured using a "go/no-go" gauge, vernier or dial caliper, narrow-land micrometer, or other method specifically approved by the coupling manufacturer for the intended application. Groove width and dimension of groove from end of pipe shall be measured and recorded.

3.1.2 Sequences of Operation

The subcontractor shall study the operation and sequence of local equipment controls, as a part of the conditions report, and note any deviations from the described sequences of operation on the contract drawings. The subcontractor shall make necessary adjustments to make the equipment operate in an optimum manner and shall fully document changes made.

3.2 INSTALLATION OF EQUIPMENT

The subcontractor shall install equipment as specified, as shown and as required in the manufacturer's instructions for a complete and fully operational control system.

3.2.1 Control Panels

Control panels shall be located as indicated on the drawings. Devices located in the control panels shall be as shown on the drawings or as needed to provide the indicated control sequences.

3.2.2 Flow Measuring Device

Fluid flow instruments shall be installed in accordance with ASME FED, unless otherwise indicated in the specification. The minimum straight unobstructed piping for the flowmeter installation shall be 10.0 pipe diameters upstream and 5.0 pipe diameters downstream. Meters for gases and vapors shall be installed in vertical piping, and meters for liquids shall be installed in horizontal piping, unless otherwise recommended by the manufacturer or indicated in the specifications.

3.2.2.1 Flow Nozzle

Flow nozzles flanges shall be installed so that the pressure taps are in a horizontal plane with the centerline of the pipe. Flow nozzles shall be installed for ease of accessibility for periodic maintenance. Differential pressure sensors shall be installed as close to the flow nozzle as possible.

3.2.2.2 Flow Switch

Flow switches shall be installed in such a manner as to minimize disturbance of the flow of fluid while maintaining reliable operation of the switch.

3.2.2.3 Magnetic Flowmeter

Meter shall be installed in vertical piping so that the flow tube remains full of the process fluid under all operating conditions. A minimum of five pipe diameters straight run upstream of the flowmeter and two pipe diameters straight run downstream of the flowmeter shall be provided.

3.2.2.4 Natural Gas or Propane Flowmeter

Meters shall be installed in accordance with ASME B31.8. Permanent gas meters shall be installed with provisions for isolation and removal for calibration and maintenance, and shall be suitable for operation in conjunction with an energy monitoring and control system.

3.2.2.5 Orifice Plates

Orifice plates shall be installed for ease of accessibility for periodic maintenance. Differential pressure sensors shall be as close to the orifice plates as possible. Orifice plates for liquid measurement shall be located in horizontal pipe runs with the orifice plate flanges installed so that the pressure taps are in the horizontal plane with the centerline of the pipe. For liquid, the differential pressure transmitter shall be installed below the orifice taps. For gas measurement, the orifice plate flanges shall be installed so that the pressure taps are 45° or more above the horizontal plane with the centerline of the pipe. For gas measurement the required differential pressure transmitter shall be physically installed above the orifice taps.

3.2.2.6 Paddle Flowmeter

Meter shall be installed using manufacturer's published procedures. Installers shall be trained for such installations in the pipes encountered. Subcontractor shall provide certificates demonstrating installer's qualifications.

3.2.2.7 Annular Pitot Tubes

Annular pitot tubes shall be installed so that the total head pressure ports are set-in-line with the pipe axis upstream and the static port facing downstream. The total head pressure ports shall extend diametrically across the entire pipe. Annular pitot tubes shall not be used where the flow is pulsating or where pipe vibration is allowed.

3.2.2.8 Positive Displacement Flow Meters

Flow meters shall be installed horizontally, and aligned correctly in the direction of flow.

3.2.2.9 Turbine Meters

Turbine meters shall be installed so that the sensor is located in the center of the fluid flow pipe on the main axis. The minimum straight unobstructed piping for the flow meter installation shall be 10 pipe diameters upstream and 5 pipe diameters downstream.

3.2.2.10 Insertion Turbine Flowmeters

Turbine meters shall be installed without interruption to service. The Subcontractor shall install a welded flanged riser of appropriate pipe line rating, with a full opening valve bolted to it. Sensor shall be located in accordance with the manufacturer's instructions for the specified flow rates and installation conditions. Reduced diameter pipe sections shall be provided as necessary to achieve required flow velocities. Meters shall be installed using the hot-tap method with tools recommended by the manufacturer. The minimum straight unobstructed piping for the flow meter installation shall be 10 pipe diameters upstream and 5 pipe diameters downstream.

3.2.2.11 Ultrasonic Flowmeter

Meter shall be installed using manufacturer's published procedures for installation. Installers shall be trained for such installations in the pipes encountered. Subcontractor shall provide certificates demonstrating installer's qualifications.

3.2.2.12 Variable Area Flowmeter

Meters shall be installed in a vertical piping section with full flow through the meter.

3.2.2.13 Venturi Flowmeter

The flowmeter shall be installed with its top above the pipeline in horizontal pipe run installations. The direction of flow shall be upward in vertical pipe run installations. The flowmeter shall be aligned to the direction of the flow and shall be rigidly mounted and vibration free. The minimum straight unobstructed piping for the flow meter installation shall be 10 pipe diameters upstream and 5 pipe diameters downstream.

3.2.2.14 Vortex Shedding Flowmeters

The flowmeter shall be installed with its top above the pipeline in horizontal pipe run installations. The direction of flow shall be upward in vertical pipe run installations. The flowmeter shall be aligned to the direction of the flow and shall be rigidly mounted and vibration free. The minimum straight unobstructed piping for the flow meter installation shall be 10 pipe diameters upstream and 5 pipe diameters downstream.

3.2.3 Level Instruments

3.2.3.1 Liquid Level Sensor (Bubble Type)

The air pressure regulating valve, air filter, moisture trap, air flow adjustment valve, level gauge, air isolation valve and pressure transducer shall be mounted on a panel where indicated on the drawings. The level gauge shall be labeled to identify the tank being measured. The isolation valve shall be located in the air supply line upstream of the moisture trap, air filter and pressure regulator. The air inlet line to the dip tube and the dip tube shall be mounted to a flange at the top of the tank. The dip tube shall extend to the bottom of the tank, leaving the manufacturer's recommended clearance between the dip tube and tank bottom. The dip tube material shall be compatible with the tank contents. The pressure regulating valve shall be adjusted to the outlet pressure recommended by the manufacturer. Where exposed, the air supply line to the tank and from the tank to the level gauge and pressure transducer shall be protected from damage.

3.2.3.2 Capacitance Liquid Level Sensors

The sensing probes shall be located close to, and parallel with, the tank or sump wall.

3.2.3.3 Conductivity Switch

Level switches shall be installed vertically and in accordance with the manufacturer's instructions. Switches shall be accessible for maintenance and calibration. In applications where switches cannot be directly mounted to a tank by the threaded or flanged connection, a mounting bracket shall be provided for connection to the inside tank wall, maintaining the minimum recommended distance from the tank fill opening.

3.2.3.4 Displacement Type Liquid Level Switch

Level switches shall be installed in accordance with the manufacturer's instructions. Switches shall be accessible for maintenance and calibration. In applications where switches cannot be directly mounted to a tank by the threaded or flanged connection, a mounting bracket shall be provided for connection to the inside tank wall.

3.2.3.5 Float Switches

Switches shall be mounted in accordance with manufacturer's published instructions. Procedures shall be those used for equipment in hazardous locations.

3.2.3.6 Ultrasonic Sensor

Sensor shall be installed vertically in the top of the tank and in accordance with the manufacturer's instructions. Switches shall be accessible for maintenance and calibration. In applications where switches cannot be directly mounted to a tank by the threaded or flanged connection, a mounting bracket shall be provided for connection to the inside tank wall. Sensor shall be positioned to maximize the return echo signal and minimize vessel obstructions in the sensors line of sight. The minimum recommended distance from the tank fill opening and from the side of the tank shall be maintained.

3.2.4 Pressure Instruments

Pressure sensors and pressure transducers shall be verified by calibration. All pressure taps shall incorporate appropriate snubbers. Pressure sensors and pressure switches shall have valves for isolation, venting, and taps for calibration. Pressure switches and pressure transducers installed on liquid or steam lines shall have drains. Pressure transducers, differential pressure sensors and differential pressure switches shall have nulling valves. Pressure switches shall be adjusted to the proper setpoint and shall be verified by calibration. Switch contact ratings and duty shall be selected for the application.

3.2.5 Temperature Instrument Installation

3.2.5.1 RTD

RTD shall be installed in a thermowell. Thermowells shall be filled with conductive heat transfer fluid prior to installation of the RTD in the thermowell. RTDs used for space temperature sensing shall include a housing suitable for wall mounting. RTDs used for outside air sensing shall have an instrument shelter or sun shield as shown to minimize solar effects, and shall be mounted to minimize building effects. RTD assemblies shall be readily accessible and installed to allow easy replacement.

3.2.5.2 Temperature Switches

Temperature switches shall be installed as specified for RTDs. Temperature switches shall be adjusted to the proper setpoint and shall be verified by calibration. Switch contact ratings and duty shall be selected for the application.

3.2.5.3 Thermometers and Temperature Sensing Elements

Thermometers and temperature sensing elements installed in liquid systems shall be installed in thermowells.

3.2.5.4 Thermocouples

Each thermocouple shall be installed in a protective tube or in a thermowell. Thermocouples shall be insulated from ambient temperature effects. Thermocouple wires shall not be installed in the same conduits as power wiring. Thermocouples shall not be used for measuring temperatures below 260° C (500° F). Type E thermocouples may be used when the atmosphere is chemically reducing environment. Type K thermocouples may be used when the atmosphere is a chemically oxidizing environment.

3.2.7 Instrument Shelters

Instrument shelters shall be installed in the location shown with the bottom 1.2 meter (4.0 feet) above the supporting surface using legs and secured rigidly to minimize vibrations from winds. Instrument shelters shall be oriented with door facing North. Instruments located in shelters shall be mounted in the 3-dimensional center of the open space of the shelter.

3.2.8 Electric Power Devices

3.2.8.1 Potential and Current Transformers

The Subcontractor shall install potential and current transformers in enclosures unless otherwise shown. Current transformer leads shall be shorted when they are not connected to the measurement circuits.

3.2.8.2 Hour Meters

Meters shall be located in the control panel or as otherwise shown. Power to the meter shall be connected to the motor starter auxiliary contacts for pumps, blowers and other motor driven devices. For devices without motor starters, the meter shall be connected in parallel with the load. Where the meter voltage differs from the metered devices voltage, transformer shall be provided as necessary.

3.2.8.3 Watt-hour Meters

The Subcontractor shall install watt-hour meters and transducers in enclosures unless otherwise shown.

3.2.8.4 Transducers

Transducers shall be wired in accordance with the manufacturer's instructions, and installed in enclosures.

3.2.8.5 Current Sensing Relays and Current Transducers for Motors

When used to sense meter/fan/pump status, current sensing relays shall be used for applications under 4 kW (5 hp). Applications over 4 kW (5 hp) shall use a current transducer.

3.2.9 Output Devices

Output devices (transducers, relays, contactors, or other devices) which are not an integral part of the control panel shall be mounted in an enclosure mounted adjacent to the control panel, unless otherwise shown. Where H-O-A and/or override switches on the drawings or required by the control sequence, the switches shall be installed so that the control system controls the function through the automatic position and other controls work through the hand position.

3.2.10 Enclosures

All enclosure penetrations shall be from the bottom of the enclosure, and shall be sealed to preclude entry of water using a silicone rubber sealant.

3.2.11 Transformers

Transformers for control voltages below 120 vAC shall be fed from the nearest power panel or motor control center, using circuits provided for the purpose. The Subcontractor shall provide a disconnect switch on the primary side and a fuse on the secondary side. Transformers shall be enclosed in a steel cabinet with conduit connections.

3.3 WIRE, CABLE AND CONNECTING HARDWARE

3.3.1 LAN Cables and Connecting Hardware

LAN cables and connecting hardware shall be installed in accordance with Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM and Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT (OSP).

3.3.2 Metering and Sensor Wiring

Metering and sensor wiring shall be installed in accordance with the requirements of ANSI C12.1, NFPA 70, Section 33 70 02.00 10 ELECTRICAL DISTRIBUTION, UNDERGROUND and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

3.3.2.1 Power Line Surge Protection

Control panels shall be protected from power line surges. Protection shall meet the requirements of IEEE C62.41. Fuses shall not be used for surge protection.

3.3.2.2 Sensor and Control Wiring Surge Protection

Digital and analog inputs shall be protected against surges induced on control and sensor wiring. Digital and analog outputs shall be protected against surges induced on control and sensor wiring installed outdoors and as shown. Fuses shall not be used for surge protection. The inputs and outputs shall be tested in both the normal and common mode using the following two waveforms: The first waveform shall be 10 microseconds by 1000 microseconds with a peak voltage of 1500 volts and a peak current of 60 amperes. The second waveform shall be 8 microseconds by 20 microseconds with a peak voltage of 1000 volts and a peak current of 500 amperes.

3.4 SOFTWARE INSTALLATION

The subcontractor shall load software required for an operational control system, including databases (for points specified and shown), operational parameters, and system, command, and application programs. The Subcontractor shall adjust, tune, debug, and commission all software and parameters for controlled systems to assure proper operation in accordance with the sequences of operation and database tables.

3.5 FIELD TESTING AND ADJUSTING EQUIPMENT

The Subcontractor shall provide personnel, equipment, instrumentation, and supplies necessary to perform site testing. The Government will witness the PVT, and written permission shall be obtained from the Government before proceeding with the testing. Original copies of data produced, including results of each test procedure, during PVT shall be turned over to the Government at the conclusion of each phase of testing prior to Government approval of the test. The test procedures shall cover actual equipment and functions specified for the project.

3.5.1 Testing, Adjusting and Commissioning

After successful completion of the factory test as specified, the Subcontractor will be authorized to proceed with the installation of the system equipment, hardware, and software. Once the installation has been completed, the Subcontractor shall test, adjust, and commission each control loop and system in accordance with NIST SP 250 and shall verify proper operation of each item in the sequences of operation, including hardware and software. The Subcontractor shall calibrate field equipment, including control devices, adjust control parameters and logic (virtual) points including control loop setpoints, gain constants, constraints, and verify data communications before the system is placed online. Ground rods installed by the Subcontractor shall be tested as specified in IEEE Std 142. The Subcontractor shall calibrate each instrumentation device connected to the control system control network by making a comparison between the reading at the device and the display at the workstation, using a standard at least twice as accurate as the device to be calibrated. The Subcontractor shall check each control point within the control system control network by making a comparison between the control command at the central station and field-controlled device. The Subcontractor shall deliver trend logs/graphs of all points showing to the Government that stable control has been achieved. Points on common systems shall be trended simultaneously. The Subcontractor shall verify operation of systems in the specified failure modes upon Control system network failure or loss of power, and verify that systems return to control system control automatically upon a resumption of control system network operation or return of power. The Subcontractor shall deliver a report describing results of functional tests, diagnostics, calibrations and commissioning procedures including written certification to the Government that the installed complete system has been calibrated, tested, adjusted and commissioned and is ready to begin the PVT. The report shall also include a copy of the approved PVT procedure.

3.5.2 Performance Verification Test (PVT)

The Subcontractor shall prepare test procedures for the PVT. The test procedure shall describe all tests to be performed and other pertinent information such as specialized test equipment required and the length of the PVT. The test procedures shall explain, in detail, step-by-step actions and the expected results, to demonstrate compliance with all the requirements of the drawings and this specification. The test procedure shall be site specific and based on the inputs and outputs, required calculated points and the sequence of control. The Subcontractor shall demonstrate that the completed Control system complies with the contract requirements. All physical and functional requirements of the project including communication requirements shall be demonstrated and shown. The Subcontractor shall demonstrate that each system operates as required in the sequence of operation. The PVT as specified shall not be started until after receipt by the Subcontractor of written permission by the Government, based on the Subcontractor's written report including certification of successful completion of testing, adjusting and commissioning as specified, and upon successful completion of training as specified. Upon successful completion of the PVT, the Subcontractor shall deliver test reports and other documentation as specified to the Government.

3.6 MANUFACTURER'S FIELD SERVICES

The Subcontractor shall obtain the services of a manufacturer's representative experienced in the installation, adjustment, and operation of the equipment specified. The representative shall supervise the installing, adjusting, and testing of the equipment.

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SECTION 15050

PIPING SYSTEMS

PART 1 - GENERAL

1.01 SECTION INCLUDES: Fabrication and installation requirements for piping systems.

1.02 RELATED SECTIONS

A. Section 02225, Trenching.

B. Section 18100, General Welding Requirements.

1.03 REFERENCES

A. ANSI B1.20.1-83, Pipe Threads, General Purpose (Inch) (R 1992)

B. ASME B31.3-95c, Chemical Plant and Petroleum Refinery Piping.

C. ASTM B32-94, Standard Specification for Solder Metal.

D. ASTM B828-92, Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube Fittings.

1.04 DEFINITIONS

A. Pressure-Relief Valve: pressure-relieving device designed to reclose after normal conditions have been restored to prevent further flow of fluid.

B. Safety Valve: pressure-relief valve actuated by inlet static pressure and characterized by rapid-opening/pop-action.

C. Relief Valve: pressure-relief valve actuated by inlet static pressure and characterized by opening in proportion to increases in inlet static pressure.

D. Safety-Relief Valve: pressure-relief valve characterized by rapid-opening/pop-action or by opening in proportion to increases in inlet static pressure, depending on application.

E. Non-closing Pressure-Relief Device: pressure-relieving device designed to remain open after operation (e.g., rupture discs, fuse plugs, etc.).

1.05 PERFORMANCE REQUIREMENTS

A. Acceptance of piping systems and associated equipment is contingent upon proper execution of specified tests and acceptable test results.

B. Acceptance of equipment is contingent upon equipment satisfactorily performing its specified function.

1.06 SUBMITTALS FOR INFORMATION

A. Red-lined copies of design drawings that indicate changes made from routing shown on design drawings.

B. Test reports for piping systems and associated equipment.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Deliver piping and valves to site in clean and protected condition.

B. Maintain end seals and flange covers in place. Remove seals and covers only for cleaning, fabrication, erection, or inspection.

C. Exercise care in handling and storage of materials and pre-fabrications to ensure that contamination by foreign material does not occur.

D. Reinstall end seals or covers on partially erected systems to prevent contamination by foreign material.

PART 2 - PRODUCT

2.01 FABRICATION

A. Code Requirements

1. Fabricate piping systems specified in Division 15 per Normal Fluid Service requirements of ASME B31.3 except where otherwise specified.

2. Additional and alternate fabrication requirements are specified in individual system sections of these specifications.

B. Cutting

1. Cut pipe and tubing accurately with pipe or tube cutters.

2. Ream cuts to remove burrs.

3. Remove defects by machining, chipping, or grinding.

C. Off-Site Fabrication: Perform off-site fabrication in compliance with on-site fabrication requirements.

2.02 SOURCE QUALITY CONTROL

A. Shop-Fabricated Piping Tolerance: ±1/8-inch maximum on overall dimensions.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

1. Follow piping route where shown on drawings. Field determined pipe routing to be approved by Field Engineer. Record as-built conditions and changes required to suit field conditions on drawings.

2. When joining dissimilar materials, provide nonconducting dielectric connections.

3. Provide clearance for installation of insulation and access to valves, flanges, and unions.

4. Provide access where valves, flanges, and unions are not exposed.

5. Install piping to conserve building space and not interfere with use of space.

6. Group piping at common elevations.

7. Install piping to allow for expansion and contraction without stressing pipe, joints, or connected equipment.

8. Work pipe carefully into place. Do not force or spring pipe into place unless cold springing is required.

9. Provide piping connections to equipment with flanges or unions.

10. Install specialties per manufacturer's instructions.

B. Underground Piping

1. Follow route shown on drawings for underground lines. Verify that excavations are to required grade, dry, and not over-excavated.

2. Maintain a 1-foot clearance between pipe surfaces at points where lines being installed cross existing lines.

3. Encase in concrete potable water lines that cross under creeks and/or cross or pass within 10 feet of sanitary, chemical, radioactive liquid-waste lines, or other hazardous services.

4. Trenching: Section 02225.

5. Clean ditch of debris and other foreign matter immediately before pipe is lowered into ditch. Where ditch is in rock, gravel, or like material, pad by filling with sand to form a cushion on bottom of ditch before pipe is lowered into ditch.

6. Allow coating to harden before lowering coated pipe into ditch. Lower pipe into ditch without placing strain on pipe. Center pipe in ditch.

7. Use only approved equipment to handle and lay pipe. Do not use chain or wire-rope slings.

8. Before back-filling, inspect line to ensure that it lies evenly on bottom of ditch and that no debris is present, and that joints are not covered until tests are completed.

9. Protect coated piping during back-filling by hand placing selected earth free from rock and other injurious materials around pipe to a minimum depth of 12 inches above pipe top surface or by wrapping pipe with 1/4-inch minimum thickness coal tar-saturated fiber wrapping held in place with banding clamps.

10. Install plastic pipe per manufacturer's installation instructions.

11. Underground Piping Cathodic Protection

    a. Locate and install anodes, rectifiers, and connections to pipe as shown on drawings.

    b. Number, type, and depth to which anodes are to be installed on drawings.

C. Pipe Sleeves

1. Provide pipe sleeves that allow 1/4-inch annular clearance around pipe or insulation for piping passing through floors, walls, and ceilings.

2. Provide pipe sleeves that allow 1/2-inch annular clearance around pipe or insulation for underground piping passing through walls.

3. Install pipe sleeves flush with walls and ceilings.

4. Provide pipe sleeves extending 3 inches above floor surface [except where specified otherwise].

D. Valves

1. Pack and make leak-proof valves for test pressure specified.

2. Disassemble, prior to heating, valves which are to be soldered, brazed, or welded. Allow valves to cool, clean if necessary, and reassemble.

3. Install globe valves with pressure under seat.

4. Install valves with stems in upright or horizontal position.

5. Provide manual shutoff valves to isolate equipment, parts of systems, or vertical risers.

6. Provide manual control valves for throttling, bypass, or manual flow control.

7. Provide check valves on discharge of pumps.

8. In copper tube systems, provide brass male adapters on both sides of valves.

9. Provide shutoff valves with unions downstream at equipment and fixture connections.

10. Provide shutoff valves for branch headers as close as practical to main header.

E. Hangers

1. Provide pipe hangers as specified in Section 15140

3.02 JOINING METHODS

A. Threaded Joints

1. Threads: ANSI B1.20.1.

2. Thread pipe after bending, forging, or heat-treating operations. Where threading must be performed first, protect threads during such operations.

3. When threading chemically cleaned pipe, use nontoxic cutting fluid containing no rust retardants or oils. After threading chemically cleaned pipe, immerse threaded end in solvent for minimum 1 minute.

4. Apply pipe joint compound to male threads only.

5. Do not apply thread tape to first two threads of pipe.

B. Soldered Joints

1. Solder: Solid-core wire type, ASTM B32 Alloy Grade Sb5.

2. Flux: Water soluble, chemically active at soldering temperature.

3. Perform soldering activities per ASTM B828 and CDA 404/0R.

4. Fillet soldered joints are not permitted.

C. Flanged Joints

1. Provide flat-face flanges and full-face gaskets where steel flanges mate with cast-iron flanged fittings, valves, or equipment.

2. Provide full-face gaskets between cast-iron flanges.

3. Provide flat ring-type gaskets between steel flanges equipped with raised serrated faces [except where specified otherwise].

4. Prior to bolt-up, align flange faces to the design plane within 1/16-inch per foot (0.5%) measured across any diameter. Align flange bolt holes to within 1/8-inch maximum offset. Assemble mating flanges flush and true.

5. Center gaskets evenly between flange faces with ring gaskets engaging fully upon raised-face flanges.

6. Provide bolts that extend through nuts by minimum one full thread when made up. Provide bolts of uniform length on a single flange.

7. Coat bolt threads with high-temperature thread joint compound prior to installation.

8. Tighten bolts uniformly to draw flanges evenly and firmly upon gasket. Use standard industrial practice for bolt tightening.

D. Hub-and-Plain-End Joints

1. Clean internal surface of hub and external surface of pipe and/or fitting to be joined to be free of dirt, mud, gravel, or other foreign material.

2. When using cut pipe, remove sharp edges by preening or lightly filing edge.

3. Insert gasket into hub. Ensure that retaining flange or collar of gasket is adjacent to face of hub.

4. Commercial Lubricants: Soap or adhesive type.

5. Apply thin coat of commercial lubricant on inside of gasket only [unless pipe manufacturer recommends lubricating plain end of pipe or fitting].

6. Align pipes to be joined to design plane within 1/16-inch per foot (0.5%) measured across any diameter.

7. Use manufacturer-recommended tools to install plain end of pipe or fitting into gasket. Ensure that tools do not damage pipe.

8. Store gaskets in undeformed condition away from excessive heat in a clean, dry area.

9. Install hub-and-plain-end pipe with hub end upstream.

10. Do not exceed deflections in hub-and-plain-end pipe shown in Table A.

Table A. Limiting factors, hub-and-plain-end pipe

	Maximum deflection in inches with pipe lengths of		
Nominal pipe size	Joint opening	12 feet	18 feet
3	0.43	14.8	22.2
4	0.41	11.1	16.7
6	0.58	11.1	16.7
8	0.65	9.7	14.6
10	0.75	9.3	14.0
12	0.75	7.9	11.9
14	0.75	6.7	10.1
16	0.75	5.9	8.8

Note: Joint Opening not to exceed 0.75 inches.

E. Mechanical Joints

1. Do not exceed deflections in mechanical joint pipe shown in Table B.

Table B. Limiting factors, mechanical joint pipe

	Maximum deflection in inches with pipe lengths of		
Nominal pipe size	Bend in one joint angle	12 feet	18 feet
3	8°-18	21	31
4	8°-18	21	31
6	7°-7	18	27
8	5°-21	13	20
10	5°-21	13	20
12	5°-21	13	20
14	3°-35	9	13½
16	3°-35	9	13½

2. Clean surfaces that contact rubber gaskets by wire brushing prior to assembly.

3. Lubricate surfaces that contact gaskets with a solution of clean, soapy water.

4. Install gland on spigot end of pipe followed with gasket.

5. Bottom spigot end of pipe in socket and properly center to provide an annular space approximately equal around pipe circumference.

6. Bring up gasket to flange of socket. Maintain approximate uniform distance between gland and flange of pipe around socket.

7. Insert bolts in properly spaced holes. Hand tighten each nut.

8. Use wrench sizes and torques in Table C to tighten nuts.

Table C: Wrenches and torque

Pipe size (inch)	Bolt diameter (inch)	Wrench length (inch)	Range of torque (ft-lb)
3	5/8	8	40 to 60
4 to 24	3/4	10	60 to 90

9. Tighten bolts by drawing up on opposite pairs, beginning at bottom, then top, then sides, and lastly remaining bolts.

10. Repeat cycle of tightening bolts until bolts are within allowable torque range.

11. If effective sealing is not attained at maximum torque indicated, disassemble joint, thoroughly clean, and then reassemble.

12. Do not overstress bolts in order to affect a seal.

F. Plastic Pipe Joints (not excluded by ASME B31.3, Paragraph 300.1.3)

1. Bonding: ASME B31.3, Paragraph A328.

2. Bonding Procedure Qualifications: ASME B31.3.

3. Bonder Performance Qualifications: ASME B31.3.

4. Inspector: ASME B31.3, Paragraphs A328.2.2 and A328.2.3.

G. Welded Joints

1. Perform welding activities per Section 18100.

H. Compression Joints

1. Clean internal surface of fitting and external surface of piping to be free of foreign materials.

2. When using cut pipe, remove sharp edges by preening or lightly filing edge.

3. Slide compression nut onto pipe so that broad shoulder of compression nut faces away from end of pipe.

4. Slip ferrules onto pipe.

5. Press threaded body of compression fitting onto end of pipe.

6. Screw compression nut onto fitting body.

7. Tighten with one wrench on compression nut and one wrench on fitting body per manufacturer's instructions.

8. Do not overstress in order to affect a seal.

I. Flared Joints

1. Clean internal surface of fitting and external surface of piping to be free of foreign materials.

2. When using cut pipe, remove sharp edges by preening or lightly filing edge.

3. Slide flare nut onto pipe so that tapered end of flared nut faces away from end of pipe.

4. Clamp end of pipe into manufacturer's recommended flaring tool and screw ram into end of pipe. Remove flaring tool from pipe.

5. Press tapered end of fitting body into flared end of pipe.

6. Screw flared nut onto fitting body.

7. Tighten with one wrench on flared nut and one wrench on fitting body per manufacturer's instructions.

8. Do not overstress in order to affect a seal.

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SECTION 15073

PRESSURE/LEAK TESTING

PART 1 - GENERAL

1.01 SECTION INCLUDES: pressure/leak testing of piping systems.

1.02 REFERENCES

A. ANSI B31.3-93, Chemical Plant and Petroleum Refinery Piping.

B. Standard Plumbing Code, Southern Building Code Congress International Incorporated (1994).

1.03 DEFINITIONS

A. Dry Oil-free Compressed Air (DCA): compressed air, oil free, with -40 to -75° F dew point at atmospheric pressure.

1.04 SUBMITTALS FOR APPROVAL

A. Test records for each piping system prepared during pressure/leak testing, indicating date of test, identification of piping system tested, test media, test pressure, and certification of results.

1.05 QUALITY ASSURANCE

A. Prepare test records for each system during pressure/leak testing, including date of test, identification of piping system tested, test media, test pressure, and certification of results. Individual test records need not be retained if certification that piping has satisfactorily passed pressure/leak testing is retained.

1.06 SEQUENCING

Perform testing after completion of installation.

PART 2 - PRODUCTS

2.01 TEST EQUIPMENT

A. Calibration Date: maximum 12 months prior to test.

B. Use test equipment with label indicating serial number, calibration date, name of firm or laboratory performing calibration.

C. Contractor representative will examine test equipment prior to test. Contractor representative may require that test equipment be submitted to Contractor for calibration check. Test equipment failing calibration check must be submitted to an approved testing laboratory for proper calibration prior to use.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine system installation for compliance with drawings and specifications.

B. Ensure pressure-relief valves have been inspected and set at required pressure by Contractor.

C. Ensure that rupture discs have been properly installed.

D. Examine system for leaks at valves, flanges, welds, connections, and joints.

E. Examine piping system for defective, broken, or cracked piping and fittings.

3.02 PREPARATION

A. Isolate or replace with spool pieces vessels, pumps, instruments, controls, safety valves, relief valves, and other equipment items rated for pressures below test pressure.

B. Provide temporary over pressurization protection devices between pressure source and test equipment.

1. For Class A - Pneumatic Test, set temporary over pressurization protection devices at test pressure plus lesser of 50 psi or 10% of test pressure.

2. For Class B - Hydrostatic Test, set temporary over pressurization protection devices at 130% of test pressure.

C. Disconnect or isolate by blinds or other means equipment that is not to be tested. Valves may be used provided valves are rated for test pressures.

D. Maintain joints, including welds and bonds, uninsulated and exposed for examination during testing. Joints previously tested may be insulated or covered.

E. Provide additional temporary supports as necessary to support test media when weight of test media exceeds weight of design system fluid.

F. Clear test area of personnel not involved with pneumatic testing.

3.03 REPAIR/RESTORATION

A. Repair leaks and retest repaired joints until test requirements have been satisfied.

3.04 CLASS A - PNEUMATIC TEST

A. Test Pressure

1. For piping 6 in. and smaller, use test pressure that is 110% of design pressure or 50 psig, whichever is greater.

2. For piping 8 in. and larger with design pressures of 45 psig and less, use test pressure that is 110% of design pressure but in no case greater than 50 psig.

3. For piping 8 in. and larger with design pressures greater than 45 psig, hydrostatically test piping per Class B test procedures.

B. Preliminary Leak Test Procedure

1. Gradually pressurize piping system to 25 psig.

2. Maintain 25 psig pressure for a minimum of 10 minutes.

3. Visually examine valves, flanges, welds, joints, and connections for major leaks.

C. Final Leak Test Procedure (test pressures of 50 psig and less)

1. Gradually pressurize piping system to test pressure.

2. Maintain test pressure for a minimum of 10 minutes.

3. Soap test welds, joints, and connections while system is at test pressure.

4. Depressurize system.

D. Final Leak Test Procedure (test pressures exceeding 50 psig)

1. Gradually pressurize system to 50% of test pressure.

2. Increase pressure in steps of 10% of test pressure until test pressure is reached.

3. Maintain test pressure for a minimum of 10 minutes.

4. Reduce pressure to design pressure.

5. Soap test welds, joints, and connections while system is at design pressure.

6. Depressurize system.

E. Reconnect instruments and equipment and retest connections at maximum operating pressure.

F. Acceptance Criteria: No continuous bubble formation is allowed.

G. Test Media: Table 1 lists test media for Class A tests.

Table 1

Service	Test media
Plant Air	DCA
Instrument Air	DCA or Nitrogen

3.05 CLASS B - HYDROSTATIC TEST

A. Special Requirements for Potable Water Systems

1. Test systems conveying potable water with dedicated and controlled test equipment that is used only on systems conveying potable water.

2. Equipment includes pumps, pressure gages, hoses, pipes, caps, and other test equipment that contacts potable water.

B. Test Pressure: 150% of design pressure or 50 psig, whichever is greater.

C. Test Procedure

1. Pressurize system to test pressure.

2. Maintain test pressure for minimum 10 minutes.

3. Examine valves, flanges, welds, joints, and connections for leaks.

4. Drain test media from system.

5. Reconnect instruments and equipment.

6. Refill system with test media, pressurize to maximum operating pressure, and examine valves, flanges, welds, joints, and connections for leaks.

D. Acceptance Criteria: No leakage is permitted at welds, brazed joints, soldered joints, compression fittings, or threaded joints. No leakage is acceptable at valves and gaskets unless specified otherwise.

E. Test Media: Table 2 lists test media for Class B tests.

Table 2

Service	Test media
Steam and Condensate 0-150	Potable Water
Steam and Condensate 150-250	Potable Water
Above Ground Potable and Safety Shower Water	Potable Water
Cooling Water	Potable Water
Potable and Process Water	Potable Water
Raw and Cooling Tower Water	Potable Water

3.06 CLASS C - WATER TEST (DRAIN)

A. Chemical Drains

1. Subject drain to 20 ft of water.

2. Examine joints and connections for leaks.

B. Building Drain and Vent Systems

1. Test per Standard Plumbing Code.

2. Perform either smoke or peppermint final test.

C. Building Sewer: Test per Standard Plumbing Code.

D. Test Media: Table 3 lists test media for Class C tests.

Table 3

Service	Test medium
Storm and Sanitary Drains	Potable Water
Chemical Drains	Potable Water

3.07 TEST PRESSURE TOLERANCE

A. Use test pressure tolerance of +5 psig and -0 psig.

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SECTION 15074

IDENTIFICATION AND LABELING

PART 1 - GENERAL

1.01 SECTION INCLUDES: Identification and labeling of piping systems.

1.02 REFERENCES

A. ANSI A13.1-81, Scheme for Identification of Piping Systems (R 1985).

B. NEMA Z535.1-91, Safety Color Code.

1.03 DEFINITIONS

A. Exposed Piping: Piping which is normally visible or may be visible after removal of covers or panels designed to provide access for inspection or maintenance.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Labels and Banding Materials: Weather-resistant, service rating for outdoor service, -20°F (-28°C) to 220°F (104°C) service temperature range, compatible with specified operating environment, low-halide content (for stainless steel application only).

2.02 LABEL FABRICATION

A. Fabricate labels with label format per ANSI A13.1.

B. Fabricate labels with background and letter colors per NEMA Z535.1.

C. Fabricate labels of type compatible with operational and service conditions.

D. Fabricate adhesive film labels with one or more adhesive-backed layers.

E. Fabricate labels with text letter heights per NEMA Z535.1 as follows:

Pipe or covering outside diameter (in.)	Letter height (in.)
Up to 1/2	1/2
1/2 to 2	3/4
2 1/2 to 6	1 1/4
8 to 10	2 1/2
10 and up	3 1/2

F. Fabricate flow direction labels of same background color as system labels.

G. Supplemental Labels

1. Fabricate supplemental pressure and temperature labels of same background color, letter color, and letter height as system labels.

2. Fabricate supplemental pressure labels to numerically indicate line operating pressure and end with letters PSIG.

3. Fabricate supplemental temperature labels numerically indicate normal operating temperature and end with symbol °F.

PART 3 - EXECUTION

3.01 LABEL INSTALLATION

A. Provide labels on straight sections of pipelines inside buildings at maximum intervals of 40 ft.

B. Provide labels on straight sections of pipelines outside buildings at maximum intervals of 100 ft.

C. Provide labels on branch lines not more than 5 ft from main header.

D. Provide labels on lines that penetrate walls or floors on each side of penetration not more than 5 ft from penetration.

E. Provide labels on banks of piping in a row, side by side, for ease of reference.

F. Provide labels with label format per ANSI A13.1.

G. Provide labels with approved piping label attributes as coordinated between Operating and Engineering Divisions.

H. Provide labels with background colors, letter colors, and letter heights per NEMA Z535.1.

I. Provide labels of type compatible with operational and service conditions.

1. On bare pipe, provide manufacturer's standard adhesive film labels or band-on labels. Stenciling may be used on services approved by Contractor.

2. On insulated pipe, provide thin adhesive film labels, snap-on labels, or band-on labels.

J. Provide flow direction labels adjacent to system label to indicate the direction of flow.

K. Supplemental Labels

1. Provide supplemental pressure labels on gaseous service piping. Provide supplemental pressure lables on liquid service piping operating at 100 psig or greater.

2. Provide supplemental temperature labels on service piping operating at 120° F or greater.

L. If available, use portable labeling system with a single label displaying required information.

3.02 LABEL APPLICATION

A. Ensure that surface to be labeled is free of scale, dirt, dust, grease, and moisture. Ensure that mastic coatings on insulated lines are completely dry before applying labels.

B. Firmly press label in place. Rub thoroughly, particularly along edges, until adhesive bonds.

C. Apply banding tape or flow-arrow tape over abutting edges of adhesive labels when multiple labels are required for supplemental information.

D. For fire protection water piping, apply labels to piping in aboveground, concealed areas only.

END OF SECTION

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SECTION 15081

EXTERIOR PIPING INSULATION

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM A 167	(2004) Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM A 240/A 240M	(2004ae1) Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels for General Applications
ASTM B 209	(2004) Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B 209M	(2004) Aluminum and Aluminum-Alloy Sheet and Plate (Metric)
ASTM C 533	(2004) Calcium Silicate Block and Pipe Thermal Insulation
ASTM C 547	(2003) Mineral Fiber Pipe Insulation
ASTM C 552	(2003) Cellular Glass Thermal Insulation
ASTM C 59/C 59M1	(2001) Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation
ASTM D 226	(2005) Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FED-STD-595	(Rev B; Am 1) Colors, Volume 1

1.2 SYSTEM DESCRIPTION

Provide field-applied insulation for exterior steam piping and existing insulated piping affected by and exterior condensate piping.

1.3 SUBMITTALS

1. Product Data for insulation and jacketing

2. Manufacturers' installation manual for field-applied insulation

PART 2 PRODUCTS

2.1 PIPING INSULATION

Products containing asbestos will not be permitted.

2.1.1 Fibrous Glass Pipe Insulation

ASTM C 547.

2.1.2 Mineral Fiber Pipe Insulation

ASTM C 547.

2.1.3 Calcium Silicate Pipe Insulation

ASTM C 533.

2.1.4 Cellular Glass Pipe Insulation

ASTM C 552.

2.1.5 Polyurethane and Polyisocyanate Pipe Insulation

ASTM C 59/C 59M1, minimum density of 27.20 kilograms per cubic meter (kg/cu m) (1.7 pcf).

2.1.6 Mineral Fiber Pipe Wrap Insulation

ASTM C 547 for material, minimum density of 36.80 kg/cu m(2.3 pcf).

2.2 MINIMUM THICKNESS OF INSULATION FOR STEAM PIPING

2.2.1 Fibrous Glass Pipe Insulation

Nominal Pipe Sizes (mm)	Aboveground Piping Insulation Thickness (mm)	Piping in Trenches on Piers Insulation Thickness (mm)
less than 80	88.90	63.50
80 thru 100	101.60	76.20
125 thru 150	114.30	88.90
200 and larger	127.00	101.60

Nominal Pipe Sizes (Inches)	Aboveground Piping Insulation Thickness (Inches)	Piping in Trenches on Piers Insulation Thickness (Inches)
less than 3	3.5	2.5
3 thru 4	4.0	3.0
5 thru 6	4.5	3.5
8 and larger	5.0	4.0

2.2.2 Mineral Fiber Pipe Insulation

Mineral fiber pipe insulation having an insulating efficiency not less than that of the specified thickness of fibrous glass pipe insulation may be provided in lieu of fibrous glass pipe insulation.

2.2.3 Calcium Silicate Pipe Insulation

Nominal Pipe Sizes (mm)	Piping in Tunnels Piping in Manholes Insulation Thickness (mm)	Piping Under Piers (Not in Trenches) Insulation Thickness (mm)
less than 80	101.60	127.00
80 thru 100	114.30	152.40
125 thru 150	127.00	177.80
200 and larger	152.40	203.20

Nominal Pipe Sizes (Inches)	Piping in Tunnels Piping in Manholes Insulation Thickness (Inches)	Piping Under Piers (Not in Trenches) Insulation Thickness (Inches)
less than 3	4.0	5.0
3 thru 4	4.5	6.0
5 thru 6	5.0	7.0
8 and larger	6.0	8.0

2.2.4 Cellular Glass Pipe Insulation

Cellular glass pipe insulation having an insulating efficiency not less than that of the specified thickness of calcium silicate pipe insulation may be provided in lieu of calcium silicate pipe insulation.

2.2.5 Mineral Fiber Pipe Wrap Insulation

Mineral fiber pipe wrap insulation having an insulating efficiency not less than that of the specified thickness of fibrous glass pipe insulation may be provided in lieu of fibrous glass pipe insulation for pipe sizes 250 mm(10 inches) and larger.

2.3 MINIMUM THICKNESS OF INSULATION FOR PUMPED CONDENSATE RETURN PIPING

Minimum thickness of insulation for pumped condensate return piping shall be as follows.

2.3.1 Mineral Fiber Pipe Insulation

Piping in Tunnels

Nominal Pipe Sizes (mm)	Piping in Manholes Insulation Thickness (mm)	Aboveground Piping Insulation Thickness (mm)
less than 80	38.10	63.50
80 thru 100	50.80	76.20
125 and larger	63.50	88.90

Piping in Tunnels

Nominal Pipe Sizes (Inches)	Piping in Manholes Insulation Thickness (Inches)	Aboveground Piping Insulation Thickness (Inches)
less than 3	1.5	2.5
3 thru 4	2.0	3.0
5 and larger	2.5	3.5

2.3.2 Fiber Glass Pipe Insulation

Fiber glass pipe insulation having an insulating efficiency not less than that of the specified thickness of mineral fiber pipe insulation may be provided in lieu of mineral fiber pipe insulation for aboveground piping.

2.4 MINIMUM THICKNESS OF INSULATION FOR GRAVITY CONDENSATE (STEAM) PIPING

Provide 25 mm (one inch) thick fibrous glass pipe insulation for aboveground piping. Provide 25 mm (one inch) thick mineral fiber, calcium silicate, or cellular glass pipe insulation for piping in manholes and tunnels.

2.5 ALUMINUM JACKET

ASTM B 209M(ASTM B 209), Temper H14, minimum thickness of 0.40 mm (0.016 inch), with factory-applied polyethylene and kraft paper moisture barrier on inside surface. Provide smooth surface jackets for jacket outside diameters less than 200 mm (8 inches). Provide corrugated surface jackets for jacket outside diameters 200 mm (8 inches) and larger. Provide stainless steel bands, minimum width of 13 mm (0.5 inch). Provide factory prefabricated aluminum covers for insulation on fittings, valves, and flanges

2.6 ASPHALT-SATURATED FELT

ASTM D 226, without perforations, minimum weight of 0.49 kilograms per square meter (10 pounds per 100 square feet).

2.7 STAINLESS STEEL JACKET

ASTM A 167 or ASTM A 240/A 240M; Type 304, minimum thickness of 0.25 mm(0.010 inch), smooth surface with factory-applied polyethylene and kraft paper moisture barrier on inside surface. Provide stainless steel bands, minimum width of 13 mm (0.5 inch). Provide factory prefabricated stainless steel covers for insulation on fittings, valves, and flanges.

PART 3 EXECUTION

3.1 INSTALLATION

Insulation shall be clean, dry, and installed prior to the application of insulation jacket. Do not use short pieces of insulation and jacket materials where a full length section will fit. Provide insulation materials and jackets with smooth and even surfaces, with jackets drawn tight, and secured on longitudinal and end laps. Insulate fittings and piping accessories with premolded, precut, or field-fabricated pipe insulation of the same pipe insulation material and thickness as the adjoining pipe insulation. Provide unions, flanges, valves, and piping accessories with removable (snap-on) sections of insulation. Provide insulation continuous through pipe hangers and pipe supports. Do not step on or walk on insulation or jacket.

3.2 PIPING INSULATION

3.2.1 Fibrous Glass Pipe Insulation

Install in accordance with the manufacturer's recommendations.

3.2.2 Mineral Fiber Pipe Insulation

Install in accordance with the manufacturer's recommendations.

3.2.3 Calcium Silicate Pipe Insulation

Install in accordance with the manufacturer's recommendations, except as modified herein. Secure with not less than 9.50 mm (0.375 inch) width fibrous glass reinforced waterproof tape or stainless steel bands spaced not more than 200 mm (8 inches) on centers. Provide one layer of asphalt-saturated felt over the insulation prior to installing aluminum jacket. Factory-applied polyethylene and kraft paper moisture barrier will not be permitted as a substitute for the asphalt-saturated felt.

3.2.4 Cellular Glass Pipe Insulation

Install as specified for calcium silicate pipe insulation.

3.2.5 Polyurethane and Polyisocyanate Pipe Insulation

Install only on aboveground pumped condensate (hot water) return piping in accordance with the manufacturer's recommendations.

3.2.6 Mineral Fiber Pipe Wrap Insulation

Install in accordance with the manufacturer's recommendations.

3.3 INSULATION JACKET

Machine cut the jacket to produce a straight, smooth edge. Lap longitudinal and circumferential seams not less than 50 mm (2 inches). Install jackets on horizontal piping with the longitudinal seam approximately midway between horizontal centerline and the bottom side of pipe. Install with the top edge of jacket overlapping the bottom edge of jacket and with the seam of each jacket offset from the seam of the adjacent jacket. Install jackets on vertical piping and on piping pitched from the horizontal from low point to high point so that the lower circumferential edge of each jacket overlaps the jacket below it. Provide factory prefabricated covers for insulation on fittings, valves, and flanges. Finish jackets neatly at pipe hangers and pipe supports. Terminate jackets neatly at the ends of unions, valves, traps, and strainers. Secure jacket with stainless steel bands spaced not more than 200 mm (8 inches) on center.

3.3.1 Additional Requirements for Insulated Piping Under Piers

Provide one layer of asphalt-saturated felt over the insulation prior to installing stainless steel jacket.

3.3.2 Under Pier Stainless Steel Jacket

In addition to the above requirements for aluminum jackets, secure longitudinal and circumferential seams with stainless steel screws spaced not more than 100 mm (4 inches) on centers. At approximately every 6 linear meter (20 linear feet) of piping, lap the circumferential seams not less than 150 mm (6 inches); omit the screws.

3.4 ASPHALT-SATURATED FELT

Apply felt with longitudinal and circumferential seams lapped not less than 150 mm (6 inches). Secure with not less than 13 mm (0.5 inch) width stainless steel bands spaced not more than 200 mm (8 inches) on center.

END OF SECTION

SECTION 15100

VALVES

PART 1 GENERAL

1.01 SCOPE OF WORK

A. Furnish all labor and material to install polyvinyl chloride (PVC) valves as shown on the piping and P&ID drawings and this section.

1.02 RELATED WORK

A. Process instruments and controls are included in Division 13. However, if applicable, valve operators shall be mounted at the factory on the valves as specified herein, as part of the work of this Section.

B. Electrical is included in Division 16.

1.03 SUBMITTALS

A. Drawings showing details of construction and dimensions.

B. Descriptive catalog information giving valve pressure and temperature ratings and all materials of construction.

1.04 REFERENCE STANDARDS

A. American Society for Testing and Materials (ASTM).

1. ASTM D1784 - Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds.

2. ASTM F1970 –Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Valves

4. ASTM D2564 - Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Piping Systems.

5. ASTM D2855 - Standard Practice for Making Solvent-Cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings.

1.05 QUALITY ASSURANCE

A. Valves and appurtenances shall be products of well established firms who are fully experienced, minimum 3 years, reputable and qualified in the manufacture of the particular equipment to be furnished. All units of the same type shall be the product of one manufacturer.

B. The equipment shall be designed, constructed and installed in accordance with the best practices and methods and shall comply with this Section as applicable.

1.06 SYSTEM DESCRIPTION

A. All of the equipment and materials specified herein is intended to be standard for use in controlling the flow of groundwater, air and chemicals as noted on the Drawings.

B. Valves, appurtenances and miscellaneous items shall be installed as shown on the Drawings and as specified, so as to form complete workable systems.

1.07 DELIVERY, STORAGE AND HANDLING

A. All shipping crates and boxes shall be identified with the appropriate purchase order number and labeled with special handling instructions. Net weight shall be shown.

B. The equipment shall be shipped with suitable in transit protections.

1.08 OPERATING INSTRUCTIONS

A. Operating manuals covering instructions and maintenance sheets on each type of valve supplied shall be furnished with the equipment.

PART 2 PRODUCTS

2.01 MATERIALS AND EQUIPMENT - GENERAL

A. Valves shall be of polyvinyl chloride (PVC) manufactured to ASTM F 1970 and constructed from PVC Type I, ASTM D-1784, Cell Classification 12454.

B. Valves and appurtenances shall be of the size shown on the Drawings or as noted; and as far as possible, equipment of the same type shall be identical and from one manufacturer.

C. Valves and appurtenances shall have the name of the maker, nominal size, flow directional arrows, working pressure for which they are designed and standard referenced, cast in raised letters or indelibly marked upon some appropriate part of the body.

D. Unless otherwise noted, valves shall have a minimum working pressure greater than or equal to rated pressure of the connected pipe.

E. Unless otherwise noted valves shall be True Union with socket ends. Flange adaptors shall be provided where connected to flanged equipment or valves.

F. Unless other noted, valves and appurtenances shall be of the same nominal diameter as the pipe or fittings they are connected to.

2.02 BALL VALVES

A. Ball valves shall be True Union buttress thread industrial valves. Provide flange adapters where necessary for mate up to check valves or other flanged fittings.

B. All PVC 1/2” through 3” ball valves shall be pressure rated at 235 psi non-shock water at 73 ^{o}F.

C. Ball valves shall be schedule 80 Full-Bore design.

D. Ball valves shall have Viton O-ring double stem seals and fully serviceable with replaceable components.

E. Ball valves shall have built-in handle lockout.

F. Ball valves shall be Spears True Union 2000 industrial ball valves or approved equal.

2.03 CHECK VALVES

A. PVC check valves shall be swing check suitable for horizontal or vertical operation.

B. Valve body shall be one-piece molded flanged body with 150 pound flange ends.

C. Valves shall be rated a 150 psig at 68° F.

D. The O-rings and seals shall be of Viton.

E. All valve components shall be replaceable and accessible without removal of valve from the line.

F. Check valves shall be Chemline SC Series swing check valve or equivalent.

2.04 AIR RELEASE VALVES/ VACUUM BREAKER VALVES

A. Air release valve body shall be PVC construction meeting the requirements of ASTM D-1784.

B. Opening and closing shall not be affected by pressure.

C. Valves shall be rated for 232 psi at 73° F.

D. Valves shall be ¾” size with threaded end connections.

E. Valves shall be IPEX Xirtec 140 or equivalent.

PART 3 EXECUTION

3.01 INSTALLATION - GENERAL

A. All valves and appurtenances shall be installed per the manufacturer's instructions in the locations shown, true to alignment and rigidly supported.

B. Valves shall be leak tested under Section 15073.

C. Valves identified on the piping and P&ID drawings with valve numbers shall be permanently identified by attaching numbered tags.

END OF SECTION

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SECTION 15140

PIPE HANGERS AND SUPPORTS

PART 1 GENERAL

1.01 SCOPE OF WORK

A. Furnish all labor, materials, equipment and incidentals and install a complete system of pipe hangers, supports, concrete inserts and anchor bolts including all metallic hanging and supporting devices for supporting non-buried piping as shown on the Drawings and as specified herein.

B. The absence of pipe supports and details on the Drawings shall not relieve the Subcontractor of the responsibility for providing them. Pipe supports indicated on the Drawings are shown only to convey the intent of the design for a particular location and are not intended to represent a complete system.

1.02 RELATED WORK

A. Piping systems are included in respective Section 15050.

B. Valves are included in Section 15100.

1.03 SUBMITTALS

A. Submit to the Subcontractor complete sets of shop drawings of all items to be furnished under this Section.

B. Submittals shall include a representative catalog cut for each different type of pipe hanger or support indicating the materials of construction, important dimensions and range of pipe sizes for which that hanger is suitable. Where standard hangers and/or supports are not suitable, submit detailed drawings showing materials and details of construction for each type of special hanger and/or support.

1.04 REFERENCE STANDARDS

A. Manufacturer's Standardization Society of the Valve and Fittings Industry (MSS)

1. MSS SP-58 - Pipe Hangers and Supports - Materials, Design and Manufacture.
2. MSS SP-69 - Pipe Hangers and Supports - Selection and Application.

B. American Society for Testing and Materials (ASTM)

1. ASTM A36 - Standard Specification for Carbon Structural Steel.
2. ASTM A307 - Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.

C. American National Standards Institute (ANSI)

1. ANSI B31.1 - Power Piping.

1.05 QUALITY ASSURANCE

A. All hangers, supports and appurtenances shall conform to the latest applicable requirements of ANSI B31.1, except as supplemented or modified by the requirements of this Section.

B. All hangers, supports and appurtenances shall be of approved standard design where possible and shall be adequate to maintain the supported load in proper position under all operating conditions.

1.06 DELIVERY, STORAGE AND HANDLING

A. All supports and hangers shall be crated, delivered and uncrated so as to protect against any damage.

B. All parts shall be properly protected so that no damage or deterioration shall occur during a prolonged delay from the time of shipment until installation is completed.

C. Finished metal surfaces not galvanized, that are not of stainless steel construction, or that are not coated, shall be grease coated, to prevent rust and corrosion.

PART 2 PRODUCTS

2.01 GENERAL

A. All of the equipment specified herein is intended to support the various types of pipe and piping systems shown on the Drawings.

B. All pipe and tubing shall be supported as required to prevent significant stresses in the pipe or tubing material, valves, fittings and other pipe appurtenances and to support and secure the pipe in the intended position and alignment. All supports shall be designed to adequately secure the pipe against excessive dislocation due to thermal expansion and contraction, internal flow forces and all probable external forces such as equipment, pipe and personnel contact.

C. The Subcontractor may propose minor field adjustments to the piping arrangements in order to simplify the supports, or in order to resolve minor conflicts in the work.

D. Where flexible couplings are required at equipment, tanks, etc, the end opposite to the piece of equipment, tank, etc, shall be rigidly supported, to prevent transfer of force systems to the equipment. No fixed or restraining supports shall be installed between a flexible coupling and the piece of equipment.

E. All pipe and appurtenances connected to the equipment shall be supported in a manner to prevent any strain from being imposed on the equipment or piping system.

F. Changes in direction (e.g. 90° elbows) shall be supported as close as practical to the fitting to avoid introducing excessive torsional stresses into the system.

G. Supports shall be sufficiently close together such that the sag of the pipe is within limits that will permit drainage and avoid excessive bending stresses from concentrated loads between supports.

H. All uninsulated non-metallic piping shall be protected from local stress concentrations at each support point. Protection shall be provided by galvanized steel protection shields or other method as approved by the Contractor. Where pipes are bottom supported 180°, arc shields shall be furnished. Where 360-degree arc support is required, such as U bolts, protection shields shall be provided for the entire pipe circumference. Protection shields shall have an 18 gauge minimum thickness, not be less than 12 in. in length and be securely fastened to pipe with stainless steel or galvanized metal straps not less than 1/2-in wide.

I. Where pipe hangers and supports come in contact with copper piping provide protection from galvanic corrosion by; wrapping pipe with 1/16-in thick neoprene sheet material and galvanized protection shield; isolators similar to Elcen, Figure No. 228; or copper plated or PVC coated hangers and supports.

J. Pipe supports where applicable shall be provided as follows:

1. Support spacing for steel and stainless steel piping 2 in. and smaller diameter and copper tubing shall not exceed 5 ft.

2. Individually supported PVC pipes shall be supported as recommended by the manufacturer at 100° F temperature except that support-spacing shall not exceed 6 ft in any size.

3. All vertical pipes shall be supported at intervals of not more than 8 ft by approved pipe collars, clamps, brackets, or wall rests and at all points necessary to insure rigid construction. All vertical pipes passing through pipe sleeves shall be secured using a pipe collar.

4. Pipe supports shall not induce point loadings but shall distribute pipe loads evenly along the pipe circumference.

5. PVC pipe hangers shall be provided with protective sleeve to spread bearing surface as recommended by the manufacturer.

6. PVC pipe hangers shall be on band, clevis, or roller that permit pipe movement unless anchoring or clamping hanger is required.

6. Supports shall be provided at changes in direction and elsewhere as shown in the Drawings or as specified herein.

6. Pipe supports shall be provided to minimize lateral forces through valves, both sides of split type couplings and sleeve type couplings and to minimize all pipe forces on pump housings. Pump housings shall not be utilized to support connecting pipes.

7. Effects of thermal expansion and contraction of the pipe shall be accounted for in the pipe support selection and installation.

K. Unless otherwise specified herein, pipe hangers and supports shall be standard catalogued components, conforming to the requirements of MSS-SP-58 and -69.

L. Hanger rods shall be hot rolled steel, machine threaded and galvanized after fabrication. The strength of the rod shall be based on its root diameter. Inserts shall be malleable iron, or steel with galvanized finish. Beam clamps, C-clamps or welded beam attachments shall be used for attaching hanger rods to structural steel members.

2.02 SINGLE PIPE HANGERS

A. Single pipes shall be supported by hangers suspended by hanger rods from structural steel members, bottom of trapeze hangers and wall mounted steel angle brackets.

B. Except as otherwise specified herein, pipe hangers shall be steel, of the adjustable clevis type as required.

C. Where pipes are near walls, beams, columns, etc, and located an excessive distance from ceilings or underside of beams, welded steel wall brackets shall be used for hanging pipe.

2.03 MULTIPLE PIPE HANGERS

A. Suspended multiple pipes, running parallel in the same horizontal plane, which are adjacent to each other shall be suspended by trapeze type hangers or wall brackets. Trapeze hangers shall consist of galvanized structural steel channel supported from galvanized threaded rod or attached to concrete walls, columns or structural steel support members as required to meet the intent of this Section.

B. Except as otherwise specified herein pipe anchors' material of construction shall be galvanized steel. Chair "U" bolts shall be tightened to allow freedom of movement for normal expansion and contraction except where pipe must be anchored to control direction of movement.

2.04 SINGLE AND MULTIPLE PIPE SUPPORTS

A. Single pipes located in a horizontal plane close to the floor shall be supported by one of the methods as specified herein.

B. Pipes 3 in. in diameter and larger shall be supported by adjustable stanchions, as necessary. Stanchions shall provide at least 4 in. adjustment and be flange mounted to floor.

C. Pipes less than 3 in. in diameter shall be held in position by supports fabricated from steel "C" channel, welded post base and pipe clamps. Where required to assure adequate support, fabricate supports using two vertical members and post bases connected together by horizontal member of sufficient load capacity to support pipe. Wherever possible, supports shall be fastened to nearby walls or other structural member to provide horizontal rigidity. More than one pipe may be supported from a common fabricated support.

2.05 WALL SUPPORTED PIPES

A. Single or multiple pipes located adjacent to walls, columns or other structural members, whenever deemed necessary, shall be supported using welded steel wall brackets; or "C" channel with steel brackets. All members shall be securely fastened to wall, column, etc, using double expansion shields or other method as approved by the Contractor. Additional wall bearing plates shall be provided where required.

B. Pipe shall be attached to supports using methods specified herein to meet the intent of this Section.

2.06 BASE ANCHOR SUPPORT

A. Where pipes change direction from horizontal to vertical via a bend, a welded or cast base bend support shall be installed at the bend to carry the load. The base bend shall be fastened to the floor, pipe stanchion, or concrete pedestal using expansion anchors or other method as approved by the Subcontractor.

2.07 VERTICAL PIPE SUPPORTS

A. Where vertical pipes are not supported by a "C" channel system as specified in Paragraph 2.08 below, they shall be supported by the following method. An extension hanger ring shall be provided with an extension rod and hanger flange. The rod diameter shall be as recommended by the manufacturer for the type of pipe to be supported. The hanger ring shall be steel or PVC clad depending on the supported pipe. The anchor flange shall be galvanized malleable iron.

2.08 SPECIAL SUPPORTS

A. Pipe supports shall be provided for closely spaced vertical piping systems required to provide a rigid installation. The interval of vertical support spacing shall be as specified, but in no case shall vertical interval exceed 10-ft. The support system shall consist of a framework suitably anchored to floors, ceilings or roofs.

B. Vertical and horizontal supporting members shall be U shaped channels. Vertical piping shall be secured to the horizontal members by pipe clamps or pipe straps. All components shall be of steel.

C. For piping larger than 3-in, the support frame shall be fabricated from structural steel shapes and secured through the use of expansion anchors.

D. The assemblies shall be furnished complete with all nuts, bolts and fittings required for a complete assembly including end caps for all "C" channel members.

E. Supports not otherwise described in this Section shall be fabricated or constructed from standard structural steel shapes in accordance with applicable provisions of Section 05500, or "C" channel frame; have anchor hardware similar to items previously specified herein, shall meet the minimum requirements listed below and be subject to the approval of the Subcontractor. The pipe support system shall not impose loads on the supporting structures in excess of the loads for which the supporting structure is designed.

2.10 SURFACE PREPARATION AND SHOP PRIME PAINTING

A. All bare metal surfaces shall be prepared and shop painted as part of the work of this Section. Any additional field hangers and supports shall be field painted.

PART 3 EXECUTION

3.01 INSTALLATION

A. Proceed with the installation of piping and supports only after any building structural work has been completed and new concrete has reached its 28-day compressive strength.

B. The installation of pipe support systems shall in no way interfere with the operation of overhead rollup doors.

C. The installed systems shall not interfere with maintenance and operational access to any equipment installed under this Section, or any other related Section.

D. Wherever possible, supports shall be fastened to nearby walls or other overhead structural members to minimize using floor space for pipe stands and supports. No floor supports shall impede door ways, access ways, or aisle ways.

E. Horizontal carrier hangers, trays, or channels shall be used to minimize floor supports for plastic pipe.

F. All pipes horizontal and vertical, requiring rigid support shall be supported from the building structure by approved methods. Supports shall be provided at changes in direction and elsewhere as shown in the Drawings or as specified herein. No piping shall be supported from metal stairs, ladders and walkways unless specifically directed or authorized by the Contractor.

G. All pipe supports shall be designed with liberal strength and stiffness to support the respective pipes under the maximum combination of peak loading conditions to include pipe weight, liquid weight, liquid movement and pressure forces, thermal expansion and contraction, vibrations and all probable externally applied forces.

H. Pipe supports shall be provided to minimize lateral forces through valves, both sides of split type couplings and sleeve type couplings (within four pipe diameters) and to minimize all pipe forces on pump housings. Pump housings shall not be utilized to support connecting pipes.

3.02 INSPECTION AND TESTING

A. After installation, each pipe support system shall be inspected for compliance with this section prior to leak tests.

B. All hangers shall be snug to pipe and supporting weight.

C. After leak testing, the hangers shall be inspected again to ensure all are supporting weight.

D. If any part of the pipe support system proves to be defective or inadequate, it shall be repaired or augmented under this Section to the satisfaction of the Contractor.

END OF SECTION

SECTION 16050

BASIC MATERIALS AND METHODS

PART 1 - GENERAL

1.01 DESCRIPTION

This section, along with the other sections included in this division of work, unless noted otherwise, covers the complete procurement, installation, and testing of all electrical material and equipment in accordance with the contract drawings and as hereinafter specified.

1.02 REFERENCES

A. Each specification section of this division (16) includes references to nationally accepted standards, codes, and regulations. These are intended to serve as the governing rules for the fabrication, construction, and testing activities specified by this specification and related drawings.

B. American National Standards Institute (ANSI) C1, National Electrical Safety Code (NESC).

C. ANSI/National Fire Protection Association 70, National Electrical Code (NEC).

D. Underwriters' Laboratories, Inc. (UL) standards where referenced in this division.

E. Temporary lighting and power circuits required for construction shall be installed in accordance with Article 305 of the NEC.

F. Procure all materials and equipment and perform all work in accordance with applicable sections of the latest officially released issue of each listed reference in effect on the date of this specification.

PART 2 - PRODUCTS

2.01 GENERAL

A. Materials

1. Furnish all new materials (and equipment), unless otherwise noted, and which are approved by UL or other nationally recognized testing laboratories whenever standards have been established by one of these agencies.

2. Required materials (and equipment) are specified on the drawings or in this specification. In the event of conflicts between the drawings and specifications, the specifications govern.

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION/ERECTION

Install all work to conform with the requirements of the NEC and the NESC and to the applicable rules of national standards and codes hereinafter referenced.

Temporary lighting and power circuits required for construction are to be installed in accordance with Article 305 of the NEC.

A. Cutting and Patching

1. Perform all cutting and patching, repairing, and other similar alterations required for the installation of electrical material and equipment by craftsmen skilled in the trade involved.

2. Patch or replace to match any existing work which is cut, removed, or otherwise damaged during the installation of electrical material and equipment.

B. Openings, Penetrations, and Inserts

1. Provide all openings required for the work.

2. Seal around all conduits penetrating floors and concrete or masonry fire-zone walls in accordance with details shown on the drawings or by installing 3-h rated flanged conduit fireseals, O-Z/Gedney Company Type CFSF.

3. Seal all cable tray and bus duct penetrations of floors and fire-zone walls in accordance with details shown on the drawings.

4. Seal around all raceways penetrating exterior building walls of wood, asbestos, sheet metal, etc., with silicone rubber sealant, General Electric RTV-102 Dow Corning 732, or equivalent.

5. Locate all chases, sleeves, inserts for hangers, supports, and fastenings in order to minimize interferences.

C. Installation Methods

1. Perform all labor required for the installation of electrical material and equipment using craftsmen skilled in the electrical trade.

2. Make fastenings to wood by means of wood screws or bolts; to masonry by means of threaded metal inserts, metal expansion screws, metal expansion shields, or bolts; and to steel by means of machine screws, bolts, or by welding. No wood or fiber plugs will be permitted. Fastenings to concrete may be accomplished with "Ramset" low-powered gun fasteners, bolts, or expansion anchors.

3. Furnish and install hangers, supports, and equipment racks for all electrical materials and equipment.

4. Fabricate hangers for supporting conduit and electrical equipment from angle iron, channel iron, "Unistrut," galvanized, or cadmium-plated rods. Space conduit hangers in accordance with Section 16111.

5. Fabricate supports for electrical equipment from angle iron, channel iron, or "Unistrut" and, when required, covered with steel plate. Supports shall be of all-welded construction. Fasten equipment to plate with hex-head bolts, hex nuts, and lock washers.

6. Fabricate equipment racks for mounting electrical equipment from P-1000 "Unistrut" unless otherwise shown on the drawings. Racks shall be of bolted or welded construction. Mount equipment to racks with hex-head bolts, spring nuts, and lock washers.

D. Painting

1. Clean rust and scale from unfinished members used in the fabrication of hangers, supports, and equipment racks. Paint with one coat of metal primer after fabrication and then, if not concealed, paint finish coat.

2. Paint unfinished surfaces of conduit, panels, cabinets, and pull boxes.

END OF SECTION

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SECTION 16111

CONDUIT

PART 1 - GENERAL

1.01 DESCRIPTION

Section includes:

A. Metal conduit.

B. Flexible metal conduit.

C. Liquid-tight flexible metal conduit.

D. Polyvinyl chloride (PVC) - coated metal conduit.

1.02 RELATED WORK

A. Section 16195 - Electrical Identification

B. Section 16450 - Grounding

1.03 REFERENCES

A. American National Standards Institute (ANSI) C80.1 - Rigid Steel Conduit, Zinc Coated.

B. ANSI/National Fire Protection Agency (NFPA) 70 - National Electrical Code.

C. NECA "Standard of Installation."

D. National Electrical Manufacturers Association (NEMA) RN 1 - Polyvinyl Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit.

E. NEMA TC 3 - PVC Fittings for Use with Rigid PVC Conduit and Tubing.

1.04 SUBMITTALS

A. Submit data for approval.

1.05 PROJECT RECORD DOCUMENTS

Accurately record actual routing of conduits and submit as-built drawings upon completion of work.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver conduit to job site in 10-ft lengths. Inspect for damage.

B. Protect conduit from corrosion and entrance of debris by storing above grade. Provide appropriate covering.

C. Protect PVC conduit from sunlight.

PART 2 - PRODUCTS

2.01 MATERIALS

Furnish products listed and classified by Underwriters Laboratories, Inc as suitable for purpose specified and shown.

A. Heavy-Wall Rigid Steel Conduit

Rigid steel conduit shall be Schedule 40 hot-dipped galvanized or electrogalvanized conduit, manufactured in accordance with UL Standard UL-6 and ANSI Specification C80.1, and be UL listed.

B. Liquid-Tight Flexible Metal Conduit

1. Liquid-tight flexible metal conduit shall be fabricated of galvanized steel flexible tubing with a synthetic jacket extruded over the tubing. It shall be manufactured in accordance with UL Standard UL-360 and be UL listed.

2. All flexible conduits exposed to weather, water, or other liquids shall be liquid-tight with connectors approved for this use.

3. Liquid-tight conduit assemblies shall include, on each end, an insulated, straight or 90-angle connector equal to Thomas & Betts Company Series 5300. This shall be the conduit assembly intended wherever a Liquid-tight assembly is called for on the drawings or in these specifications.

4. Liquid-tight conduit assemblies shall be used between motor terminal boxes or other equipment subject to vibration and/or mechanical adjustment, the rigid conduit systems, or elsewhere as shown on the drawings. Liquid-tight conduit used to connect to motor terminal boxes for housing motor conductors shall be not less than 12 times the trade size in length but in no case less than 12 in.

C. Rigid Polyvinyl Chloride Conduit

Rigid PVC conduit shall be Schedule 40 PVC. It shall be manufactured in accordance with NEMA TC 2 and be listed as in compliance with UL Standard UL-651.

PART 3 - EXECUTION

3.01 PROJECT FIELD CONDITIONS

A. Verify that field measurements shown on drawings.

B. Verify routing and termination locations of conduit prior to rough-in.

C. Conduit shown on drawings is routed in approximate locations unless dimensioned. Route as required to complete wiring system.

D. Conduit runs in floor slab or underground shall be installed exactly as shown and dimensioned on the construction drawings. Any deviations from the locations shown on the drawings must be approved by the Field Engineer prior to installation of the conduit. The location of underground conduit shall be marked aboveground in the manner specified on the drawings.

E. When not shown in detail on the drawings, the exact locations and routing of conduit and the location and sizing of conduit sleeves passing through floors, walls, etc., shall be determined by the Field Engineer subject to approval of the Project Manager or designee.

3.02 INSTALLATION ABOVEGROUND (EXPOSED OR CONCEALED)

A. Install exposed conduits at right angles to or parallel to building structural members. Diagonal runs will be permitted only in concrete slabs or in special cases with prior approval of the Project Manager or designee.

B. Conduit shall in no case be secured directly to other piping. Conduit parallel to or crossing uninsulated hot water or steam pipes must be separated from them by 12 in. if parallel or 6 in. if crossing. Where these lines are insulated, conduit parallel to or crossing them must clear the insulation surface by 2 in. Conduit shall not be run directly under cold water lines and shall be separated from them in other directions by at least 3 in.

C. Conduit shall be cut square with an approved conduit cutter and threaded with an approved conduit threader. The ends shall be reamed of burrs, and all metal shavings and cutting lubricants shall be removed before the conduit is connected to the conduit system.

D. IMC, rigid metal conduit, PVC conduit, and EMT, whether concealed or exposed, shall be adequately supported in accordance with paragraphs 345-12, 346-12, 347-8, and 348-12 of the National Electrical Code, respectively.

E. Metallic conduit shall be secured to walls, building framing, etc., by the use of malleable iron, galvanized U-bolts, beam clamps, conduit straps, or "Unistrut" fittings where "Unistrut" racks or supports are used.

F. IMC and rigid metal conduit shall be securely fastened to all outlet boxes, pull boxes, cabinets, and switch boxes with double lock nuts and insulating bushings unless boxes with hubs are provided.

G. EMT shall be terminated with rain-tight, compression-type connectors with insulated throats. Couplings used with EMT shall be rain-tight, compression type. Set screw-type connectors and couplings are unacceptable.

H. Rigid PVC conduit shall be secured to walls, building framing, etc., by the use of stainless steel or PVC-coated conduit straps, hangers, or "Unistrut" fittings. The use of beam clamps or any other support device that places substantial pressure upon the conduit is prohibited. PVC conduit and fittings shall be joined using PVC conduit couplings and solvent cement specifically approved for use with PVC. Expansion couplings shall be installed in all straight conduit runs exceeding 100 ft. Termination of PVC conduit in electrical boxes and enclosures shall be made utilizing threaded PVC terminal adapters.

I. Use appropriate tools to install PVC-coated conduit, and take care to avoid damage to the exterior coating. After installation, repair any damaged area with Plasti-Bond touch-up compound.

J. All field-cut threads in IMC and rigid steel conduit shall be coated with electrically conductive, antiseize compound, Thomas & Betts "KOPR-SHIELD" or approved equal.

K. All conduit connections shall be made with appropriate fittings and securely tightened. Improperly made connections or terminations, as well as any which have not been adequately tightened, will be rejected.

L. Conduit openings into which dirt, plaster, motor mix, or debris may fall shall be closed with caps or tight-fitting plugs during the construction period. Conduits in which such material has accumulated shall be thoroughly cleaned. Where such accumulations cannot be readily removed, the conduit shall be replaced.

M. Conduits to be sealed for the purpose of preventing airflow and rodent and insect access shall be sealed where specified on the drawings with a pliable, duct-sealing compound, such as John-Manville "Duxseal." Compounds which solidify, such as Crouse-Hinds "Chico," shall be used with sealing-type conduit fittings.

N. Expansion couplings shall be installed in all conduit runs crossing building expansion joints and shall be located between conduit supports adjacent to the expansion joint.

3.03 INSTALLATION UNDERGROUND

A. All threaded connections in conduits installed in building floor slabs or underground shall be sealed watertight with "Permatex" Type 2 nonhardening sealant. Conduit must be clean and dry and must pass standard sizing test after concrete is poured. All unused conduits shall be capped. Those conduits subject to being filled with water shall have watertight caps.

B. Underground conduit shall be IMC, rigid galvanized steel, PVC, or fiber as specified on the drawings.

END OF SECTION

SECTION 16120

BUILDING WIRE AND CABLE - 600 V AND BELOW

PART 1 - GENERAL

1.01 DESCRIPTION

Section includes:

A. Building wire and cable.

B. Underground feeder and branch circuit cable.

C. Service entrance cable.

1.02 RELATED SECTIONS

A. Section 16111 - Conduit.

B. Section 16123 – Splices and Terminations - 600 V and Below.

C. Section 16195 – Electrical Identification.

D. Section 16950 – Electrical Testing.

1.03 REFERENCES

A. American National Standards Institute/National Fire Protection Agency (ANSI/NFPA) 70 - National Electrical Code.

B. National Electrical Manufacturers Association (NEMA) WC-5 - Thermoplastic-Insulated Wire and Cable.

1.04 SUBMITTALS

A. Submit for approval.

B. Test Reports: Submit in accordance with Section 16950. Indicate procedures and values obtained.

1.05 QUALIFICATIONS

Manufacturer: Company specializing in manufacturing products specified in this section with minimum 3 years experience.

1.06 REGULATORY REQUIREMENTS

A. Conform to requirements of ANSI/NFPA 70.

B. Furnish products listed and classified by Underwriters' Laboratories, Inc. (UL) as suitable for purpose specified and shown.

1.07 PROJECT CONDITIONS

A. Verify that field measurements shown on drawings.

B. Conductor sizes are based on copper unless indicated as aluminum or "AL."

C. Wire and cable routing shown on drawings is approximate unless dimensioned. Route wire and cable as required meeting project conditions.

D. Where wire and cable routing is not shown and destination only is indicated, determine exact routing and lengths required.

1.08 COORDINATION

A. Coordinate work with other crafts.

B. Determine required separation between cable and other work.

C. Determine cable routing to avoid interference with other work.

PART 2 - PRODUCTS

2.01 MANUFACTURERS - BUILDING WIRE AND CABLE

A. ANNIXTER

B. SOUTHWIRE

C. ALPHA

D. Substitutions: Submit for approval.

2.02 BUILDING WIRE AND CABLE

A. Description: Single conductor insulated wire.

B. Conductor: Copper as specified on the drawings.

C. Stranding:

1. All wire No. 8 and larger shall be stranded. Wire No. 10 AWG and smaller feeding lights and receptacles shall be solid. Wire No. 10 AWG and smaller installed for motor leads and control wiring shall be stranded.

2. Cables shall have standard stranding for sizes as follows: 7 strands up through No. 2; 19 strands from No. 1 through No. 4/0; 37 strands from 250 MCM through 500 MCM; and 61 strands from 600 MCM through 1,000 MCM [except where noted otherwise on the drawings].

D. Insulation Voltage Rating: 600V.

E. Insulation: Conductors installed in conduit and raceways; ANSI/NFPA 70:

1. Type THW or XHHW insulation for feeders and branch circuits larger than No. 10 AWG;

2. Type THHN/THWN insulation for feeders and branch circuits No. 10 AWG and smaller;

3. Type THHN/THWN insulation for conductors enclosed in fluorescent lighting fixtures.

F. Color Coding:

1. All grounded (neutral) conductors No. 2 AWG and smaller shall have white insulation. Grounded conductors larger than No. 2 AWG shall be identified at all terminal or junction points by wrapping with white, self-adhesive, vinyl-plastic electrical tape, Scotch 35. Sufficient length of cable nearest terminal or junction point shall be taped so that neutral conductors shall be easily identifiable when covers of lighting panels, transformers, junction boxes, safety switches, etc., are removed. Color code ungrounded (phase) conductors as follows:

a. 240/120-V, single-phase systems

Ungrounded conductor - black
Ungrounded conductor - red

b. 208/120-V, three-phase systems

Phase "A" - black
Phase "B" - red
Phase "C" - blue

c. 480/277-V, three-phase systems

Phase "A" - brown
Phase "B" - orange
Phase "C" - yellow

d. 480-V, three-phase "Delta" systems

Phase "A" - brown
Phase "B" - orange
Phase "C" - yellow

2. Any insulated conductor intended solely for grounding purposes shall be identified by a continuous green color or a continuous green color with one or more yellow stripes.

3. Ungrounded single-conductor control circuit wiring may be a combination of any colors other than white, gray, or green. The grounded control circuit conductor shall be identified in accordance with para. F.1.

4. Conductors of multiwire branch power and lighting circuits shall have identifying colors in conformity with the color coding schedule on the drawings. A unique color scheme shall be used for each different voltage system.

2.03 600-V CONTROL CABLE

A. Multiconductor control cables shall be moisture resistant, small diameter type unless otherwise specified on the drawings. Cables shall be Type TC (tray cable), 600 V, 90°C per NEC Article 340 and NEMA WC-5. Cables shall be approved by UL for conduit, cable tray, and underground duct installations.

B. Conductors shall be stranded copper with heat- and moisture-resistant polyvinyl chloride (PVC) insulation, 15 mils thick minimum, and covered with clear nylon jacket, 5 mils thick minimum. Conductors shall be color coded in accordance with NEMA WC-5, Appendix I, Table I-1 for NEC applications or Table I-2 for control circuit applications. Cables shall have an overall flame-resistant sheath of PVC.

C. The number and size of conductors and the exact color-coding requirements shall be as specified on the drawings.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that mechanical work likely to damage wire [and cable] has been completed.

3.02 PREPARATION

A. No wire and cable shall be pulled until the conduit system is complete from pull point to pull point.

B. Completely and thoroughly swab raceway before installing wire.

C. Care shall be exercised while installing wire in conduits so as not to damage the conductor insulation. Ideal Industries' "Yellow-77" or "Wire Lube" or Electro Compound Company's

"Y-ER-EAS" compound may be used in pulling nonarmored conductors and shall be used if wire is pulled by mechanical means.

3.03 GENERAL WIRING METHODS

A. Exterior Locations: Use only building wire Type THW or XHHW insulation in raceway

B. Use wiring methods indicated on drawings.

C. Use no wire smaller than No. 12 AWG for power and lighting circuits and no smaller than No. 16 AWG for control wiring.

D. Place an equal number of conductors for each phase of a circuit in same raceway or cable.

E. Splice only in junction or outlet boxes.

F. Neatly train and lace wiring inside boxes, equipment, and panel boards.

G. Make conductor lengths for parallel circuits equal.

H. The bending radius of any wire or cable shall not be less than the minimum recommended by the manufacturer. Maximum pulling tension and sidewall pressure of any wire or cable shall not exceed manufacturer's recommended values.

3.04 WIRING INSTALLATION IN RACEWAYS

A. Install products in accordance with manufacturers' instructions.

B. Use solid conductor for feeders and branch circuits No. 10 AWG and smaller.

C. Use stranded conductors for control circuits.

D. Pull all conductors into raceway at same time.

3.05 IDENTIFICATION

A. Identify wire and cable under provisions of Section 16195.

B. Identify each conductor with its circuit number or other designation indicated on drawings.

3.06 INSPECTIONS AND TESTS

A. Perform field inspection and testing under provisions of Section 16950.

B. Inspect wire and cable for physical damage and proper connection.

C. Testing: All single- and multiconductor wire cables insulated for 600 V service shall be tested as follows:

Test No. 1 - Continuity

1. Make test for continuity and correctness of wiring and identification on all conductors of lighting and receptacle branch circuits, power and control circuits, and motor leads.

2. Test shall be made with a direct current test device, such as a bell, a buzzer, or a light.

Test No. 2 - Insulation Resistance

3. All 600 V, insulated cables No. 4 AWG and larger installed as branch circuit conductors from substations shall be given an "Insulation Resistance Test" using a 1,000 V insulation tester (Simpson Model 405 or approved equal).

4. The test shall be made with the conductors disconnected at the equipment. The test shall be made between one conductor and ground with the other conductors grounded. Each conductor shall be tested in the same manner. The voltage shall be applied for a minimum of 3 minutes and until the reading reaches a nearly constant value.

5. Acceptable minimum resistance readings shall be 50 megaohms. If Megger readings indicate damaged insulation, the conductor shall be rejected and shall be replaced by the Seller. The replacement conductor must pass the required Megger test.

6. More than one conductor may be listed on the same cable test report provided all conductors listed are tested and accepted on the same date. Reports shall include complete identification of the feeder, Megger readings vs time data, ambient temperature, and weather conditions.

C. Reporting Test Results: The subcontractor shall report all test results in accordance with Section 16950.

END OF SECTION

SECTION 16122

MEDIUM-VOLTAGE CABLE - 15-kV INSULATED

PART 1 - GENERAL

1.01 DESCRIPTION

Section includes:

Medium-voltage cable, 15-kV insulated.

1.02 RELATED SECTIONS

A. Section 16111 - Conduit

B. Section 16124 - Splices and Terminations Medium Voltage Cables

C. Section 16950 – Electrical Testing

1.03 REFERENCES

A. American National Standards Institute (ANSI)/Institute of Electrical and Electronic Engineers (IEEE) C2 - National Electric Safety Code, Association of Edison Illuminating Companies.

B. Association of Edison Illuminating Companies (AEIC) CS5 - Specifications for Thermoplastic and Crosslinked Polyethylene Insulated Shielded Power Cables Rated 5 through 46 kV, 37 pages.

C. AEIC CS6 - Specifications for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 through 69 kV, 36 pages.

D. AEIC 1-68 - Solid-Type Impregnated-Paper-Insulated Lead-Covered Cable Specifications, 53 pages.

E. IEEE 400-80 - Making High-Direct-Voltage Tests on Power Cable Systems in the Field, Guide.

F. National Electrical Manufacturers Association (NEMA) WC7 - Cross-Linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

G. NEMA WC8 - Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

1.04 SUBMITTALS

A. Submit product data for approval indicating cable and accessory construction, materials, and ratings. The following data shall be supplied for each 15-kV cable: complete description of cable, including diameters over conductor, insulation, semicon insulation shield, and overall diameter and ampere rating per conductor based on an ambient temperature of 40°C and a copper temperature of 90°C or 105°C as specified.

B. Submit manufacturers' installation instructions. The following data shall be supplied for each 15-kV cable: manufacturers' instructions for splices and terminations, factory high-potential test voltage, minimum duct-bend radii, maximum pulling tension, and maximum sidewall pressure.

C. Submit manufacturer's certificate that medium voltage cable meets or exceeds specified requirements.

D. Submit "as built" drawings upon completion of work and accurately record exact sizes and locations of cables.

1.05 QUALITY ASSURANCE

A. Manufacturer: Company specializing in medium voltage cable and accessories with minimum 5-years documented experience.

B. Installer: Company specializing in installation of medium voltage cable with minimum 5-years experience.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver cable and accessories on-site in manufacturer's packages and inspect for damage.

B. Protect cable and accessories from weather by covering with opaque plastic or canvas; provide ventilation to prevent condensation. Both ends of all cables shall be sealed to protect the cables against dirt and moisture during storage.

PART 2 - PRODUCTS

2.01 GENERAL

A. Each reel of cable shall bear the manufacturer's name and approval tag, which shall indicate the cable size and type of insulation and shall bear the Underwriters' Laboratories, Inc. (UL) label.

B. All cable furnished and installed shall be listed by UL, for the specific type of installation (conduit, duct, cable tray, etc.) shown on the drawings.

C. All conductors shall be copper.

D. Conductors shall have standard stranding for sizes as follows: 7 strands up through No. 2; 19 strands from No. 1 AWG through No. 4/0; 37 strands from 250 MCM through 500 MCM; and 61 strands from 600 MCM through 1,000 MCM, unless otherwise noted on the drawings.

E. Single-conductor insulation shall be black unless otherwise specified on the drawings. Multiple-conductor cables must contain phase identification by means of letters, numbers, or colored tapes over individual conductor insulations. The color of the individual conductor insulation may be all black or manufacturer's standard for the type cable specified.

F. Cables shall be surface marked at regular intervals, not exceeding 24 in. in accordance with the National Electrical Code Article 310-11.

2.02 CABLE, 15,000 VOLT, SINGLE CONDUCTOR, SHIELDED

A. The cables specified on the drawings as 1/C-15 kV shall be single-conductor, shielded, solid-dielectric type rated for 90°C operations. The cables shall be listed by UL as Type MV-90 and have a 15,000-V rating.

B. The conductor shall be stranded copper, sized in accordance with the drawings. The insulation level shall be 133% of rated voltage with a minimum thickness of 220 mils. The insulation shielding shall be uncoated copper tape.

C. The cables shall conform to one of the following:

1. The cable shall have cross-linked polyethylene (XLP) insulation with a polyvinyl chloride (PVC) jacket and be constructed and tested in conformance with NEMA Standard WC-7 and Association of Edison Illuminating Companies (AEIC) Specification CS5. The cable shall be equal to Rome Cable Type 7245.

2. The cable shall have ethylene-propylene-rubber (EPR) insulation and be constructed in conformance with NEMA Standard WC-8 and AEIC Specification CS6. The cable shall be equal to Rome Cable Corporation Type 7292.

2.03 CABLE, 15,000 VOLT, THREE CONDUCTOR, SHIELDED

A. The cables specified on the drawings as 3/C-15 kV shall be three-conductor, shielded; solid-dielectric type rated for 105°C operations. The cables shall be listed by UL as Type MV-105 and have a 15,000-V rating.

B. The conductor shall be stranded copper, sized in accordance with the drawings. The insulation level shall be 133% of rated voltage with a minimum thickness of 220 mils. The insulation shielding shall be uncoated copper tape.

C. The cable shall have ethylene-propylene-rubber (EPR) insulation and be constructed in conformance with NEMA Standard WC-8 and AEIC Specification CS6. The cable shall be equal to Rome Cable Corporation Type 7525.

PART 3 - EXECUTION

3.01 INSPECTION

A. Verify that conduit or trench is ready to receive work.

B. Verify field measurements shown on drawings.

C. Beginning of installation means installer accepts existing conditions.

3.02 PREPARATION

Thoroughly swab conduits to remove foreign material before pulling cables.

3.03 INSTALLATION

A. Install cable and terminations in accordance with manufacturer's instructions and to ANSI/IEEE C2.

B. Ground cable shield at each termination and splice.

C. No cable shall be pulled until the conduit system is complete from pull point to pull point.

D. Care shall be exercised while installing cable in conduits so as not to damage the conductor insulation. Ideal Industries' "Yellow-77" or "Wire Lube" or American Polywater Corporation's "Polywater J or J-WG" compound may be used in pulling nonarmored conductors and shall be used if cable is pulled by mechanical means.

E. The bending radius of any cable shall not be less than the minimum recommended by the manufacturer. Maximum pulling tension and sidewall pressure of any wire or cable shall not exceed the manufacturers' recommended values.

F. Install cable in manholes along those walls providing the longest route and most spare cable lengths. Arrange cable to avoid interferences with duct entrances into manhole.

G. Where specified on the drawings, cables in manholes, pullboxes, and vaults and exposed high-voltage cable terminations at transformers, potheads, etc., shall be fireproofed. The fireproofing material shall be 3M Company "Irvington" No. 7700 ARC and fireproofing tape or an approved equal. Application of the tape, securing of tape to the cable, and other installation details shall be in accordance with details shown on the drawings.

3.04 FIELD QUALITY CONTROL

A. General

1. Field inspection and testing will be performed under provisions of this section and Section 16950.

2. Inspect exposed cable sections for physical damage. Verify that cable is connected according to drawings and that shield grounding, cable support, and terminations are properly installed.

3. In setting up the test set, special safety precautions should be taken regarding grounding of the test equipment. The test set, its sphere gap (if used), its voltmeter, and the cable sheath should all be grounded to the same ground.

4. Exposed cable connections shall be attended throughout the duration of the test. The machine operator shall coordinate the overall safety effort although each organization is individually responsible for the safety of its personnel.

5. Insulating gloves shall be worn by test personnel making connections during all tests.

6. Test values applied shall not exceed the maximum permissible field test value of component part included in the test.

B. Test No. 1 - Shield Continuity

A continuity test of metallic shields shall be made with an ohmmeter.

C. Test No. 2 - Insulation Resistance No. 1

1. The insulation shall be given an "Insulation Resistance Test" using a 2,500-V insulation tester (Simpson Model 405 or an approved equal). This test shall be made before the "DC High-Potential Test" (Test No. 3).

2. ll 1/C insulated cables shall be tested between conductor and ground with the cable shield grounded.

3. All multiconductor insulated cables shall be tested between one of the conductors and ground with the other two conductors and cable sheath (if shielded) grounded to the same ground. Each conductor shall be successively tested in the same manner.

4. The voltage shall be applied for a long enough duration to fully charge the cable. Resistance readings shall be taken every 15 seconds during the first 3 minutes and at 1-minute intervals thereafter. The test shall continue until three equal readings, 1 minute apart, are obtained. The cable then may be considered to be fully charged.

5. Minimum acceptable resistance readings for 15-kV cables shall be 5,000 megohms for cable lengths of 1,000 ft or less.

D. Test No. 3 - High Potential

1. A "DC High-Potential Test" shall be made after all splices, potheads, and stress cones are made. This test shall be in accordance with IEEE Standard 400-1980.

2. The "DC High-Potential Test" shall be made only after the Contractor’s project representative has approved an initial "Insulation Resistance Test" and before terminal equipment, such as transformers, etc., have been connected.

3. All 1/C insulated cables shall be tested between conductor and ground with the cable shield grounded.

4. All multiconductor insulated cables shall be tested between one of the conductors and ground with the other two conductors and cable sheath grounded to the same ground. Each conductor shall be successively tested in the same manner.

5. The preferred method of conducting the "DC High-Potential Test" is with the negative lead of the high-potential machine connected to the cable under test and the positive lead connected to ground. If a positive-ground machine is unavailable, the test may be made with the polarity opposite that indicated. In either case, the test report shall state which kind of machine was used.

6. The "DC High-Potential Test" voltages shall be 55 kV for 15-kV-rated cables.

7. Apply test voltage slowly, from an initial value not to exceed 25 kV, in increments of equal value (6 kV max, 2 kV min) to the maximum specified level. Allow sufficient time (1 minute suggested) at each step for the leakage current to stabilize or to show unreadably low values. Record leakage current at the end of each step duration.

8. Maintain the maximum test voltage (55 kV) for 5 consecutive minutes. Record the leakage current values at 1-min intervals.

9. Should the leakage current values significantly increase during the soak period, the test shall be aborted. Retest shall proceed only after approval from the Project Manager.

10. After successful completion of the test duration or a failure is experienced, the test potential shall be removed at approximately the same rate as used during its application. Allow the residual voltage on the circuit to decay to at least 20% (10 kV) of the test voltage before applying manual grounds. A retest or reconnection of circuit components shall not be started until the cable has been solidly grounded for a period at least four times (20 min) the test duration.

Caution: It should be recognized that direct current charges can build up potentially dangerous levels if grounds are removed before absorption energy is dissipated.

11. For the cable to be acceptable, the steady-state leakage current values at maximum test voltage must be approximately equal and, in general, less than 25 microamperes.

12. Cables shall not be subjected to more than one "DC High-Potential Test" without the approval of the CONTRACTOR. The maximum test voltage for a second test, should it be necessary, shall be as specified by the CONTRACTOR or DESIGNATED PROJECT REPRESENTATIVE.

E. Test No. 4 - Insulation Resistance No. 2

1. The cable shall be given a second "Insulation Resistance Test" using a 2500-V insulation tester (Simpson Model 405 or approved equal) after completion of Test No. 3.

2. For the cable to be acceptable, the resistance readings must be reasonably parallel to Test No. 2 "Megger" readings.

F. Reporting Test Results

The subcontractor shall report the results of all tests in accordance with Section 16950.

END OF SECTION

SECTION 16123

SPLICES AND TERMINATIONS - 600 V AND BELOW

PART 1 - GENERAL

1.01 DESCRIPTION

Section includes:

A. Wire nuts.

B. Mechanical and compression type connectors suitable for aluminum and copper conductors.

1.02 RELATED SECTIONS

A. Section 16120 - Building Wire and Cable - 600V and Below

1.03 REFERENCES

A. American National Standards Institute (ANSI) A449 - Steel Bolts.

B. ANSI B18.2.2 - Square and Hex Nuts.

C. ANSI B18.22.1 - Plain Washers.

1.04 SUBMITTALS

A. None Required.

PART 2 - PRODUCTS

2.01 CONNECTORS FOR SPLICING AND TERMINATIONS

A. Product definition of connectors for splicing and terminating conductors is listed in Part 3 for the different type and sizes of conductors and for different type terminations and connections.

B. Substitutions: Submit for approval.

PART 3 - EXECUTION

3.01 GENERAL

A. Splices and taps shall generally be made in junction boxes or wiring gutters. Solderless connectors shall be used exclusively.

B. All compression connectors shall be installed in strict accordance with manufacturer's instructions, using properly sized and keyed connectors and dies. Aluminum connectors shall be factory supplied with an appropriate amount of aluminum joint compound inside the connector. All compression connectors shall be Thomas & Betts or an approved equal.

3.02 COPPER CONDUCTOR CONNECTORS 300 V OR LESS

A. Splices, taps, and terminations of stranded conductors No. 10 AWG and smaller shall be made with pressure connectors, Thomas & Betts "Sta-Kon" or equal. Splices and taps in solid No. 10 AWG and smaller shall be made with split-bolt connectors or with insulated wire nuts, Thomas & Betts "Piggy" or equal. Terminations of solid conductors No. 10 AWG and smaller may be made by forming the wire to fit under a screw head, thus requiring no connector.

B. Splices and taps in copper conductors No. 8 AWG through No. 1 AWG and terminations of these sizes of conductors other than in equipment lugs (i.e., molded-case circuit breakers) shall be made with either copper mechanical connectors or with wrought-copper compression connectors.

Type of connection	Type of connector	Thomas & Betts Series No.
Splice	Mechanical - Split-bolt	2T through 8T
Tap	Mechanical - Split-bolt	2T through 8T
Termination	Mechanical - One-hole lug	31000
Splice	Compression - Two-way connector	54500
Tap	Compression - "C" tap	54700
Termination	Compression - One-hole lug	54100

C. Splices and taps in copper conductors No. 1/0 AWG through No. 4/0 AWG and terminations of these sizes of conductors other than in equipment lugs (i.e., molded-case circuit breakers) shall be made with wrought-copper compression connectors.

Type of connection	Type of connector	Thomas & Betts Series No.
Splice	Two-way connector	54500
Tap	C" tap	54700
Termination	Two-hole lug	54200

D. Splices in copper conductors 250 MCM and larger and terminations of these sizes of conductors other than in equipment lugs (i.e., molded-case circuit breakers) shall be made with heavy-duty, cast-copper compression connectors. Taps in these sizes of conductors shall be made with wrought-copper "C" taps.

Type of connection	Type of connector	Thomas & Betts Series No.
Splice	Two-way connector	53500
Tap	"C" tap	54700
Termination	Two-hole lug	53200

E. Copper conductors shall be thoroughly cleaned before connectors are installed.

3.03 COPPER CONDUCTOR CONNECTORS OVER 300 V

All connectors specified for use with copper conductors carrying 300 V or less are applicable for use with conductors carrying up to 600 V, except insulated wire nuts shall not be used. Splices in conductors No. 10 and smaller shall be made with split-bolt connectors.

3.04 ALUMINUM CONDUCTOR CONNECTORS

A. All aluminum-to-aluminum and aluminum-to-copper conductor splices and taps and terminations of all aluminum conductors shall be made with tin-plated, aluminum-bodied, compression-type connectors. Bronze or copper compression or mechanical connectors and aluminum mechanical connectors, whether tin plated or unplated, shall not be used for aluminum conductors.

B. Splices and taps in aluminum conductors up through No. 4/0 AWG and terminations of these sizes of conductors shall be made with wrought-aluminum compression connectors.

Type of connection	Type of connector	Type of cable	Thomas & Betts Series No.
Splice	Two-way	Aluminum to aluminum	60500
Splice	Reducing	Aluminum to copper	60900
Tap	H-tap	Aluminum to aluminum	63100
Tap	H-tap	Aluminum to copper	63100
Termination	1-hole lug	Aluminum	60100
Termination	2-hole lug	Aluminum	60200

Conductors size 1/0 AWG through 4/0 AWG shall terminate with two-hole lugs.

Splices in aluminum conductors 250 MCM and larger and terminations of these sizes of conductors shall be made with heavy-duty, cast-aluminum compression connectors. Taps in these sizes of conductors shall be made with wrought-aluminum "H" taps.

Type of connection	Type of connector	Type of cable	Thomas & Betts Series No.
Splice	Two-way	Aluminum to aluminum	53500A
Splice	Reducing	Aluminum to copper	53500A
Tap	H-tap	Aluminum to aluminum	63100
Tap	H-tap	Aluminum to copper	63100
Termination	2-hole lug	Aluminum	53200A

C. Before installing compression fittings on aluminum conductors, aluminum joint compound, Thomas & Betts Cat. No. 21059, shall be applied to the exposed conductor and wire brushed through it to remove the aluminum oxide film. The fitting shall be installed immediately after wire brushing the conductor.

D. When aluminum conductors are used to supply circuit breakers, switches, motor control centers, etc., that have been furnished by the vendor with lugs other than tin-plated, compression-type aluminum fittings, they shall be installed by one of the following methods.

1. The aluminum conductors shall be terminated in compression-equipment adapters, such as Thomas & Betts BI-Metal pin connectors, No. 61900 series, Burndy "HYPLUG," Homac Type "MPT," Mac-Products "MAC-ADAPT," or other approved equal. The compression-equipment adapters shall be terminated in the vendor-supplied lugs.

2. The aluminum conductors shall be run in conduit to an appropriately sized junction box mounted adjacent to the subject equipment. The aluminum conductors shall be spliced to copper conductors of equivalent ampacity with tin-plated aluminum, compression-reducing connectors inside the junction box. The copper conductors shall then be extended into subject breaker or switch and shall be terminated in the vendor-supplied lugs.

E. An acceptable alternative to the methods described in para. 4.E is to specify that the equipment be supplied with tang terminals and extra enclosure space to allow termination of lug-type compression fittings.

3.05 BUS CONNECTIONS AND ATTACHMENT OF CABLE LUGS

A. All bolted connections in both copper and aluminum bus and attachment of cable lugs to both types of bus shall be made using "Belleville" conical, compression-type washers. The connections shall be made in accordance with details shown on the drawings.

The following hardware shall be used for indoor, dry, noncorrosive installations. Hardware for other environmental conditions shall be specified on the drawings.

1. Bolts shall be regular, semifinished, hex-head, cadmium-plated, medium carbon steel, SAE Grade 5, high-strength type with UNC, Class 2B threads. Bolts shall conform to ANSI/American Society for Testing and Materials (ASTM) A-449.

2. Nuts shall be regular, semifinished, hexagon, cadmium-plated, medium carbon steel, SAE Grade 5, high-strength type with UNC, Class 2B threads. Nuts shall conform to ANSI Bl8.2.2.

3. Flat washers shall be Type A plain, wide-series, cadmium-plated, mild steel. Washers shall conform to ANSI B18.22.1 and the following table.

4. "Belleville" compression washers shall be American Iron and Steel Institute, Inc., 6150 steel, heat treated to 47/50 RC, and mechanically cadmium plated 0.0005 in. thick. Washers shall conform to the following table.

Compression washer

Bolt size	Max OD	Min pounds load at 100% deflection	Thomas & Betts Cat. No.	Flat washer OD	Flat washer ID	Thickness
1/4	11/16	800	60800	3/4	5/16	0.065
3/8	15/16	1,400	60802	1	7/16	0.083
1/2	1 3/16	2,700	60803	1 3/8	9/16	0.109
5/8	1 1/2	4,000	60804	1 3/4	11/16	0.134

B. Contact surfaces of bolted connections in copper bus shall be tin plated to a minimum thickness of 0.1 mil. These surfaces and areas of copper bus on which cable lugs are to be terminated shall be thoroughly cleaned of oxide and coated with A. B. Chance Company "Contact-Aid" prior to making the connections and terminating the lugs.

C. Contact surfaces of bolted connections in aluminum bus shall be tin plated to a minimum thickness of 0.1 mil. These surfaces shall be thoroughly cleaned and coated with Thomas & Betts "Aluma-Shield" aluminum joint compound prior to making the connections.

D. Unplated surfaces of aluminum bus on which cable lugs are to be terminated shall be wire brushed with Thomas & Betts "Aluma-Shield" aluminum joint compound to remove the aluminum oxide film. These surfaces shall be wiped clean and immediately relocated with clean "Aluma-Shield" prior to terminating the lugs. Plated surfaces of aluminum bus shall not be wire brushed, but joint compound shall be used.

E. All bolts used in bus connections and in cable lug terminations shall be tightened until the "Belleville" compression washer is completely flat. Connections are not to be torqued, but tightening the joint sufficiently to flatten the "Belleville" washer is essential.

3.06 INSULATION OF SPLICES AND TAPS 600 V OR LESS

A. Splices and taps in thermoplastic and rubber-insulated conductors shall be insulated in accordance with 1 or 2 below.

1. The connection shall first be insulated with rubber tape, 3M Company No. 130C, Plymouth Rubber Company "Plyvolt," or Okonite Company No. 10. The connection shall then be wrapped with all-weather, vinyl-plastic tape, 3M Company No. 88 or Plymouth Rubber Company "Premium Grey." The inner tape shall be wrapped in a manner so as to pad the sharp edges and fill the indents of the connector. The outer tape shall be applied until the total area of the inner taping is covered with a minimum of four layers. The total thickness of the combination of tapes shall be at least equal to the thickness of the conductor insulation.

2. The sharp edges and indents of the connection shall first be padded with 3M Company "Scotchfil" insulation pad, Plymouth Rubber Company "Plyseal" insulation pad, or Okonite Company No. 75 filler tape. The connection shall then be covered with an appropriately sized, heat-shrinkable sleeve, Rachem Company Type "WCS" or Thomas & Betts Type "HS," or with prestretched tubing, 3M Company Type "PST."

B. Connections insulated in accordance with 3.05.A.1) or 3.05.A.2) that are not housed in a junction box or other metal enclosure shall have an additional protective wrapping of friction tape, Plymouth Rubber Company "Special ASTM" or Okonite Company "Manson" No. 5, to protect the connection from abrasions.

C. All outdoor splices and taps, such as splices at service entrances and any connections which are subjected to high humidity, shall be insulated in accordance with 3.05.A and 3.05.B and then wrapped with linen cloth tape and painted with two brushed-on coats of General Electric "Glyptal."

D. Underwriters' Laboratories, Inc., approved insulators for splices and taps, similar to Burndy "Poly-Tap," may be used only where specified on the drawings.

END OF SECTION

SECTION 16124

SPLICES AND TERMINATIONS – MEDIUM VOLTAGE CABLES

PART 1 - GENERAL

1.01 DESCRIPTION

Section includes:

A. Terminations, 5-kV and 15-kV insulated cables.

B. Splices, 5-kV and 15-kV insulated cables.

C. Taps, 5-kV and 15-kV insulated cables.

D. Potheads.

1.02 RELATED SECTIONS

A. Section 16122 - Medium Voltage Cables - 15kV Insulated

1.03 REFERENCES

A. Institute of Electrical and Electronic Engineers (IEEE) 48 - Class 1 Terminations for Medium Voltage Cables.

B. American National Standards Institute C2 - National Electrical Safety Code.

1.04 SUBMITTALS

A. Submit product data for approval.

B. Submit manufacturer's instructions for splicing and terminating aluminum conductors.

PART 2 - PRODUCTS

2.01 SPLICES AND TERMINATIONS

A. Solid Dielectric Shielded Power Cables (XLP and EPR)

1. General

Items 2, 3, 4, 5, 6, and 7 below specify requirements for terminating and making splices and taps in 15-kV solid dielectric shielded power cables, unless specified otherwise on the drawings, and specify acceptable manufacturer's product lines. Products other than those listed herein and on the drawings shall not be used unless approved by the Project Manager or designee.

The subcontractor shall furnish appropriate kits, selected from the acceptable manufacturer's product lines, that will properly match the sizes and configurations of cables specified. Outdoor kits shall be used for all outdoor installations.

All splicing and terminating materials must be installed in strict adherence to the manufacturer's instructions, and care must be exercised to keep the cable ends and insulating materials clean and dry during installation.

All termination products must meet IEEE 48 requirements for Class 1 type terminations.

2. 15-kV Cable Terminations

Terminations of 15-kV cables shall be made with 15-kV premolded termination kits. RAYCHEM "HVT"-series kits.

3. 15-kV Cable Splices

Straight (180°) splices in 15-kV cables shall be made with heat-shrinkable splice kits. RAYCHEM "HVS"-series kits are acceptable.

4. 15-kV Cable Dead Ends
Dead-end seals in 15-kV cables shall be made with 15-kV, factory-premolded heat-shrinkable kits. RAYCHEM “HVES” – series kits are acceptable.

PART 3 - EXECUTION

3.01 SCHEDULING

A. When splice kits and prefabricated terminations are used on solid dielectric 5-kV and 15-kV cable, the work should be scheduled such that terminations and splices can be completed prior to the end of the work shift. However, if a splice or termination is not complete at the end of the work shift, then the splice shall be covered with plastic and taped to exclude moisture and dirt (idle period shall not exceed 48 h). Upon continuation of the splice during the next work shift, the cable components shall be wiped clean and dry before continuing with splice completion. In all areas other than heated buildings, the wrapped incomplete splice or stress cone terminator shall be protected with silica gel or dry air purge as described in 3.01B.

B. The enclosure size shall be kept to a minimum, and reusable desiccating canisters of humidity indicating silica gel shall be inserted inside the enclosure to absorb moisture that enters during the period of time the splice (pothead) is idle. Two 40-g canisters of silica gel shall be used for each cubic foot of volume in the enclosure. "Dri-Can" canisters, manufactured by Multiform Desiccant Products, Inc., or equal, shall be used. Continuous purging of the wrapped incomplete splice or pothead, with air or nitrogen gas with a dew point of -60°F or better is an acceptable alternative to the use of silica gel.

3.02 CLEANLINESS CONTROL

Temporary protection shelters (wood frame and plastic sheet or equivalent) shall be installed over open entry ways when splicing solid dielectric cables during inclement weather or in environments where airborne contaminants are present that are detrimental to a successful splice. Similar shelters, under similar conditions, shall be used for making up stress cone terminators.

3.03 SKILLED PERSONNEL

Craft personnel making splices and terminations shall be skilled in the procedures and techniques required for the particular type of work assigned.

3.04 IDENTIFICATION

Each individual splice or termination shall be completed from start to finish by the same individual(s). All splices and terminations shall be tagged with an aluminum band (around the cable at the splice or termination) identifying the date of completion, the initials of the craftsman, and the subcontractor employing the craftsman.

END OF SECTION

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SECTION 16195

ELECTRICAL IDENTIFICATION

PART 1 - GENERAL

1.01 DESCRIPTION

Section includes:

A. Nameplates and tape labels.

B. Wire and cable markers.

1.02 SUBMITTALS

A. Include schedule for nameplates and tape labels.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Nameplates

Engraved three-layer laminated plastic, white letters on a black background.

B. Tape Labels

Embossed adhesive tape with 3/16 in. (5 mm) white letters on black background.

C. Wire and Cable Markers

Cloth markers, split sleeve or tubing type.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Degrease and clean surfaces to receive nameplates and tape labels.

B. Install nameplates and tape labels parallel to equipment lines.

C. Install weather-resistant nameplates on outdoor equipment. Secure nameplates to equipment fronts using screws, rivets, or adhesive. Secure nameplate to inside face of recessed troffers.

D. Tape Labels: "Dymo" 5134-09, 3/4-in. black plastic adhesive tape having letters approximately 1/2 in. high.

E. The identification shall be in accordance with the one-line diagram and shall include the following:

a. maximum voltage,
b. equipment designation,
c. source of supply, and
d. equipment supplied.

F. Interior electrical devices can be identified by means of "Dymo" 158-9, 1/2-in. black plastic adhesive tape having letters approximately 5/32 in. high. The tape shall be applied to the front cover plates. For example, a switch fed from Circuit 15 from Panel B would be marked "120 V, 1-ph, Circuit 15, LP-B."

G. Surfaces shall be cleaned with a solvent such as Varsol prior to applying tape. After the tape has been applied to the equipment or device, a brush coat of clear lacquer shall be applied over the tape making sure that all edges of the tape are well covered. The identification tape and seal coating of clear lacquer shall be applied prior to field painting. The identification tape shall then be masked until field painting is completed, after which the masking shall be removed.

3.02 CONDUCTORS

A. All single-conductor power and control wiring shall be identified in all readily accessible junction boxes in the wiring system and at all terminations. Conductors need not be identified in pull points where no taps or splices are made. Numbers and letters shall be attached to each conductor in accordance with the numbering system on the drawings, using 3M Company "Scotch Code" wire markers or W. H. Brady "Quick Label" labels.

B. All three-phase power feeder conductors shall be identified by phase designations (e.g., 0/A, 0/B, and 0/C).

END OF SECTION

SECTION 16450

GROUNDING

PART 1 - GENERAL

1.01 DESCRIPTION

Section includes:

A. Electrical equipment grounding.

1.02 REFERENCES

A. American National Standards Institute (ANSI)/Institute of Electrical and Electronic Engineers (IEEE) Standard 8l, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.

B. IEEE 80, Guide for Safety in AC Substation Grounding.

C. National Electrical Code (NEC) Article 250, Grounding.

D. NEC Article 250-26, Grounding Separately Derived Alternating-Current Systems.

1.03 SYSTEM DESCRIPTION

A. The grounding of electrical equipment, grounded electrical circuits, etc., shall be in accordance with the details shown on construction drawings. In addition to the grounding specified herein or on the drawings, all ground connections required by the NEC shall be furnished and installed. Where grounding conductor sizes are omitted from the drawings, the minimum requirements of Article 250 of the NEC shall apply.

1.04 SUBMITTALS

A. Submit shop drawings for approval.

B. Indicate layout of system grounding electrode connections and electrode conductor.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Ground Rods: Copperweld type, Joslyn No. J8350, 3/4 in. diam, minimum length 15 ft.

B. Connectors: Compression type, Thomas & Betts Series No. 52000, No. 53000, or equal.

C. Bonding: Thermic type, Cadweld or equal.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Electrical Equipment Grounding

1. The equipment -grounding conductor shall be a continuous copper wire and shall be run in the same conduit with the current carrying conductors. Aluminum ground wires are not permitted and will not be accepted. Wire installed in steel conduit may be either bare or green insulated. Wires No. 8 AWG and larger shall be stranded.

2. Equipment grounding conductors shall connect to the existing ground grid at ground busses and ground inserts or to existing equipment grounding conductors. Grounding or bonding of equipment to building steel as a sole means of grounding will not be acceptable, and the use of conduit as the equipment grounding conductor is not permitted.

3. Connections to ground busses and connections of equipment grounding conductors shall be made with either bolted mechanical lugs or compression connectors. Before connections are made, all contact surfaces shall be clean and bright; and a compound to prevent oxidizing, such as "No-Oxide" or "Contact Aid," shall be applied to ensure good electrical contact.

4. Metal shields and/or lead sheaths of 5-kV and 15-kV cables shall be bonded for continuity at splices and grounded at each termination. The equipment grounding conductor shall connect to the ground grid system.

3.02 FIELD QUALITY CONTROL

A. Test No. 1 - Individual Ground Rods

1. Before connection to the ground mat, each ground rod shall be tested for resistance to earth by a Biddle null balance "Earth Tester," using the "Three-Point-Method" described in ANSI/IEEE Standard 81 using two auxiliary rods.

2. Individual ground rod resistance to earth shall be 15 ohms or less. If the resistance is found to be higher than 15 ohms, additional ground rods shall be driven and connected in multiple, with the rod under test until 15 ohms are obtained. Spacing of rods shall be a minimum of 10 ft.

B. Test No. 2 - Complete Ground Mat

1. After completion of Test No. 1, all ground rods shall be connected to the ground conductor. Before any backfilling is done, the complete ground mat shall be visually inspected to ensure that all connections have been made mechanically tight by the "Cadweld" or other approved process.

2. After a satisfactory visual inspection, backfilling shall be done; and the resistance of the complete ground mat to earth shall then be tested. The mat resistance shall be determined by use of the "Fall-of-Potential Method" as described in ANSI/IEEE Standard 81.

3. The maximum acceptable resistance for the complete ground mat shall be 1 ohm.

C. Test No. 3 - Ground Pigtails

Terminations of ground cables coming up from the buried ground mat, shall be visually inspected for solidness of connections, workmanship, and conformance with drawings and specifications.

D. Test No. 4 - Equipment Ground Conductors

1. A test shall be made at the ground conductor terminations to determine the adequacy of the equipment ground conductor.

2. A "Kelvin Bridge" shall be connected between the equipment ground bus (to which the equipment ground conductor is connected) and the nearest ground point connected directly to the system ground grid.

3. The readings taken will indicate the resistance between the equipment ground bus and the building ground grid. The maximum permissible resistance shall be 0.1 ohm.

F. Reporting Test Results: It is the responsibility of the subcontractor to report the results of all tests in accordance with Section 16950.

END OF SECTION

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SECTION 16480

MOTOR CONTROL

PART 1 - GENERAL

1.01 DESCRIPTION

Section includes:

A. Manual motor starters.

B. Magnetic motor starters.

C. Combination magnetic motor starters.

D. Motor starter panelboards.

1.02 RELATED WORK

A. Section 16950 – Electrical Testing

1.03 REFERENCES

A. American National Standards Institute/National Electrical Manufacturers Association (ANSI/NEMA) ICS 6 - Enclosures for Industrial Controls and Systems.

B. ANSI/Institute of Electrical and Electronic Engineers 344 - Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.

C. ANSI/Underwriters' Laboratories, Inc. (UL) 198C - High-Intensity Capacity Fuses; Current-Limiting Types.

D. ANSI/UL 198E - Class R Fuses.

E. FS W-C-375 - Circuit Breakers, Molded Case, Branch Circuit and Service.

F. FS W-F-870 - Fuseholders (For Plug and Enclosed Cartridge Fuses).

G. FS W-P-115 - Power Distribution Panel.

H. FS W-S-865 - Switch, Box (Enclosed), Surface-Mounted.

I. NEMA AB 1 - Molded Case Circuit Breakers.

J. NEMA ICS 2 - Industrial Control Devices, Controllers, and Assemblies.

K. NEMA KS 1 - Enclosed Switches.

L. NEMA PB 1 - Panelboards.

M. NEMA PB 1.1 - Instructions for Safe Installation, Operation, and Maintenance of Panelboards Rated 600 Volts or Less.

1.04 SUBMITTALS

A. Submit shop drawings and product data for approval.

B. Provide product data on motor starters and combination motor starters, relays, pilot devices, and switching and overcurrent protective devices.

C. Submit manufacturer's instructions for review and record.

D. Submit operation and maintenance data for record.

E. Include spare parts data listing, source and current prices of replacement parts and supplies, and recommended maintenance procedures and intervals.

PART 2- PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS - MOTOR STARTERS

A. Allen-Bradley.

B. Square D.

C. General Electric.

D. Substitutions: Submit for approval.

2.02 COMBINATION MAGNETIC MOTOR STARTERS

A. Magnetic Motor Starters: NEMA ICS 2, alternating current general-purpose Class A magnetic controller for induction motors rated in horsepower. Magnetic motor starters shall be rated for 600 V and shall be combination type with circuit breaker mounted within the enclosure.

B. Full Voltage Starting: Nonreversing type.

C. Coil Operating Voltage: 120 V, 60Hz.

D. Size: NEMA ICS 2; size as shown on drawings.

E. Overload Relay: NEMA ICS 2, melting alloy.

Magnetic starters for three-phase motors shall be equipped with three thermal overload relays for overload protection.

F. Enclosure: NEMA ICS 6; Type 1 or as shown on drawings.

G. Auxiliary Contacts: NEMA ICS 2, field convertible contacts as shown on drawings in addition to seal-in contact.

H. Push buttons, selector switches, and indicating lights shall be heavy-duty, oil-tight, surface mounted in NEMA 13 enclosure, indoors; NEMA type 4 enclosure, outdoors; and NEMA type 7 enclosure, in hazardous areas, unless otherwise noted on the drawings.

I. Indicating Lights: NEMA ICS 2, heavy duty, oil-tight RUN: red in front cover

J. Selector Switches: NEMA ICS 2, heavy duty, oil-tight HAND/OFF/AUTO

K. Individual units shall be furnished with standard size legend plates. Markings on the plates shall be in accordance with the drawings.

L. Control Devices shall be Allen Bradley, Bulletin 800T; Square D, Class 9001; or GE, Form CR 2940.

M. Relays: NEMA ICS 2, relays shall have 120-V, 60-Hz coils with convertible contacts, rated for 10 A at 600 V [unless otherwise noted on the drawings].

N. Relays shall be Allen Bradley, Bulletin 700; Square D, Class 8501, type D; or GE, Form CR 2810-A14.

O. Control Power Transformers: 120 V secondary, 100 VA minimum, in each motor starter. The X1 terminal of the control transformer secondary shall be fused. The X2 terminal of the control transformer secondary shall be grounded.

2.04 COMBINATION STARTER OVERCURRENT PROTECTION AND DISCONNECTING MEANS

A. Operating Handles: The circuit breaker or disconnect switch shall be operable by hand from outside the enclosure and shall be so interlocked with the door that it must be turned in the "Off" position before the door can be opened. A semisecret device shall be included to permit qualified personnel to open enclosure with breaker closed. The operating handle shall be lockable in the "OFF" position.

B. Molded Case Thermal-Magnetic Circuit Breakers: NEMA AB 1, circuit breakers with integral thermal and instantaneous magnetic trip in each pole.

C. Motor Circuit Protector: NEMA AB 1, circuit breakers with integral instantaneous magnetic trip in each pole.

D. Nonfusible Switch Assemblies: NEMA KS 1, quick-make, quick-break, load interrupter enclosed knife switch.

E. Fusible Switch Assemblies: NEMA KS 1, quick-make, quick-break, load interrupter enclosed knife switch. Fuse Clips: Designed to accommodate Class R fuses.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install motor control equipment in accordance with manufacturer's instructions.

B. Motor Starter Panelboard Installation: In conformance with NEMA PB 1.1.

C. Install fuses in fusible switches.

D. Select and install heater elements in motor starters to match installed motor characteristics.

E. Motor Data: Provide neatly typed label inside each motor starter enclosure door identifying motor served, nameplate horsepower, full load amperes, code letter, service factor, and voltage/phase rating.

3.02 TESTING AND INSPECTION

A. Inspection

1. Verify that all wiring connections are tight.
2. Verify that movable contact assembly is not binding and is free to move.
3. Verify that coil voltage is correct.

B. Operational Test

1. Verify proper phasing and rotation for connected motor.
2. Energize starter and record motor load current.

C. Reporting Test Results

The subcontractor shall report all test results in accordance with Section 16950.

END OF SECTION

SECTION 16850

ELECTRICAL HEAT TRACING FOR FREEZE PROTECTION

PART 1 - GENERAL

1.1 Scope

This specification covers the design and installation of electrical heat tracing for freeze protection of piping and equipment.

1.2 References

Electrical heat tracing systems shall be designed, installed, and tested in accordance with the most recently issued regulations, standards, recommended practices, and/or codes covering the intended application that are issued by or contained in the following:

- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- Factory Mutual (FM)
- Institute of Electrical and Electronic Engineers (IEEE)
- IEEE 622A, Heat Trace Recommendation
- National Electrical Code (NEC)
- National Electrical Manufacturer's Association (NEMA)
- 250, Enclosures for Electrical Equipment (1000 volts maximum)
- Underwriter's Laboratories (UL)

1.3 Definitions (Not Used)

1.4 Submittals

1.4.1 All required submittals stated herein or elsewhere in this specification shall be submitted for review and approval. Submittals that do not meet the project requirements will be rejected. Rejected submittals shall be resubmitted in a timely manner to avoid delays.

1.4.2 The complete design of each system shall be carried out by the subcontractor or the manufacturer of the heat tracing system to be used. Completed design shall be submitted to the Project Manager or designee for approval. To aid in this design, the following documents will be furnished to the heat tracing vendor:

- Process Line List, Instrument List, and Equipment List - A list of items to be electrically traced, identified by service and number; the minimum temperature to be maintained; and insulation requirements

- Piping and Instrument Diagrams - Piping and instrument diagrams showing the previously listed lines, instruments, and equipment

- Plans, Elevations, and Isometrics - Drawings indicating the exact length and configuration of the items to be electrically traced

- The electrical classification of hazardous locations where tracing and controls will be installed

- Instructions to cover special conditions such as splice kit requirements, etc.

1.4.3 The completed electrical heat tracing system designed by the subcontractor and/or the heat tracing vendor shall include plans or elevations to show the installation and location of all components. The design shall include wiring diagrams, installation instructions, and a performance guarantee. A data sheet listing the following information for each heater shall be included with the completed heat tracing system package.

- Heater circuit number
- Heater catalog number
- Heater length
- Voltage required
- Ampere load of heater with test switch
- Total output of heater in watts
- Piping process temperature
- Customer drawings reference numbers
- Vendor drawings reference numbers
- Output of heater in watts per foot.

PART 2 - PRODUCTS

2.1 Ambient temperature design conditions for tracing are:

- Maximum 110^{o}F
- Minimum -20^{o}F.

2.2 The heat tracing subcontractor or heat tracing vendor shall use existing distribution panels and components where possible. The heat tracing subcontractor shall provide necessary circuit breakers, transformers, and components as may be required for a complete and operable heat trace system.

2.3 The maximum acceptable heat trace voltage is 120 volts. The maximum allowed single circuit shall be 15 amperes. Each circuit shall be protected with a 30-milliampere (mA) ground-fault circuit (GFCI) breaker.

2.4 Loss-of-power alarms shall be provided on critical circuits where specified in the design specification.

2.5 All materials used for electrical heat tracing shall be furnished by:

Chemelex
837 Second Avenue
Redwood City, CA 94063

or approved equal.

2.6 Each freeze-protection heater element shall be a two-wire cable, self-limiting resistance type and, for pipe and equipment tracing, have various inner and outer insulations, sheaths, and temperature ratings that vary power output to respond to temperature along its length.

2.7 Thermostats and other controls shall be supplied by the heat tracing vendor. For application on nonmetallic pipe, the heat tract temperature shall not exceed 38° C (100°F).

2.8 Heat transfer cement, fasteners, and other installation materials shall be supplied by the heat tracing vendor.

2.9 In addition to the materials required for the initial installation, the heat tracing vendor shall supply a sufficient number of splicing kits to enable future removal and/or repair of lines, equipment, instruments, etc.

PART 3 - EXECUTION

3.1 The preparation of the surfaces of the piping or equipment to be traced, and the methods, hardware, and fittings used for the installation and testing of the system, including heaters, thermostats, heat transfer cement, and channels, etc., shall be in strict accordance with the heat tracing vendor's recommendations, instructions, and standards.

3.2 All thermostats, power connection splice, tees, and end cap boxes should be mounted above the insulation.

3.3 Assistance and field instruction available from the heat tracing vendor should be utilized as required.

3.4 After attaching electrical heating cables to piping or equipment system, the cables shall be tested at 2,500 volts DC for continuity and insulation resistance to ground measured minimum mega-ohms. Where leakage is detected, cabling shall be removed and replaced with new cabling, then retested to demonstrate compliance.

3.6 On completion of cable installation, the cable circuit shall be energized and its performance shall be demonstrated in accordance with the requirements.

3.7 Testing shall be conducted in accordance with Section 16950, Electrical Testing. The tracing system shall be inspected and accepted by the Project Manager or designee before the insulation is installed.

3.8 All traced items shall be insulated per Section 15081, Exterior Piping Insulation.

3.9 Each individual length of heating element shall be provided with a metal tag. The tag shall bear a stamped number corresponding to the tracer number shown on the tracer layout. The tag shall be attached to the operating thermostat unless otherwise noted on the drawings. Tags shall be 20 AWG aluminum, 1-1/2 inch diameter with 1/8 inch high lettering and spacing and attached with 22 AWG wire, or vendor's standard.

END OF SECTION

SECTION 16950

ELECTRICAL TESTING

PART 1 - GENERAL

1.01 DESCRIPTION

A. This section includes a summary of the electrical testing requirements necessary for the acceptance of electrical equipment and installations as well as one copy of the form upon which each test is to be reported.

B. The purpose of the specified tests and inspections is to determine that each piece of equipment is in satisfactory condition to successfully perform its intended function.

C. It is the intent of these procedures to ensure that all workmanship, materials, the manner and method of erection, and installation conform to manufacturer's instructions and, except as modified herein, the National Electrical Code, Institute of Electrical and Electronic Engineers, American National Standards Institute, American Society for Testing and Materials, Underwriters' Laboratories, Inc., National Electrical Manufacturers Association, and Association of Edison Illuminating Companies Standards.

1.02 SUBMITTALS

A. A report for each test performed

B. Each report shall be submitted on the form shown in Attachment A.

PART 2 - PRODUCTS

Not used.

PART 3 - EXECUTION

3.01 RESPONSIBILITY

A. The subcontractor shall perform and supervise all tests unless specifically noted otherwise herein or on the drawings. The subcontractor shall furnish all test equipment required for the tests performed by him and shall be responsible for providing such safety measures as are required for each test.

B. The subcontractor shall schedule all testing with the Project Manager or designee, and no testing of any kind shall be performed without the Project Manager’s or designee’s approval.

C. The subcontractor shall notify all involved parties prior to test advising them of the test to be performed and the scheduled date and time.

D. The subcontractor shall give manufacturers sufficient notice to allow the necessary arrangements to be made and to have their engineer or representative present at tests where their presence is required. Where the manufacturer's responsibility includes both electrical and mechanical performance, the subcontractor shall coordinate the tests with the others involved.

E. The subcontractor shall furnish all test equipment required to perform the tests for which he is responsible. For test instruments to be acceptable for use, they must bear a label documenting the fact that the equipment has been calibrated during the previous 12 months. The label must show instrument serial number, date of calibration, and name of firm or laboratory performing calibration.

F. The Project Manager or designee will examine the subcontractor's test equipment prior to use and may, at his discretion, require that the equipment be submitted to the contractor for a calibration check. Equipment that fails to be within acceptable limits must be submitted by the subcontractor to an approved testing laboratory for proper calibration. The subcontractor must then submit evidence of proper calibration to the Project Manager or designee.

G. The Project Manager or designee will ascertain that all tests specified are performed or waived and that all test reports or waivers are retained in the project file.

3.02 FIELD QUALITY CONTROL

A. Test Reports

1. The subcontractor shall perform all tests listed in these specifications and shall submit a formal test report to the Project Manager or designee for each test conducted. Each test report shall contain, as a minimum, the following information:

   a. Job title
   b. Date of test
   c. Equipment, system, or cable identification
   d. Specific type of test
   e. Description of test instrument and date of calibration
   f. Section of specification defining test
   g. Test results (correct all insulation-resistance readings to 20ºC)
   h. Signature of person supervising test
   i. Signature of subcontractor representative
   j. Space for Project Manager or designee signature

2. Test reports shall be submitted on Test Form located in Attachment A unless alternate forms are approved by the Project Manager or designee or are required by specific test procedures. Upon completion of each test or series of similar tests, the subcontractor shall complete the test report(s) and submit them to the Project Manager or designee for approval within five working days after the testing is performed. The Project Manager or designee shall be notified within 24 hours when any test results fail to meet acceptance criteria.

B. Acceptance

1. Acceptance of all electrical equipment and cables covered by test procedures shall be contingent upon proper execution of the required tests and acceptable test results. Signing of the submitted test report by the Project Manager or designee shall certify Project Manager or designee approval of the test. The Project Manager or designee shall give the subcontractor a copy of all signed test reports and distribute copies to Electrical Engineering and responsible Operations departments. The Project Manager or designee shall retain all original test reports.

2. Acceptance of all electrical equipment shall be dependent upon each piece of equipment satisfactorily performing its intended function as determined by the Project Manager or designee.

3. The Project Manager or designee may, at their discretion, prepare and issue an acceptance report for any accepted piece of equipment or system. The original copy shall be retained in the project file.

END OF SECTION

ATTACHMENT A

ELECTRICAL TEST REPORT

THIS TEST REPORT IS TO BE USED FOR POWER CABLE, GROUND GRIDS, ETC., AND ELECTRICAL EQUIPMENT, SUCH AS TRANSFORMERS, SWITCHGEAR, ETC.

JOB TITLE ________________________________ TEST REPORT NO. ________________________

W. O. _____________ BLDG. _____________ PLANT __________ DATE ______________________

WEATHER CONDITIONS ___________________ SOIL CONDITIONS __________________________

EQUIPMENT, DESCRIPTION, LOCATION, AND NAME PLATE DATA _______________________

____

____

SPECIFIC TYPE OF TEST ____

SECTION OF SPECIFICATION DEFINING TEST ____________________ PAGE ________________

ACCEPTABLE VALUE: MIN. ______________________ MAX. ______________________________

TEST INSTRUMENT ____

MODEL NO. ______________________________ CALIBRATION DATE _______________________

TEST PERFORMED BY _______________________ COMPANY ______________________________

TEST SUPERVISED BY _______________________ COMPANY ______________________________

TEST WITNESSED BY _______________________ COMPANY ______________________________

PROJECT MANAGER OR DESIGNEE ____

SECTION 18100

GENERAL WELDING REQUIREMENTS

PART 1 - GENERAL

1.01 SECTION INCLUDES:

A. Welding fabrication and construction activities occurring both on-site and off-site. These requirements apply to structural welding, pipe welding, and ductwork welding when invoked by other technical sections or when drawings require fabrication to codes referenced in this document. These requirements do not apply to work on ASME-stamped components, AWWA tanks, or API tanks.

B. Special Qualification Requirements for Welding

1. If conditions of access for welding require the use of a mirror, the welder shall demonstrate his/her ability to weld using a mirror on a welder qualification test under access conditions which simulate the production conditions.

2. If conditions of access for any weld are such that the welder and/or the welder's supervisor/foreman determines that it is doubtful that the weld can be successfully made, the supervisor/foreman shall either:

    a. Have the welder weld a mockup duplicating the conditions that make the success of the weld questionable. The weld mockup shall be examined in the same manner and meet the same requirements as required for the production weld, or;

    b. Request that the designer evaluate the connection for redesign to provide for adequate access for welding.

3. Examiners shall include, in inspections and in spot checks, an evaluation of the adequacy of conditions for making acceptable welds.

4. Prior to manually making complete penetration pipe welds in difficult to weld materials (e,g., Nickel, Hastelloy, Monel, Inconel, Haynes 556), each welder shall successfully demonstrate ability to weld these materials by one of the following:

    a. Weld a mockup in the horizontal pipe position or a welder qualification test on the same material as the production welds. Radiograph the mockup weld and examine to the same requirements as the production weld. Submit the request for the test on the form included on Attachment A.

    b. With prior approval of the Project Manager or designee, radiograph the first production weld completed by the welder.

    c. Submit the examination record for an on-site production weld of the same materials as the specified production welds, welded within the previous six months, which was radiographed and found to be acceptable without repair.

5. Conduct a pre-job briefing with the welders and supervisors to review special welding requirements resulting from the materials, personal protective equipment, or accessibility restrictions.

1.02 RELATED SECTIONS

A None.

1.03 REFERENCES

A. AWS D-1.1, Structural Welding Code, Steel, 1998 Edition.

B AWS D-1.2, Structural Welding Code, Aluminum, 1997 Edition.

C. AWS D-1.3, Structural Welding Code, Sheet Steel, 1989 Edition.

D. AWS B-2.1, Standard for Welding Procedure and Performance Qualification, 1984 Edition.

E. AWS D-9.1, Sheet Metal Welding Code, 1990 Edition.

F. AWS QC-1, Specification for Qualification and Certification of Welding Inspectors, 1996 Edition.

G. ASME Boiler and Pressure Vessel Code, Sect. IX, Welding and Brazing Qualifications, 1998 Edition.

H. ASME Boiler and Pressure Vessel Code, Sect. V, Nondestructive Examination, 1998 Edition.

I. ASME Boiler and Pressure Vessel Code, Sect. II, Part C, Material Specification, 1998 Edition.

J. Technical Specification Div. 18B, On-Site Welding, January 1999 Edition (available on request).

K. ASME B31.3, Chemical Plant and Petroleum Refinery Piping, 1996 Edition.

L. ASNT, Recommended Practice SNT-TC-1A, December 1996 Edition.

1.04 DEFINITIONS

A. **Engineer**: The engineering organization or representative responsible for the design of the system, component, or structure.

B. **Examination**: Nondestructive examination performed on a weld to determine its compliance with established acceptance standards. A visual examination evaluates specifically listed attributes to established acceptance criteria. Only certified examiners perform examinations.

C. **Examiner**: A qualified and certified individual who performs examinations and inspections.

D. **Faying Surface**: The mating surface of a member which is in contact with or in close proximity to another member to which it is to be joined.

E. **Inspection**: Oversight function of welding provided by the Project Manager or designee to verify that specified requirements applicable to the welding program are satisfied.

F. **Spot Check**: Random observation by an individual designated by the organization performing welding activities to verify conformance to the welding program requirements of this specification.

G. **Procedure Qualification Record (PQR)**: Written documentation of the qualification of a welding procedure specification (WPS) by examination and testing of physical weld specimens made using the WPS.

H. **Performance Qualification Test (PQT)**: Standard performance test(s) which a welder must successfully pass in order to be qualified to weld. The requirements for these tests are based on a qualified WPS and establish a specific range of essential variables the welder is qualified for.

I. **Shared WPS**: A welding procedure specification that, when qualified by one company, may be used by another company without additional testing after accepting it in writing.

J. **Welder Performance Qualification (WPQ)**: The record which documents a welder's successful completion of a performance qualification test and establishes the range of variables the welder is qualified for.

K. **Welding Procedure Specification (WPS)**: A written document which establishes the essential, nonessential, and supplementary essential (when required) variables for welding and provides direction to the welder for making production welds to ensure compliance with requirements.

L. **Weld Sketches**: Informal sketches that show the location of welds in a system so that documentation such as certified material test reports, welder identification, and weld examination records can be traced to the weld it represents.

1.05 SUBMITTALS

A. All Welding

1. The following summarizes submittals required for performing all welding activities. Approval of the following by the Project Manager or designee are required prior to welding.

    a. WPQ records, including evidence of updates.

    b. WPSs and PQRs (unless prequalified per AWS D-1.1).

    c. Visual examination and nondestructive examination procedures.

    e. Qualifications of examination personnel.

2. Submit nondestructive examination reports including two complete sets of radiographs of all welds radiographed prior to delivery of the equipment.

1.06 QUALITY ASSURANCE

A. Welding to this specification requires that welders, welding procedures, examiners, and examination procedures meet the requirements specified in Part 2 and Part 3. For all welding, the Subontractor performs examinations using personnel and procedures approved by the Project Manager or designee.

PART 2 - PRODUCTS

2.01 MATERIAL REQUIREMENTS

A. Welding Rods and Electrodes

1. Verify filler materials delivered are legibly marked in accordance with the General Requirements for each specification listed in AWS or the ASME Boiler and Pressure Vessel Code, Sect. II, Part C, Material Specifications.

2. Verify bare filler material is identified with the applicable classification and/or specification numbers and is attached to each rod, strip, coil, or spool. Label each piece of rod when it is separated from a labeled rod.

3. Control, handle, and identify welding rods and electrodes at all times to avoid material degradation or inappropriate usage and to ensure they are identifiable as acceptable material until the material is consumed in the welding process.

   a. Unless otherwise specified by the Project Manager or designee, store and handle low-hydrogen electrodes in accordance with AWS D-1.1.

4. Technical Specifications 15137 and 15142 require Certified Material Test Reports for stainless steel and alloy filler materials. Heat number traceability to the time of consumption is required by these technical specifications for these materials. Purchase either ASME Section III, Class 3 filler materials, or filler materials with a minimum of Schedule H level of testing and lot classification Class S3 per AWS A5.01.

   a. Use ASME SFA 5.11 or AWS A5.11, Classification ER NiCu-7 filler materials for Sect. 15137 or 15142 Monel welds.

B. Base Material Control

1. Control base material and the marking of cut material to ensure the material is identifiable and traceable to applicable documentation when required by the Technical Specification or Contract.

2.02 WELDING REQUIREMENTS

A. Welding Procedures

1. Prepare written welding procedures and qualify them for the scope of welding required in accordance with the applicable code in paragraph 3.01.
2. Written approval of the WPS and PQR is required prior to welding.

B. Qualification of Welders

1. Qualify welders and welding operators using the appropriate approved and qualified welding procedure specification. Submit records of welder qualification, including updates, required by the applicable code for the procedure. The welder performance qualification requirements and limits of qualification are those of the code for which the procedure is qualified.

2. Written approval of the welder performance qualification records is required prior to welding.

C. Welder Identification

1. The Subcontractor assigns each welder or welding operator a unique identification symbol. Welders use this symbol to identify each weld, either by stenciling or marking the symbol adjacent to the weld or by records traceable to the weld joint.

2.03 INSPECTION/EXAMINATION OF WELDS

A. The Subcontractor is responsible for the performance and documentation of specified weld examinations. These examinations shall be performed by qualified Subcontractor personnel or by an outside qualified examination service. The following applies for examination of all welds:

1. Certify examination personnel per the requirements in Part 3 of this specification.

2. Submit weld examination procedures for approval in accordance with the applicable construction code in Part 3 of this specification prior to welding.

3. Examine welds in accordance with Part 3 of this specification.

4. Prepare and file nondestructive examination reports. Submit them to the Project Manager or designee prior to final acceptance of work.

B. Welds and weld records are subject to inspection by the Contractor. The Contractor may request additional weld examinations on any weld to establish the quality of the weld. The Contractor reserves the right to accept, reject, or demand removal of welds which are interpreted by the Contractor to be in violation of this specification.

PART 3 - EXECUTION

3.01 GENERAL WELDING REQUIREMENTS

A. Make groove and butt welds complete joint penetration and continuous unless specified otherwise by the Project Manager or desginee. Backwelding of groove welds is acceptable. Weld size and length shall comply with design tolerances as indicated in the specifications, drawings, and referenced codes. Do not change the location of welds without the approval of the engineer.

B. Structural Welding

1. Compliance with AWS D-1.1 is required for structural welding. For structural welding not prequalified per AWS D-1.1 (e.g., stainless steel, aluminum, and sheet metal), qualify welding procedures in accordance with the requirements of AWS B-2.1, AWS D-1.2, AWS D-1.3, or ASME Sect. IX. Qualify welders in accordance with the code used to qualify the WPS. All other requirements of AWS D-1.1 not associated with the WPS or the welder qualification apply.

   b. Do not use copper or aluminum temporary backing without approval.

   c. Unless otherwise noted on the drawing or specification, make welds complete penetration in accordance with AWS D-1.1.

   d. GMAW with short circuiting transfer is prohibited for structural welding.

C. Pipe Welding

1. Weld piping systems in accordance with ASME B31.3.

   a. Use the gas tungsten arc process for welds in the following materials:

      1) butt welds in piping 1 1/2-in. outside diameter and smaller,

      2) the root pass of stainless steel piping,

      3) copper and copper-base alloy piping, and

      4) the root pass of nickel and nickel-base alloy piping.

   b. Purge the back side of the weld with Argon for the following materials until a minimum of 3/16-in. material thickness separates the weld from the back side of the weld. Analyze the purge with an oxygen analyzer to assure that oxygen does not exceed 1%.

      1) stainless steel and

      2) nickel and nickel-base alloys.

   c. Do not use copper or aluminum as temporary backing for pipe welding.

   d. Do not use backing rings unless permitted on the drawing or in the piping specification.

   e. Do not use the SMAW, FCAW, or SAW process for root pass welding of stainless steel piping welds.

   f. The GTAW, SMAW, GMAW, or FCAW process may be used for fillet welds or groove welds in pipe, fittings, and branch connections larger than 1 ½ inch outside diameter.

   g. GMAW with short circuiting transfer is prohibited for pipe welding.

D. Ductwork Welding

1. Compliance with AWS D-9.1 is required for ductwork welding. AWS D-9.1 applies to welds in or to the duct pressure boundary.

   a. Welds for ductwork stiffener and support materials may be made using WPSs qualified to AWS D-9.1, AWS D-1.1, or ASME Sect. IX provided the welders are qualified to the same code used to qualify the WPS. All other requirements of AWS D-9.1 not associated with the WPS or welder qualification apply.

   b. Ductwork fabricated from pipe may be made using WPSs qualified to the requirements of ASME Sect. IX provided the welders are qualified to ASME Section IX. All other requirements of AWS D-9.1 not associated with the WPS or welder qualification apply.

   c. Unless otherwise specified on drawings or standards, make continuous fillet welds when the root or face is in contact with the contained media to eliminate cracks and crevices.

   d. Make pressure boundary weld joints continuous.

   e. Grind weld joints which are a portion of a gasket seating surface smooth and flush with adjacent base metals.

   f. Wire brush welded joints and seams to remove surface oxides, burrs, sharp edges, and weld spatter.

   g. Brush stainless steel material with clean, stainless steel wire brushes which have not previously been used on materials other than stainless steel.

   h. GMAW with short circuiting transfer is prohibited for ductwork welding of materials greater than 1/8 in. thick.

3.02 PERSONNEL CERTIFICATION REQUIREMENTS FOR WELD EXAMINATIONS

A. Personnel performing nondestructive examination other than visual shall be currently certified per the employers' written practice in accordance with SNT-TC-1A. Only individuals certified as NDT Level II or III may perform nondestructive examinations in accordance with this specification.

B. Personnel performing visual examination of welds shall be currently certified either as an AWS CWI or as a visual testing Level II per the employers' written practice in accordance with SNT-TC-1A. If certified in accordance with SNT-TC-1A, the training and experience requirements shall be satisfied entirely by time spent in weld examination related work.

C. The Level III shall, in the methods certified, conduct the examination of Level II personnel for those same methods.

3.03 EXAMINATION OF STRUCTURAL WELDS

A. Required Examinations

1. Visually examine all completed structural welds in accordance with AWS D-1.1, Sect. 6.

B. Examination Procedures and Acceptance

1. Perform examinations to written procedures in accordance with AWS D1.1. Submit weld examination procedures for approval prior to welding.

2. Acceptance criteria for examination of structures is in accordance with the criteria for Statically Loaded Nontubular Connections of AWS D-1.1, Table 6.1.

3. Acceptance criteria for examination of dynamically loaded structures is per the criteria for Cyclically Loaded Nontubular Connections AWS D-1.1, Table 6.1. (The drawing identifies structures or components designed for dynamic loading. This is used for bridges and where other special vibrating loads are encountered.)

3.04 EXAMINATION OF PIPING WELDS

A. Required Examinations

1. Examination Required for Category D Fluid Service Pipe Welding

   a. The inspector shall randomly select a sufficient number of welds (5% min) for examination in order to be satisfied that they conform to the specification. Include welds made by each welder or welder operator in those examined. Perform a final visual examination of these welds in accordance with ASME B31.3, para. 341.4.1(a).

   b. If a random examination reveals a defect, the requirements of ASME/ANSI B31.3, para. 341.3.4, Progressive Examination, apply.

2. Examination Requirements for Normal Fluid Service Pipe Welding

   a. The inspector shall randomly select a sufficient number of welds (5% min) for examination in order to be satisfied that they conform to the specification. Include welds made by each welder or welder operator in those examined. Perform a final visual examination of these welds in accordance with ASME B31.3, para. 341.4.1(a).

   b. Examine fully by random radiography in accordance with ASME B31.3, para. 344.5, the circumferential butt and miter groove welds selected for visual examination. Include at least 1 1/2 in. of the longitudinal welds which intersect the circumferential or miter groove welds in the radiographs.

   c. Perform a final visual examination of fabricated longitudinal welds (excluding those in components made in accordance with a material specification) in accordance with ASME B31.3, para. 341.4.1(a).

   d. Radiograph 100% of fabricated longitudinal welds (excluding those in components made in accordance with a material specification) in accordance with ASME B31.3, para. 344.5.

   e. When approved by the Engineer in writing, the in-process visual examination alternative to radiography described below may be substituted for every field weld that it is not practical to move to a remote location for radiography.

f. If a random examination reveals a defect, the requirements of ASME B31.3, para. 341.3.4, Progressive Examination, apply.

3. Examination Requirements for Special Service

a. Perform a visual examination of the weld joint fit-up of all welds to assure, at a minimum, that markings and certifications are in accordance with specified requirements, the base metals are of specified thicknesses and types, materials are free from contaminants, fit-up meets the joint detail for the welding procedure specification, the weld purge is set up properly and exit gas is being analyzed with calibrated equipment, and the welder is qualified to make the weld.

b. Perform a final visual examination of all welds (not just the 5% specified by ASME B31.3) in accordance with ASME B31.3, para. 341.4.1(a).

c. Examine fully by radiography all circumferential butt and miter groove welds in accordance with ASME B31.3, para. 344.5. Include at least 1 1/2 in. of the longitudinal welds which intersect the circumferential or miter groove welds in those radiographed.

d. Fully radiograph 100% of fabricated longitudinal welds (excluding those in components made in accordance with a material specification) in accordance with ASME B31.3, para. 344.5.

e. Liquid-penetrant examine all pressure boundary welds and attachment welds to the pressure boundary after completion of the last layer of weld in accordance with ASME B31.3, para. 344.4.

The in-process alternative to radiography is not permitted for hydrogen fluoride service.

f. When approved by the Engineer in writing, the following alternative to radiography may be substituted for every field weld that it is not practical to move to a remote location for radiography.

1) in-process examination as described below;

2) liquid-penetrant examine the root layer and the final welds in accordance with ASME B31.3, para. 344.4.

4. In-process Examination Requirements

a. When approved by the Engineer, perform the following visual examinations as a substitute for the required radiography:

1) joint preparation and cleanliness;

2) preheating;

3) fit-up, joint clearance, and internal alignment prior to joining;

4) variables specified by the joining procedure, including filler material, position, electrode, etc;

5) condition of the internal weld root surface by direct visual examination, by the use of a borescope, or by using the “window method” of examining the partially completed weld root prior to final closure of the weld roots;

6) condition of the root pass external surface after cleaning aided by liquid penetrant or magnetic particle examination when specified in the engineering design (As is the case for 15128);

7) slag removal and weld condition of at least each layer of weld metal. The welder shall notify the examiner after each layer of weld before progressing to the next layer;

8) a final weld examination for at least the attributes and to the acceptance criteria specified in ASME B31.3.

b. The weld examiner records individual weld examination for in-process examinations.

B. Examination Procedures and Acceptance Criteria

1. Perform examinations to written procedures in accordance with ASME B31.3, para. 343. For radiography, the geometric unsharpness shall not exceed the limits of ASME Section V, paragraph T-285. Two complete sets of acceptable radiographs for each weld radiographed are required. Submit weld examination procedures for approval prior to welding.

2. The acceptance criteria of ASME B31.3, para. 341.3.2, and Table 341.3.2 for normal fluid service apply for visual and radiographic examination with the exception that incomplete penetration for complete penetration welds is unacceptable.

3. The acceptance criteria for liquid-penetrant examination follows:

a. Relevant indications are those with major dimensions greater than 1/16 in.

b. The following relevant indications are unacceptable:

1) cracks;

2) linear indication (indication whose length is more than three times its width);

3) rounded indications with dimensions greater than 3/16 in.;

4) four or more rounded indications in a line separated by 1/16 in. or less edge to edge; and

5) ten or more rounded indications in any 6 in.^{2} of surface area with the major dimension of this area not to exceed 6 in. and with the area taken in the most unfavorable location relative to the indications being evaluated.

3.05 EXAMINATION OF DUCTWORK WELDS

A. Required Examinations

1. Visually examine all final ductwork welds.

2. For ductwork systems, visually and liquid-penetrant examine the final weld surface of all pressure boundary and wetted perimeter welds, in accordance with ASME V, Article 6.

B. Examination Procedures and Acceptance Criteria

1. Perform visual examinations to written procedures in accordance with AWS D9.1. Perform liquid penetrant examinations to written procedures in accordance with ASME Section V, Article 6, or ASTM E-165.

2. The acceptance criteria of AWS D-9.1, para. 6 applies for visual examination of welds.

3. Indications exceeding 1/16 in. in any dimension are rejectable for liquid-penetrant examinations.

END OF SECTION

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EQUIPMENT DATA SHEETS

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SHAW ENVIRONMENTAL, INC.	EQUIPMENT SPECIFICATION				SHAW SPEC. NO. 122064-A102
	NO	BY	DATE	REV.	SHEET 1 OF 1
	B	TDS	7/7/08	internal review	PROJECT NAME C-400 SOIL VAPOR & GWTS
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS	2				JOB NO. 122064
AREA: C-400 CLEANING BLDG **TAG NO.:** A-102 **EQUIP:** AIR STRIPPER	3				LOCATION PADUCAH, KY BY TDS / APPR SES/KT / DATE 7/7/08

Process Data:

Fluid:	Groundwater
Normal Flow Rate:	60 gpm
Min Flow Rate:	20 gpm
Max Flow Rate:	90 gpm
Fluid Temp:	50-195°F
Fluid pH:	2.0-7.0
Fluid Spec Gravity:	1.0
Air Temperature:	0 to 110 °F

Groundwater Composition:		Influent Conc.	Discharge Limit (Note1)	Percent Removed
Analyte/Design Parameter	Trichloroethene	1,100 ppm	30 ppb	97.0
	Vinyl Chloride	133 ppb	530 ppb	-
	trans-1,2-Dichloroethane	1,200 ppb	140,000 ppb	-
	cis-1,2-Dichloroethene	195 ppb	No limit specified	-
	1,1-DCE	154 ppb	3.2 ppb	-
	Technetium-99	40 - 160 pCi/L	900 pCi/L	-
	Total Suspended Solids	10 - 50 ppm	30 ppm daily avg/ 60 ppm daily max	
	Total Dissolved Solids	N/A	No limit	-
	Turbidity	N/A	No limit specified	-
	Chloride	70 - 160 ppm	600 ppm daily avg/ 1200 ppm daily max	

Design Data:

Equipment Location:	Outdoors
Ambient Temp:	0 to 110 °F
Wind Load:	90 mph
Seismic Design:	Kentucky Category E, Ss=2.56 g, S1=0.78 g
Design Pressure:	Full of Water
Materials of Construction:	304L Stainless Steel (air stripper wetted parts)

Notes:
1. Discharge limits are based on 401 KAR 5:031 standards discharge through KPDES permitted Outfall 001.
2. Vendor shall provide a skid mounted air stripping system including air stripper and all instrumentation and controls noted within the boundaries of the vendor's package system. The system should be prepiped and prewired to the extent practical prior to shipment to the owner's site. The vendor shall fabricate a control panel to house electrical devices such as motor starters, relays, push buttons, pilot lights, instrument displays, and other electrical apparatus and controls.
3. Vendor shall provide stainless steel I.D. tags for all equipment and instrumentation within scope of supply.
4. The vendor shall clearly state any exceptions to the requirements outlined in this data sheet.

Data to be Provided by Vendor:

Equipment Arrangment Plan and Elevation Drawings
Equipment Materials of Construction
Stripper Vessel/Column Liquid Holdup (including Sump Capacity)
Skid Weight
Fan Performance Curve
Fan Horsepower
Stripper Effluent Concentrations @ Maximum Groundwater Flow
Stripper Design Min & Max Flow Range
Equipment and Instrument Cut Sheets
Air Stripper System P&ID
Required Fluid Pressure at Maximum Flow Rate

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LATA Enviromental Services of Kentucky, LLC	VACUUM BLOWER SPECIFICATION				LATA SPEC. NO. SPM-PHC400-P002
	NO	BY	DATE	REV	PAGE 1 OF 1
					PROJECT NAME C-400 SOIL VAPOR & GWTS
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS					JOB NO. C-400 IRA
AREA: C-400 CLEANING BLDG					LOCATION PADUCAH, KY
TAG NO.: B-101 A/B					BY / APPR / DATE
EQUIPMENT: VACUUM BLOWER					

	Manufacturer:	Roots or equal (Must be exact replacement for a Roots Model XX Blower)
	Model Number:	624 RAM-VJ with water seal, or equal (2 replacement blowers required)
	Gas & Material Handled:	Air saturated w/water @ 100 deg F w/max, 10,000 ppmv TCE
G	Inet Flow:	775 SCFM total (50% flow to each of 2 blowers), 1,965 Inlet CFM total
	Inlet Temperature:	100 deg F
E	Gas Density	0.029 lb./ft3 at inlet conditions
	S. P.	17.4 inches Hg Vacuum
N	Outlet Pressure	6 inches water downstrem of existing silencer
	Skid Dimensions:	N/A
E	Noise Rating	TBD (1)
	Gage & Material of Rims:	TBD (1)
R	Blade Material	TBD (1)
	Housing Gage & Materials	TBD (1)
A	Skid Weight:	N/A
	Oil Sump Capacity:	TBD (1)
L	Total Cooling Water Flow	TBD (1)
	Inlet/Exhaust Connection Size:	10"/8"
	Bearings - type:	TBD (1)
	Shaft Diameter at Bearings:	TBD (1)
	Maximum Shaft Speed	TBD (1)
	Impeller Material:	TBD (1)
	Seal Type:	TBD (1)
	ELECTRIC MOTOR:	Note: Electric motor information is for information only - existing equipment.
	Speed	1,800 rpm
D	volts	480V
R	Phase:	3
I	Cycles:	60 Hz
V	Enclosure	TEFC
E	Service Factor	Inverter Rated
R	BHP	100
	Temperature Rise:	
	OPTIONS:	
	Discharge Silencer:	Yes - Existing
	Inlet Expansion Joint:	Yes - Existing
	Discharge Expansion Joint:	Yes - Existing
	Inlet Filter Silencer:	No - Refer to arrangement drawing
	Water cooling	Yes - Inlet water injection
	Interstage cooler type:	No
	Oil Cooler type:	Water cooled-If needed
Ambient Conditions:		
	Equipment Location:	Outdoors
	Ambient Temp:	0 to 120 deg F
	Wind Load:	90 mph
	Seismic Design:	Kentucky Category E Seismic Ss=2.56 g, S1=0.78g

Notes:
1. Vendor to complete information marked *
2. Refer to Vacuum Blower Specification SPM-PHC400-P002 for all technical requirements.

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LATA Enviromental Services of Kentucky, LLC	AIR STRIPPER BLOWER SPECIFICATION				LATA SPEC. NO.
	NO	BY	DATE	REV	PAGE 1 OF 1
					PROJECT NAME: C-400 SOIL VAPOR & GWTS
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS					JOB NO.: C-400 IRA
AREA: C-400 CLEANING BLDG					LOCATION: PADUCAH, KY
TAG NO.:					BY / APPR / DATE
EQUIPMENT: AIR STRIPPER PRESSURE BLOWER					

	Manufacturer:	TBD (1)
	Model Number:	TBD (1)
	Gas & Material Handled:	Ambient Air
G	Inet Flow:	450 SCFM
	Inlet Temperature:	100 deg F
E	Gas Density	0.071 lb./ft3 at inlet conditions
	S. P.	62 inches water gage
N	Outlet Pressure	62 inches water gage
	Skid Dimensions:	TBD (1)
E	Noise Rating	TBD (1)
	Gage & Material of Rims:	TBD (1)
R	Blade Material	TBD (1)
	Housing Gage & Materials	TBD (1)
A	Skid Weight:	TBD (1)
	Oil Sump Capacity:	N/A
L	Total Cooling Water Flow	N/A
	Inlet/Exhaust Connection Size:	TBD (1)
	Bearings - type:	TBD (1)
	Shaft Diameter at Bearings:	TBD (1)
	Maximum Shaft Speed	TBD (1)
	Impeller Material:	TBD (1)
	Seal Type:	TBD (1)
	ELECTRIC MOTOR:	
	Speed	TBD (1)
D	volts	480V
R	Phase:	3
I	Cycles:	60 Hz
V	Enclosure	TEFC
E	Service Factor	Inverter Rated
R	BHP	TBD (1)
	Temperature Rise:	TBD (1)
	OPTIONS:	
	Discharge Silencer:	No
	Inlet Expansion Joint:	No
	Discharge Expansion Joint:	Yes
	Inlet Filter Silencer:	Yes - with enclosure if needed to meet noise specification
	Water cooling	No
	Interstage cooler type:	No
	Oil Cooler type:	No
Ambient Conditions:		
	Equipment Location:	Outdoors
	Ambient Temp:	0 to 120 deg F
	Wind Load:	90 mph
	Seismic Design:	Kentucky Category E Seismic Ss=2.56 g, S1=0.78g

Notes:
1. Vendor to complete information marked *
2. Refer to Vacuum Blower Specification SPM-PHC400-P002 for all technical requirements.

SHAW ENVIRONMENTAL, INC.	**ION EXCHANGE UNIT SPECIFICATION**				SHAW SPEC. NO. **122064-C102 A,B**
	NO	BY	DATE	REVISION	SHEET 1 OF 1
	A	TDS	1/17/07	for internal review	PROJECT NAME **C-400 SOIL & VAPOR GWTS**
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	1				JOB NO. **122064**
AREA: **C-400 CLEANING BLDG**					LOCATION **PADUCAH, KY**
TAG NO.: **C-102A,B**	2				BY TDS / APPR SES/KT / DATE **1/9/07**
EQUIPMENT: **ION EXCHANGE**					

1			Field Erected?	NO	No. Units:	One w/2 Tanks
2		Operating Pressure:	psia	20		
3		Operating Temperature:	F	100		
4		Contents Lethal?		NO		
5		Design Pressure:	PSIG	70		
6		Design Temperature:	F	120		
7		Process Fluid:		Treated Groundwater		
8	D	Volumetric Flow Rate:	GPM	100		
9	E	Vessel Volume (each Tank):	cu.ft.			
10	S	Resin Material Type:		Purolite A-520E -Anion exchange resin		
11	I	Quantity resin material in each tank:	cu.ft.	80 cu. ft / tank (actual resin volume)		
12	G	Tank Diameter:	ft.	5		
13	N	Tank Height:	ft.	7		
14		Shell Corrosion Allowance:				
15	D	Code:		Stamp:		
16	A	Radiograph:		Stress Relieve:	NO	
17	T	Type Supports:				
18	A	Insulation: NO				
19		Sandblast: YES		Paint:	YES	
20		Manhole: YES	Hinged? NO	Davited?	NO	Other:
21		Platform Clips: NO	Ladder Clips:		NO	Insul. Rings:
22		Pipe Supports: NO				
23		Wind Load: 90 mph		Seismic Design:	Kentucky Category E, Ss=2.56 g, S1=0.78 g	
24		Weight Empty: * lbs	Weight with Adsorber: *	lbs		

25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
26		Shell	*	CS	SA-516 70
27	M	Heads	*	CS	SA-516 70
28	A				
29	T				
30	E				
31	R				
32	I				
33	A	Nozzle Necks	A-53		CS
34	L	Flanges	A-105		CS (150 #)
35	S	M.H. Cover	N/A		
36		Supports	A-36		CS
37		Bolts/Studs	Studs		CS
38		Nuts	Heavy Hex		Alloy
39		Gaskets			

40		Service	Mark	No.	Size	Rating	Face	Type
41		Inlet	A	1	*			
43	N	Outlet	B	1	*			
44	O	Vent	G	1	*			
45	Z	Drain	D	1	*			
46	Z	Manway	E	1	18 "			
47	L		G					
48	E		H					
49	S		J					
50			K					
51			L					
52			M					

53		1. Ion exchange beds are used to remove any possible Technetium-99 in the water.
54	N	2. Each tank contains a minimum of 80 cubic feet of usable resin.
55	O	3. Ion exchange is skid mounted with all pipe and valves needed to allow either bed to operate
56	T	as the lead or lag unit.
57	E	4. Tank interior will require epoxy coating.
58	S	
59		

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SHAW ENVIRONMENTAL, INC.	**CARBON ADSORBERS SPECIFICATION**			SHAW SPEC. NO. **122064-C103 A,B**
	NO	BY	DATE	REVISION
		TDS	1/17/07	for internal review
	1			
	2			

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PROJECT NAME **C-400 SOIL & VAPOR GWTS**

JOB NO. **122064**

LOCATION **PADUCAH, KY**

BY	APPR	DATE
TDS	SES/KT	**1/9/07**

PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**
AREA: **C-400 CLEANING BLDG**
TAG NO.: **C-103A,B**
EQUIPMENT: **LIQUID CARBON ADSORBERS**

1			Field Erected? NO	No. Units: One w/2 Vessels
2		Operating Pressure:	psia	20
3		Operating Temperature:	F	100
4		Contents Lethal?		NO
5		Design Pressure:	PSIG	80
6		Design Temperature:	F	150
7		Process Fluid:		Treated Groundwater
8	D	Volumetric Flow Rate:	GPM	100
9	E	Vessel Volume (each Tank):	cu.ft.	93 (actual carbon volume)
10	S	Adsorber Material Type:		Activated Carbon
11	I	Quantity adsorber material in each adsorber		2,500 lbs / adsorber
12	G	Tank Diameter:	ft.	5
13	N	Tank Height:	ft.	7
14		Shell Corrosion Allowance:		*
15	D	Code:		Stamp:
16	A	Radiograph:		Stress Relieve: NO
17	T	Type Supports: *		
18	A	Insulation: NO		
19		Sandblast: YES		Paint: YES
20		Manhole: YES Hinged? NO	Davited? NO	Other:
21		Platform Clips: NO	Ladder Clips: NO	Insul. Rings:
22		Pipe Supports: NO		
23		Wind Load: 90 mph	Seismic Design:	Kentucky Category E, Ss=2.56 g, S1=0.78 g
24		Weight Empty: * lbs	Weight with Adsorber: * lbs	

		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
26		Shell	*	CS	SA-516 70
27	M	Heads	*	CS	SA-516 70
28	A				
29	T				
30	E				
31	R				
32	I				
33	A	Nozzle Necks	A-53		CS
34	L	Flanges	A-105		CS (150 #)
35	S	M.H. Cover	N/A		
36		Supports	A-36		CS
37		Bolts/Studs	Studs		CS
38		Nuts	Heavy Hex		Alloy
39		Gaskets			

		Service	Mark	No.	Size	Rating	Face	Type
40		Service	Mark	No.	Size	Rating	Face	Type
41		Inlet	A	1	*			
43	N	Outlet	B	1	*			
44	O	Vent	G	1	*			
45	Z	Drain	D	1	*			
46	Z	Manway	E	1	18 "			
47	L		G					
48	E		H					
49	S		J					
50			K					
51			L					
52			M					

53		1. Carbon adsorbers are used to remove any residual VOCs in the water.
54	N	2. Each tank contains 2,500 lbs of usable carbon.
55	O	3. Carbon adsorber is skid mounted with all pipe and valves needed to allow either bed to operate
56	T	as the lead or lag unit.
57	E	4. Tank interior will require epoxy coating.
58	S	5. The carbon beds will require change out every 2 to 4 weeks.
59		

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SHAW ENVIRONMENTAL, INC.	**CARBON ADSORBERS SPECIFICATION**			SHAW SPEC. NO. **122064-C106 A,B**
	NO	BY	DATE	REVISION
	B	TDS	7/07/08	for internal review
	1			
	2			

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PROJECT NAME: **C-400 SOIL & VAPOR GWTS**

JOB NO. **122064**

LOCATION: **PADUCAH, KY**

BY	APPR	DATE
TDS	SES/KT	**7/07/08**

PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**
AREA: **C-400 CLEANING BLDG**
TAG NO.: **C-106A,B**
EQUIPMENT: **POLISHING VAPOR CARBON ADSORBERS**

1			Field Erected? NO	No. Units: One w/ dual cells	
2		Operating Pressure:	psia	14.7 to 16.0	
3		Operating Temperature:	F	70	
4		Contents Lethal?		NO	
5		Design Pressure:	PSIG	2	
6		Design Temperature:	F	120	
7		Process Fluid:		Vapor from Vapor Recovery System	
8	D	Air Volumetric Flow Rate:	ACFM	1900	
9	E	Vessel Volume (each Adsorber):	cu.ft.	70 (actual carbon volume)	
10	S	Adsorber Material Type:		Activated Carbon	
11	I	Quantity adsorber material in each adsorber:		2,000 lb /each	
12	G	Adsorber Diameter:	ft.	5	
13	N	Adsorber Height:	ft.	7	
14		Shell Corrosion Allowance:			
15	D	Code:		Stamp:	
16	A	Radiograph:		Stress Relieve: NO	
17	T	Type Supports:			
18	A	Insulation: NO			
19		Sandblast: YES		Paint: YES	
20		Manhole: YES Hinged? NO	Davited? NO	Other:	
21		Platform Clips: NO	Ladder Clips: NO	Insul. Rings:	
22		Pipe Supports: NO			
23		Wind Load: 90 mph		Seismic Design: Kentucky Category E, Ss=2.56 g, S1=0.78 g	
24		Weight Empty: * lbs	Weight with Adsorber: * lbs		

		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
26		Shell	*	CS	SA-516 70
27	M	Heads	*	CS	SA-516 70
28	A				
29	T				
30	E				
31	R				
32	I				
33	A	Nozzle Necks	A-53		CS
34	L	Flanges	A-105		CS
35	S	M.H. Cover	N/A		
36		Supports	A-36		CS
37		Bolts/Studs	Studs		CS
38		Nuts	Heavy Hex		Alloy
39		Gaskets			

		Service	Mark	No.	Size	Rating	Face	Type
40		Service	Mark	No.	Size	Rating	Face	Type
41		Inlet	A	1	*			
43	N	Outlet	B	1	*			
44	O	Vent	G	1	*			
45	Z	Drain	D	1	*			
46	Z	Manway	E	1	18 "			
47	L		G					
48	E		H					
49	S		J					
50			K					
51			L					
52			M					

53		1. Adsorbers are designed to remove low levels of VOCs (20 to 50 ppmv).
54	N	2. Each adsorber contains 2,000 lbs of activated carbon.
55	O	3. Adsorbers are skid mounted with all pipe and valves needed to allow either adsorber to operate
56	T	as the lead or lag unit.
57	E	4. Tank interior will require epoxy coating.
58	S	5. The activated carbon beds will require change out every 2 to 4 weeks.
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SHAW ENVIRONMENTAL, INC.	ZEOLITE SYSTEM SPECIFICATION				SHAW SPEC. NO. 122064-C107 A,B
	NO	BY	DATE	REVISION	SHEET 1 OF 1
	A	TDS	7/07/08	for internal review	PROJECT NAME C-400 SOIL & VAPOR GWTS
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS	1				JOB NO. 122064
AREA: C-400 CLEANING BLDG					LOCATION PADUCAH, KY
TAG NO.: C-107A,B **EQUIPMENT:** POLISHING VAPOR ZEOLITE SYSTEM	2				BY TDS / APPR SES/KT 1/9/07 / DATE 7/07/08

1			Field Erected?	NO	No. Units: One w/ dual cells			
2		Operating Pressure:	psia	14.7 to 16				
3		Operating Temperature:	F	70				
4		Contents Lethal?		NO				
5		Design Pressure:	PSIG	2				
6		Design Temperature:	F	120				
7		Process Fluid:		Vapor from Vapor Recovery System				
8	D	Air Volumetric Flow Rate:	ACFM	1900				
9	E	Vessel Volume (each Adsorber):	cu.ft.	70 (actual zeolite volume)				
10	S	Adsorber Material Type:		Zeolite media impregnated w/potasium permanganate				
11	I	Quantity adsorber material in each adsorber:		4,000 lb /each				
12	G	Adsorber Diameter:	ft.	5				
13	N	Adsorber Height:	ft.	7				
14		Shell Corrosion Allowance:						
15	D	Code:		Stamp:				
16	A	Radiograph:		Stress Relieve: NO				
17	T	Type Supports:						
18	A	Insulation: NO						
19		Sandblast: YES		Paint: YES				
20		Manhole: YES	Hinged? NO	Davited? NO	Other:			
21		Platform Clips: NO	Ladder Clips: NO	Insul. Rings:				
22		Pipe Supports: NO						
23		Wind Load: 90 mph		Seismic Design: Kentucky Category E, Ss=2.56 g, S1=0.78 g				
24		Weight Empty: * lbs	Weight with Adsorber: * lbs					
25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality			
26		Shell	*	CS	SA-516 70			
27	M	Heads	*	CS	SA-516 70			
28	A							
29	T							
30	E							
31	R							
32	I							
33	A	Nozzle Necks	A-53		CS			
34	L	Flanges	A-105		CS			
35	S	M.H. Cover	N/A					
36		Supports	A-36		CS			
37		Bolts/Studs	Studs		CS			
38		Nuts	Heavy Hex		Alloy			
39		Gaskets						
40		Service	Mark	No.	Size	Rating	Face	Type
41		Inlet	A	1	*			
43	N	Outlet	B	1	*			
44	O	Vent	G	1	*			
45	Z	Drain	D	1	*			
46	Z	Manway	E	1	18 "			
47	L		G					
48	E		H					
49	S		J					
50			K					
51			L					
52			M					
53		1. Adsorbers are designed to remove vinyl chloride.						
54	N	2. Each adsorber contains 4,000 lbs of zeolite.						
55	O	3. Adsorbers are skid mounted with all pipe and valves needed to allow either adsorber to operate						
56	T	as the lead or lag unit.						
57	E	4. The zeolite beds will require change out every 1 to 3 weeks.						
58	S							
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SHAW ENVIRONMENTAL, INC.	ION EXCHANGE UNIT SPECIFICATION				SHAW SPEC. NO. 122064-C108 A,B		
	NO	BY	DATE	REVISION	SHEET 1 OF 1		
	A	TDS	11/26/07	for internal review	PROJECT NAME C-400 SOIL & VAPOR GWTS		
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS	1				JOB NO. 122064		
AREA: C-400 CLEANING BLDG					LOCATION PADUCAH, KY		
TAG NO.: C-108 A,B	2				BY	APPR	DATE
EQUIPMENT: ION EXCHANGE					TDS	SES	11/26/07

1			Field Erected? NO	No. Units: One w/2 Tanks				
2		Operating Pressure: psia	20					
3		Operating Temperature: F	160					
4		Contents Lethal?	NO					
5		Design Pressure: PSIG	70					
6		Design Temperature: F	200					
7		Process Fluid:	Treated Groundwater					
8	D	Volumetric Flow Rate: GPM	15					
9	E	Vessel Volume (each Tank): cu.ft.						
10	S	Resin Material Type:	Purolite A-520E -Anion exchange resin					
11	I	Quantity resin material in each tank: cu.ft.	19 cu. ft / tank (actual resin volume)					
12	G	Tank Diameter: ft.	2 ft - 6 in					
13	N	Tank Height: ft.	7					
14		Shell Corrosion Allowance:						
15	D	Code:	Stamp:					
16	A	Radiograph:	Stress Relieve: NO					
17	T	Type Supports:						
18	A	Insulation: NO						
19		Sandblast: YES	Paint: YES					
20		Manhole: YES Hinged? NO	Davited? NO	Other:				
21		Platform Clips: NO	Ladder Clips: NO	Insul. Rings:				
22		Pipe Supports: NO						
23		Wind Load: 90 mph	Seismic Design: Kentucky Category E, Ss=2.56 g, S1=0.78 g					
24		Weight Empty: * lbs	Weight with Adsorber: * lbs					
25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality			
26		Shell	*	CS	SA-516 70			
27	M	Heads	*	CS	SA-516 70			
28	A							
29	T							
30	E							
31	R							
32	I							
33	A	Nozzle Necks	A-53		CS			
34	L	Flanges	A-105		CS (150 #)			
35	S	M.H. Cover	N/A					
36		Supports	A-36		CS			
37		Bolts/Studs	Studs		CS			
38		Nuts	Heavy Hex		Alloy			
39		Gaskets						
40		Service	Mark	No.	Size	Rating	Face	Type
41		Inlet	A	1	*			
43	N	Outlet	B	1	*			
44	O	Vent	G	1	*			
45	Z	Drain	D	1	*			
46	Z	Manway	E	1	18 "			
47	L		G					
48	E		H					
49	S		J					
50			K					
51			L					
52			M					
53		1. Ion exchange beds are used to remove any possible Technetium-99 in the water.						
54	N	2. Each tank contains a minimum of 80 cubic feet of usable resin.						
55	O	3. Ion exchange is skid mounted with all pipe and valves needed to allow either bed to operate						
56	T	as the lead or lag unit.						
57	E	4. Tank interior will require epoxy coating.						
58	S							
59								

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SHAW ENVIRONMENTAL, INC.	FIN COIL HEAT EXCHANGER SPECIFICATION				SHAW SPEC. NO. E-101 HEAT EXCHANGER 1	
	NO	BY	DATE	REV	PAGE 1 OF 1	
	B	TDS	7/07/08	internal review	PROJECT NAME C-400 SOIL VAPOR & GWTS	
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS AREA: C-400 CLEANING BLDG TAG NO.: E-101 EQUIPMENT: VAPOR COOLER					JOB NO. 122064 LOCATION PADUCAH, KY	
					BY TDS	APPR SES/KT — DATE 7/07/08

Process Data:	Process Fluid	Service Fluid
Fluid:	Air/steam (contami. w/ 20,000 ppmv TCE)	Water
Inlet Pressure:	10 inch Hg Vacuum (or 9.8 psia)	30 psig
Pressure Loss:	3.6 to 5 inches water	* lb/sq.in.
Volumetric Flow Rate:	5827 ACFM	781 gpm
Flow In: lb/hour	Dry Air: 7,270; Steam: 4052; TCE: 571	* lb/hr
Flow Out: lb/hour	Dry Air: 7,270; Steam: 607; TCE: 571	* lb/hr
Condensed (lb/hr):	Water 3,445 lb/hr	
Fluid Temp inlet:	203 °F	80 to 90 °F max.
Fluid Temp outlet:	105 °F	100 °F max.
Estimated duty (design)	3,906,000 BTU/hr	
Design Data:		
Manufacturer/Model:	Xchanger Model C-250 or Equivalent	
Design Temperature:	-20 to 250 °F	50 to 200 °F
Design Pressure: psig	-6 to 6 lb/sq.in.	-14.7 to 100 lb/sq.in.
Test Pressure: psig	9 lb/sq.in.	100 lb/sq.in.
Tube Material:	**Copper**	
Fin Material:	**Aluminum**	
Housing Material:	**Carbon Steel**	
Casing Material:	**Galvanized Steel**	
Flange Material:	1/4" Steel flat plate flange w/matching ANSI/ASTM bolt pattern	
Mist Eliminator:	None	
Tube Circuit Type:	Trapped	
Gas Flow Direction:	Right Hand Horizontal	
Process Inlet:	10" flanged, 1/4" steel plate w/bolt pattern matching ANSI	
Process Outlet:	10" flanged, 1/4" steel plate w/bolt pattern matching ANSI	
Service Inlet:	4 inch	
Service Outlet:	4 inch	
Unit Dimensions:	*	
Unit Weight (dry/wet):	*	
Ambient Conditions:		
Equipment Location:	Outdoors	
Ambient Temp:	0 to 120 °F	
Wind Load:	90 mph	
Seismic Design:	Kentucky Category E, Ss=2.56 g, S1=0.78 g	

Notes:

1. Vendor to complete information marked *
2. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Calculation Data, Installation Instruction, Operating/Maintenance Manual etc.
3. Vendor to include Delivery Schedules, and certified shop hydrostatic test data if required.
4. Equipment shall be provided with stainless steel I.D. tags.
5. Design duty for 1,500 scfm dry air + 4072 lb/hr water vapor + 571 lb/hr TCE.
6. The unit is not designed for cycling process vapor.
7. Maximum allowable pressure drop is 6" water.

SHAW ENVIRONMENTAL, INC.	**FIN COIL HEAT EXCHANGER SPECIFICATION**				SHAW SPEC. NO. E-102 **HEAT EXCHANGER 2**
	NO	BY	DATE	REV	PAGE **1 OF 1**
	B	**TDS**	**7/07/08**	**internal review**	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS **AREA:** C-400 CLEANING BLDG **TAG NO.:** E-102 **EQUIPMENT:** VAPOR CHILLER					JOB NO. **122064** LOCATION **PADUCAH, KY** BY **TDS** APPR **SES/KT** DATE **7/07/08**

Process Data:		**Process Fluid**	**Service Fluid**
Fluid:		Air/steam (contami. w/ 20,000 ppmv TCE)	Ethylene Glycol 20%
Inlet Pressure:		5 inch water	
Pressure Loss:		*	*
Volumetric Flow Rate:		2,303 acfm	* gpm
Flow In:	lb/hour	Dry Air: 7,270; Steam: 607; TCE: 571	* lb/hr
Flow Out:	lb/hour	Dry Air: 7,270; Steam: 114; TCE: 571	* lb/hr
Condensed (lb/hr):		Water 460 lb/hr	
Fluid Temp inlet:		225 ^{o}F	45
Fluid Temp outlet:		70 ^{o}F	60
Estimated duty (design)		841,000 BTU/hr	
Design Data:			
Manufacturer/Model:		Xchanger or Equivalent *	
Design Temperature:		-20 to 250 ^{o}F	50 to 200 ^{o}F
Design Pressure:	psig	-6 to 6 lb/sq.in.	-14.7 to 150 lb/sq.in.
Test Pressure:	psig	9 lb/sq.in.	260 lb/sq.in.
Tube Material:		Copper	
Fin Material:		Aluminum	
Housing Material:		Carbon Steel	
Casing Material:		Galvanized Steel	
Flange Material:		1/4" Steel flat plate flange w/matching ANSI/ASTM bolt pattern	
Mist Eliminator:		None	
Tube Circuit Type:		Trapped	
Gas Flow Direction:		Right Hand Horizontal	
Process Inlet:		10" flanged, 1/4" steel plate w/bolt pattern matching ANSI	
Process Outlet:		10" flanged, 1/4" steel plate w/bolt pattern matching ANSI	
Service Inlet:		* inch	
Service Outlet:		* inch	
Unit Dimensions:		*	
Unit Weight (dry/wet):		*	
Ambient Conditions:			
Equipment Location:		Outdoors	
Ambient Temp:		0 to 120 ^{o}F	
Wind Load:		90 mph	
Seismic Design:		Kentucky Category E, Ss=2.56 g, S1=0.78 g	

Notes:

1. Vendor to complete information marked *
2. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Calculation Data, Installation Instruction, Operating/Maintenance Manual etc.
3. Vendor to include Delivery Schedules, and certified shop hydrostatic test data if required.
4. Equipment shall be provided with stainless steel I.D. tags.
5. Design duty for 1,500 scfm dry air + 607 lb/hr steam/water vapor.
6. The unit is not designed for cycling process vapor.
7. Maximum allowable pressure drop is 6" water.

SHAW ENVIRONMENTAL, INC.	PLATE HEAT EXCHANGER SPECIFICATION				SHAW SPEC. NO. E-104 HEAT EXCHANGER 4		
	NO	BY	DATE	REV	PAGE 1 OF 1		
	B	TDS	7/07/08	internal review	PROJECT NAME C-400 SOIL VAPOR & GWTS		
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS					JOB NO. 122064		
AREA: C-400 CLEANING BLDG					LOCATION Paducah, Kentucky		
TAG NO.: E-104					BY	APPR	DATE
EQUIPMENT: AIR STRIPPER EFFLUENT COOLER					KT	SES/KT	7/07/08

Process Data:		Process Fluid	Service Fluid
Fluid:		Treated Hot Groundwater	Cooling Water
Pressure:		100 psig	* psig
Pressure Drop:		*	*
Max Flow Rate:		45 gpm Hot Water	258 gpm
Max Flow In:	lb/hr		
Max Flow Out:	lb/hr		
Fluid Temp inlet:		157 °F	85 °F
Fluid Temp outlet:		90 °F	100 °F
Fluid Specific Gravity or Density:		As for water	
Fluid Viscosity:		As for water	
Estimated duty (design)		1,289,000 BTU/hr	
Design Data:			
Manufacturer/Model:		Xchanger or Equivalent *	
Design Temperature:		220 °F	220 °F
Design Pressure:	psig	100 lb/sq.in.	100 lb/sq.in.
Test Pressure:	psig	130 lb/sq.in.	130 lb/sq.in.
Plate Material:		ANSI 304	
Plate Number:		*	
Gasket Material:		Viton	
Frame Material:		Carbon Steel	
Flange Material:			
Mist Eliminator:		None	
Tube Circuit Type:			
Gas Flow Direction:			
Process Inlet:		* inch, 150#	
Process Outlet:		* inch, 150#	
Service Inlet:		* inch, 150#	
Service Outlet:		* inch, 150#	
Unit Dimensions:		*	
Unit Weight (dry/wet):		*	
Ambient Conditions:			
Equipment Location:		Outdoors	
Ambient Temp:		0 to 120 °F	
Wind Load:		90 mph	
Seismic Design:		Kentucky Category E, Ss=2.56 g, S1=0.78 g	

Notes:

1. Vendor to complete information marked *
2. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Calculation Data, Installation Instruction, Operating/Maintenance Manual etc.
3. Vendor to include Delivery Schedules, and certified shop hydrostatic test data if required.
4. Equipment shall be provided with stainless steel I.D. tags.
5. The unit is not designed for cycling process water.
6. E-104 is a cooling unit and is intended to cool the water to 85 deg F before entering the ion exchange and carbon adsorber systems.

SHAW ENVIRONMENTAL, INC.			**FILTER SPECIFICATION**		SHAW SPEC. NO. **122064-F101A,B**
	NO	BY	DATE	REV.	SHEET 1 OF 1
	A	TDS	1/17/07	for internal review	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	2				JOB NO. **122064**
AREA: **C-400 CLEANING BLDG**					LOCATION **PADUCAH, KY**
TAG NO.: **F-101A/B**	3				BY: TDS / APPR: SES/KT / DATE: 1/9/07
EQUIP.: AIR STRIPPER EFFLUENT FILTERS					

Number of Units: 2 (TWO)

PERFORMANCE DATA

Bag Filter: YES — Microns: 20 microns
Single Basket: YES — Perforations: 9/64 in dia.

PROCESS DATA

Liquid: Groundwater — Temp: 60 - 200 deg F — Pressure: 70 psig
Flow: GPM 100 — PRESS. Drop: Clean <3 PSI; Dirty * PSI
Vapor: LB./HR. N/A
Design PRESS. 70 PSIG — Flanges 3 in DIA. ______ PSI Type Threaded
Design TEMP. 200 deg. F.

MECHANICAL DESIGN DATA

Manufacturer: ROSEDALE OR APPROVED EQUAL — Model *
Shell Material: CARBON STEEL
Filter Material: POLYPROPYLENE — Area: Gross * SQ. IN. Free * SQ. IN.
Basket Material: STAINLESS STEEL — Area: Gross * SQ. IN. Free * SQ. IN.
Elastomers: NEOPRENE
Support Lugs: (YES) NO — Code Stamp: YES (NO)
Flanged & Bolted Cover: (YES) NO — With Swing Bolts: (YES) NO

Vent Dia. * IN. — Clean Out Opening *
Press. Gage Taps * IN. — Hand Hole to Service Valves
Drain Valve: Slide Gate — Ball — Globe — Plug Cock
Are valves mechanically interlocked? NO
Dimensions Body: Length * — Width * — Height *
Filter: *
Shipping Weight *
Remarks

1. VENDOR TO COMPLETE INFORMATION MARKED *
2. FILTER ASSEMBLY TO INCLUDE DRAIN PORT.
3. VENDOR TO PROVIDE STAINLESS STEEL I.D. TAG FOR THE EQUIPMENT.
4. Seismic Design: Kentucky Category E, Ss=2.56 g, S1=0.78 g

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SHAW ENVIRONMENTAL, INC.	FILTER SPECIFICATION	SHAW SPEC. NO. 122064-F102A,B

NO	BY	DATE	REV.	SHEET 1 OF 1
A	TDS	1/17/07	for internal review	PROJECT NAME C-400 SOIL VAPOR & GWTS
2				JOB NO. 122064
3				LOCATION PADUCAH, KY

BY	APPR	DATE
TDS	SES/KT	1/9/07

PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS
AREA: C-400 CLEANING BLDG
TAG NO.: F-102A/B
EQUIP.: AIR STRIPPER INFLUENT FILTERS

1
2 Number of Units 2 (TWO)
3 **PERFORMANCE DATA**
4 Bag Filter YES Microns: 20 microns
5 Single Basket YES Perforations: 9/64 in dia.
6
7 **PROCESS DATA**
8 Liquid: Groundwater Temp: 60 - 200 deg F Pressure: 70 psig
9 Flow: GPM 100 PRESS. Drop: Clean <3 PSI; Dirty * PSI
10 Vapor: LB./HR. N/A
11 Design PRESS. 70 PSIG Flanges 3 in DIA. PSI Type Threaded
12 Design TEMP. 200 deg. F.
13
14 **MECHANICAL DESIGN DATA**
15 Manufacturer ROSEDALE OR APPROVED EQUAL Model *
16 Shell Material: CARBON STEEL
17 Filter Material: POLYPROPYLENE Area: Gross * SQ. IN. Free * SQ. IN.
18 Basket Material: STAINLESS STEEL Area: Gross * SQ. IN. Free * SQ. IN.
19 Elastomers: NEOPRENE
20 Support Lugs: (YES) NO Code Stamp: YES (NO)
21 Flanged & Bolted Cover: (YES) NO With Swing Bolts: (YES) NO
22
23 Vent Dia. * IN. Clean Out Opening *
24 Press. Gage Taps * IN. Hand Hole to Service Valves
25 Drain Valve: Slide Gate Ball Globe Plug Cock
26 Are valves mechanically interlocked? YES NO
27 Dimensions Body: Length * Width * Height *
28 Filter: *
29 Shipping Weight *
30 Remarks
31 1. VENDOR TO COMPLETE INFORMATION MARKED *
32 2. FILTER ASSEMBLY TO INCLUDE DRAIN PORT.
33 3. VENDOR TO PROVIDE STAINLESS STEEL I.D. TAG FOR THE EQUIPMENT.
34 4. Seismic Design: Kentucky Category E, Ss=2.56 g, S1=0.78 g
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SHAW ENVIRONMENTAL, INC.	**PUMP SPECIFICATION**				SHAW SPEC. NO. **122064-P101**
	NO	BY	DATE	REV.	SHEET **1** OF **1**
	A	**TDS**	**1/17/07**	**internal review**	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJ: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	2				JOB NO. **122064**
AREA: **C-400 CLEANING BLDG**					LOCATION **PADUCAH, KY**
TAG NO.: **P-101**	3				BY TDS / APPR SES/KT / DATE **1/9/07**
EQUIP: **LIQUID/VAPOR SEPARATOR PUMP**					

1	C	Manufacturer: **Gorman-Rupp or approved equal**		Model No.: *	
2	O	No. of Units: **1 (One)**		Normal Flow : **10 gpm**	Discharge Press: 41.4 ft
3	N	Liquid Pumped: **Water with TCE**		Max. Flow at P.T.: **10 gpm**	Suction Press: 9.7 ft
4	D	Pumping Temp.: **60-185 °F**	Sp. Gr. @ P.T.: **0.973**	Viscosity @ P.T.: 1 cp	Suction Press: 4.199 psia
5	T	Differential Press.: psi	Differential Head: **34.87** Ft.	Fluid pH 6	NPSH Available: 6 Ft.
6	N	Discharge Press.@ Norm:	Discharge Press. @ Max: **50 ft H_2O**		NPSH Required (Water): * Ft.
7	S	Type: **Centrifugal pump**		Location: **Outdoors @ T-102**	
8		Horizontal or Vertical Arrangement? **Horizontal**		Single or Double Suction?	**Single**
9	C	CW OR CCW Direction of Rotation Facing Pump Coupling:		Case Design Press.: psig	Max. Allow. W.P.: psig
10	O	Number of Stages: 1	Speed: * rpm	Shut-off Press.: PSIG	Vol. Eff. @ Rating: %
11	N	BARREL: *	Split? *	Horizontal?	Vertical?
12	S	IMPELLER: *	Type: *	Max. Diameter: * In.	Min. Diameter: * In.
13	T	Actual Imp. Dia.: * In.	Vent and Drain Tapped? *	Thrust Bearing Type: *	Radial Bearing Type: *

		Nozzles	Size	Rating	Facing	Location		
14	R	Nozzles	Size	Rating	Facing	Location	Bearing Lub. Type: *	
15	U	Suction	*	*	*	*	Oiler? *	Oiler Type: *
16	C	Discharge	*	*	*	*	Coupling Mfr.: *	Coupling Model: *
17	T	Vents	*	*	*	*	Baseplate? *	Type Baseplate: *
18	I	Drains	*	*	*	*	Water Cooling: Csng, Stffg Bx, Brgs, Pdstl, Glnd or none? *	
19	O	Cooling H2O	*	*	*	*	Total Water Req'd: * gpm	Smothering Gland? *

20	N	Stuffing Box Lubrication: Oil, Grease or None?		Type Packing: *	Seal Oil Connection? *
21		MECHANICAL SEAL:	Furnished By: *	Manufacturer: *	Type: *
22	D	Single or Double? *	Inside or Outside? *	Balanced or Unbalanced? *	
23	E	Rotary Unit: *	Seal Ring Mtrl: *	Face Material: *	Shaft Packing: *
24	T	Insert: *	Reversible? *	Face Material: *	
25	A	Insert Mounting: Clamped, O-Ring or Press Fit? *			
26	I	Gland: *	Plain? *	Carbon Throttle Bushing? *	
27	L	Gland Stuffing Box Machined & Tapped for: *		Dead End Lub.? *	Circulating Lub.? *
28	S	Flushing Seal Faces with Discharge Bypass? *		Quenching? *	Vent & Drain? *
29		Flushing Seal Faces with External Fluid? *		Auxilliary Stuffing Box Required? *	
30		Weight of Pump: * lbs.	Weight of Base: * lbs.	Weight of Driver: * lbs.	Shipping Weight: * lbs.
31	M	Casing & Covers: **D. I.**	Shaft: **316 SS**	Casing wear Rings: *	Shaft Sleeves: *
32	T	Impeller: **316 SS**	Lantern Rings: *	Impeller Wear Rings: *	Stuffing Box Bushings: *
33	L	Glands: *	Gaskets: *		

34		Furnished By: **Vendor**	Elec. or Steam Turbine? **Elec.**	Direct, Gear, V-Belt or Rope?	**V-belt**
35		ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:	Mfr.:
36		Mounted By: **Vendor**	Enclosure: **TEFC**	Mounted By:	Model:
37	D	Speed: **1750** rpm	Service Factor: *	Horsepower: HP	Water Rates: Lbs/Hr
38	R	Volts: **480**	Temp. Rise: *	Speed rpm	Vacuum (if any):
39	I	Phase: **3**	Insulation: *	Inlet Steam Press.:	Inlet Steam Temp.:
40	V	Cycles: **60**	Frame: *	Normal: psig	Normal: deg. F
41	E	Nominal Size * HP	Est. BHP Req'd: **0.75** HP	Max.: psig	Max.: deg F
42	R	SPEED REDUCERS:	Mfr.:	Backpressure: psig	

				Nozzles	Size	Rating	Facing	Location
43		Ratio:	Model:	Nozzles	Size	Rating	Facing	Location
44		Integral or Separate?	Class:	Inlet				
45				Exhaust				
46		See Driver Specification No.:						

47	T	Performance Curve? *	Certified?	M	Serial Number:
48	E	Curve No.:		I	Outline Drawing Number:
49	S	Hydrotest?	Pressure: psig	S	Cross Section Drawing Number:
50	T	Witness Testing?	Shop Inspection?	C	

51		**1. Vendor to verify correct pump model no. and motor horsepower.**
52		**2. Vendor shall clearly state any exceptions to the requirements outlined in this data sheet.**
53	N	**3. Vendor to provide air release valve with pump.**
54	O	**4. Vendor to tap pump suction and discharge for the installation of pressure gauges.**
55	T	**5. Pump and associated instrumentation shall be provided with stainless steel I.D. tags.**
56	E	**6. Pump shall be constructed such that the entire rotating assembly of the pump (impeller, shaft,**
57	S	**and bearings) may be removed from the pump without removing the pump casing from the**
58		**baseplate or disconnecting the attached piping.**
59		**7. Vendor to complete information marked *.**
60		**8. Seismic design to Kentucky Category E, Ss=2.56 g, S1=0.78 g**

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SHAW ENVIRONMENTAL, INC.	PUMP SPECIFICATION				SHAW SPEC. NO. **122064-P103**
	NO	BY	DATE	REV.	SHEET **1** OF **1**
	A	**TDS**	**1/17/07**	**internal review**	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJ: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	2				JOB NO. **122064**
AREA: **C-400 CLEANING BLDG**					LOCATION **PADUCAH, KY**
TAG NO.: **P-103**					
EQUIP: **AIR STRIPPER EFFLUENT PUMP**	3				BY **TDS** / APPR **SES** / DATE **1/9/07**

1	C	Manufacturer: **Gorman-Rupp or approved equal**					Model No.: *	
2	O	No. of Units: **1 (One)**					Normal Flow : **87 gpm**	Discharge Press: 142 ft
3	N	Liquid Pumped: **Groundwater**					Max. Flow at P.T.: **100 gpm**	Suction Press: 33 ft
4	D	Pumping Temp.: **60-100 °F**	Sp. Gr. @ P.T.: **0.973**				Viscosity @ P.T.: **1** cp	Suction Press: 14.3 psia
5	T	Differential Press.: psi	Differential Head: **114.5** Ft.				Fluid pH 6	NPSH Available: **10** Ft.
6	N	Discharge Press.@ Norm:	Discharge Press. @ Max: **150 ft H_2O**					NPSH Required (Water): * Ft.
7	S	Type: **Centrifugal pump**					Location: **Outdoors @ T-103**	
8		Horizontal or Vertical Arrangement? **Horizontal**					Single or Double Suction?	**Single**
9	C	CW OR CCW Direction of Rotation Facing Pump Coupling:					Case Design Press.: psig	Max. Allow. W.P.: psig
10	O	Number of Stages: **1**	Speed: * rpm				Shut-off Press.: PSI(	Vol. Eff. @ Rating: %
11	N	BARREL: *	Split? *				Horizontal?	Vertical?
12	S	IMPELLER: *	Type: *				Max. Diameter: * In.	Min. Diameter: * In.
13	T	Actual Imp. Dia.: * In.	Vent and Drain Tapped? *				Thrust Bearing Type: *	Radial Bearing Type: *
14	R	Nozzles	Size	Rating	Facing	Location	Bearing Lub. Type: *	
15	U	Suction	*	*	*	*	Oiler? *	Oiler Type: *
16	C	Discharge	*	*	*	*	Coupling Mfr.: *	Coupling Model: *
17	T	Vents	*	*	*	*	Baseplate? *	Type Baseplate: *
18	I	Drains	*	*	*	*	Water Cooling: Csng, Stffg Bx, Brgs, Pdstl, Glnd or none?	*
19	O	Cooling H2O	*	*	*	*	Total Water Req'd: * gpm	Smothering Gland? *
20	N	Stuffing Box Lubrication: Oil, Grease or None?					Type Packing: *	Seal Oil Connection? *
21		MECHANICAL SEAL:	Furnished By: *				Manufacturer: *	Type: *
22	D	Single or Double? *	Inside or Outside? *				Balanced or Unbalanced? *	
23	E	Rotary Unit: *	Seal Ring Mtrl: *				Face Material: *	Shaft Packing: *
24	T	Insert: *	Reversible? *				Face Material: *	
25	A	Insert Mounting: Clamped, O-Ring or Press Fit? *						
26	I	Gland: *	Plain? *				Carbon Throttle Bushing? *	
27	L	Gland Stuffing Box Machined & Tapped for: *					Dead End Lub.? *	Circulating Lub.? *
28	S	Flushing Seal Faces with Discharge Bypass? *					Quenching? *	Vent & Drain? *
29		Flushing Seal Faces with External Fluid? *					Auxilliary Stuffing Box Required?	*
30		Weight of Pump: * lbs.	Weight of Base: * lbs.				Weight of Driver: * lbs.	Shipping Weight: * lbs.
31	M	Casing & Covers: **D. I.**	Shaft: **316 SS**				Casing wear Rings: *	Shaft Sleeves: *
32	T	Impeller: **316 SS**	Lantern Rings: *				Impeller Wear Rings: *	Stuffing Box Bushings: *
33	L	Glands: *	Gaskets: *					
34		Furnished By: **Vendor**	Elec. or Steam Turbine? **Elec.**	Direct, Gear, V-Belt or Rope? **V-belt**				
35		ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:				Mfr.:
36		Mounted By: **Vendor**	Enclosure: **TEFC**	Mounted By:				Model:
37	D	Speed: **3500** rpm	Service Factor: *	Horsepower: HP				Water Rates: Lbs/Hr
38	R	Volts: **480**	Temp. Rise: *	Speed rpm				Vacuum (if any):
39	I	Phase: **3**	Insulation: *	Inlet Steam Press.:				Inlet Steam Temp.:
40	V	Cycles: **60**	Frame: *	Normal: psig				Normal: deg. F
41	E	Nominal Size * HP	Est. BHP Req'd: 7.5 HP	Max.: psig				Max.: deg F
42	R	SPEED REDUCERS:	Mfr.:	Backpressure: psig				
43		Ratio:	Model:	Nozzles	Size	Rating	Facing	Location
44		Integral or Separate?	Class:	Inlet				
45				Exhaust				
46		See Driver Specification No.:						
47	T	Performance Curve? *	Certified?	M	Serial Number:			
48	E	Curve No.:		I	Outline Drawing Number:			
49	S	Hydrotest?	Pressure: psig	S	Cross Section Drawing Number:			
50	T	Witness Testing?	Shop Inspection?	C				
51		**1. Vendor to verify correct pump model no. and motor horsepower.**						
52		**2. Vendor shall clearly state any exceptions to the requirements outlined in this data sheet.**						
53	N	**3. Vendor to provide air release valve with pump.**						
54	O	**4. Vendor to tap pump suction and discharge for the installation of pressure gauges.**						
55	T	**5. Pump and associated instrumentation shall be provided with stainless steel I.D. tags.**						
56	E	**6. Pump shall be constructed such that the entire rotating assembly of the pump (impeller, shaft,**						
57	S	**and bearings) may be removed from the pump without removing the pump casing from the**						
58		**baseplate or disconnecting the attached piping.**						
59		**7. Vendor to complete information marked *.**						
60		**8. Seismic design to Kentucky Category E, Ss=2.56 g, S1=0.78 g**						

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SHAW ENVIRONMENTAL, INC.		PUMP SPECIFICATION		SHAW SPEC. NO. 122064-P104
		DATE	REV.	SHEET 1 OF 1
	B	TDS	7/07/08	internal review
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PROJ: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS
AREA: C-400 CLEANING BLDG
TAG NO.: P-104
EQUIP: WATER INJECTION PUMP

PROJECT NAME: C-400 SOIL VAPOR & GWTS
JOB NO.: 122064
LOCATION: PADUCAH, KY
BY: TDS | APPR: SES | DATE: 7/07/08

1	C	Manufacturer: Gorman-Rupp or approved equal		Model No.: *	
2	O	No. of Units: 1 (One)		Normal Flow : 64 gpm	Discharge Press: 87 ft
3	N	Liquid Pumped: Treated groundwater		Max. Flow at P.T.: 64 gpm	Suction Press: 34 ft
4	D	Pumping Temp.: 100-160 °F	Sp. Gr. @ P.T.: 0.993	Viscosity @ P.T.: 1 cp	Suction Press: 15 psia
5	T	Differential Press.: 25 psi	Differential Head: 58.4 Ft.	Fluid pH 6	NPSH Available: 10 Ft.
6	N	Discharge Press.@ Norm:	Discharge Press. @ Max:		NPSH Required (Water): * Ft.
7	S	Type: Centrifugal pump		Location: Outdoors @ T-104	
8		Horizontal or Vertical Arrangement? Horizontal		Single or Double Suction?	Single
9	C	CW OR CCW Direction of Rotation Facing Pump Coupling:		Case Design Press.: psig	Max. Allow. W.P.: psig
10	O	Number of Stages: 1	Speed: * rpm	Shut-off Press.: PSIG	Vol. Eff. @ Rating: %
11	N	BARREL: *	Split? *	Horizontal?	Vertical?
12	S	IMPELLER: *	Type: *	Max. Diameter: * In.	Min. Diameter: * In.
13	T	Actual Imp. Dia.: * In.	Vent and Drain Tapped? *	Thrust Bearing Type: *	Radial Bearing Type: *

		Nozzles	Size	Rating	Facing	Location		
14	R	Nozzles	Size	Rating	Facing	Location	Bearing Lub. Type: *	
15	U	Suction	*	*	*	*	Oiler? *	Oiler Type: *
16	C	Discharge	*	*	*	*	Coupling Mfr.: *	Coupling Model: *
17	T	Vents	*	*	*	*	Baseplate? *	Type Baseplate: *
18	I	Drains	*	*	*	*	Water Cooling: Csng, Stffg Bx, Brgs, Pdstl, Glnd or none? *	
19	O	Cooling H2O	*	*	*	*	Total Water Req'd: * gpm	Smothering Gland? *

20	N	Stuffing Box Lubrication: Oil, Grease or None?		Type Packing: *	Seal Oil Connection? *
21		MECHANICAL SEAL:	Furnished By: *	Manufacturer: *	Type: *
22	D	Single or Double? *	Inside or Outside? *	Balanced or Unbalanced? *	
23	E	Rotary Unit: *	Seal Ring Mtrl: *	Face Material: *	Shaft Packing: *
24	T	Insert: *	Reversible? *	Face Material: *	
25	A	Insert Mounting: Clamped, O-Ring or Press Fit? *			
26	I	Gland: *	Plain? *	Carbon Throttle Bushing? *	
27	L	Gland Stuffing Box Machined & Tapped for: *		Dead End Lub.? *	Circulating Lub.? *
28	S	Flushing Seal Faces with Discharge Bypass? *		Quenching? *	Vent & Drain? *
29		Flushing Seal Faces with External Fluid? *		Auxilliary Stuffing Box Required? *	
30		Weight of Pump: * lbs.	Weight of Base: * lbs.	Weight of Driver: * lbs.	Shipping Weight: * lbs.
31	M	Casing & Covers: D. I.	Shaft: 316 SS	Casing wear Rings: *	Shaft Sleeves: *
32	T	Impeller: 316 SS	Lantern Rings: *	Impeller Wear Rings: *	Stuffing Box Bushings: *
33	L	Glands: *	Gaskets: *		
34		Furnished By: Vendor	Elec. or Steam Turbine? Elec.	Direct, Gear, V-Belt or Rope? V-belt	
35		ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:	Mfr.:
36		Mounted By: Vendor	Enclosure: TEFC	Mounted By:	Model:
37	D	Speed: 3500 rpm	Service Factor: *	Horsepower: HP	Water Rates: Lbs/Hr
38	R	Volts: 480	Temp. Rise: *	Speed rpm	Vacuum (if any):
39	I	Phase: 3	Insulation: *	Inlet Steam Press.:	Inlet Steam Temp.:
40	V	Cycles: 60	Frame: *	Normal: psig	Normal: deg. F
41	E	Nominal Size * HP	Est. BHP Req'd: 1.5 HP	Max.: psig	Max.: deg F
42	R	SPEED REDUCERS:	Mfr.:	Backpressure: psig	
43		Ratio:	Model:	Nozzles / Size / Rating	Facing / Location
44		Integral or Separate?	Class:	Inlet	
45				Exhaust	
46		See Driver Specification No.:			
47	T	Performance Curve? *	Certified?	M Serial Number:	
48	E	Curve No.:		I Outline Drawing Number:	
49	S	Hydrotest?	Pressure: psig	S Cross Section Drawing Number:	
50	T	Witness Testing?	Shop Inspection?	C	

51		**1. Vendor to verify correct pump model no. and motor horsepower.**
52		**2. Vendor shall clearly state any exceptions to the requirements outlined in this data sheet.**
53	N	**3. Vendor to provide air release valve with pump.**
54	O	**4. Vendor to tap pump suction and discharge for the installation of pressure gauges.**
55	T	**5. Pump and associated instrumentation shall be provided with stainless steel I.D. tags.**
56	E	**6. Pump shall be constructed such that the entire rotating assembly of the pump (impeller, shaft,**
57	S	**and bearings) may be removed from the pump without removing the pump casing from the**
58		**baseplate or disconnecting the attached piping.**
59		**7. Vendor to complete information marked *.**
60		**8. Seismic design to Kentucky Category E, Ss=2.56 g, S1=0.78 g.**

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SHAW ENVIRONMENTAL, INC.		PUMP SPECIFICATION		SHAW SPEC. NO. 122064-P106
		DATE	REV.	SHEET 1 OF 1
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PROJ: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS
AREA: C-400 CLEANING BLDG
TAG NO.: P-106
EQUIP: AIR STRIPPER FEED PUMP

PROJECT NAME: **C-400 SOIL VAPOR & GWTS**
JOB NO.: **122064**
LOCATION: **PADUCAH, KY**

BY	APPR	DATE
TDS	SES	1/9/07

1	C	Manufacturer: **Gorman-Rupp or approved equal**		Model No.: *	
2	O	No. of Units: **1 (One)**		Normal Flow : **87**	Discharge Press: 82 ft
3	N	Liquid Pumped: **Groundwater**		Max. Flow at P.T.: **100 gpm**	Suction Press: 33 ft
4	D	Pumping Temp.: **60-194 °F**	Sp. Gr. @ P.T.: **0.973**	Viscosity @ P.T.: **1** cp	Suction Press: 14.3 psia
5	T	Differential Press.: psi	Differential Head: **53.9** Ft.	Fluid pH 6	NPSH Available: **10** Ft.
6	N	Discharge Press.@ Norm:	Discharge Press. @ Max: **90 ft H_2O**		NPSH Required (Water): * Ft.
7	S	Type: **Centrifugal pump**		Location: **Outdoors @ T-106**	
8		Horizontal or Vertical Arrangement? **Horizontal**		Single or Double Suction?	**Single**
9	C	CW OR CCW Direction of Rotation Facing Pump Coupling:		Case Design Press.: psig	Max. Allow. W.P.: psig
10	O	Number of Stages: **1**	Speed: * rpm	Shut-off Press.: PSIG	Vol. Eff. @ Rating: %
11	N	BARREL: *	Split? *	Horizontal?	Vertical?
12	S	IMPELLER: *	Type: *	Max. Diameter: * In.	Min. Diameter: * In.
13	T	Actual Imp. Dia.: * In.	Vent and Drain Tapped? *	Thrust Bearing Type: *	Radial Bearing Type: *
14	R	Nozzles / Size / Rating / Facing / Location		Bearing Lub. Type: *	
15	U	Suction / * / * / * / *		Oiler? *	Oiler Type: *
16	C	Discharge / * / * / * / *		Coupling Mfr.: *	Coupling Model: *
17	T	Vents / * / * / * / *		Baseplate? *	Type Baseplate: *
18	I	Drains / * / * / * / *		Water Cooling: Csng, Stffg Bx, Brgs, Pdstl, Glnd or none? *	
19	O	Cooling H2O / * / * / * / *		Total Water Req'd: * gpm	Smothering Gland? *
20	N	Stuffing Box Lubrication: Oil, Grease or None?		Type Packing: *	Seal Oil Connection? *
21		MECHANICAL SEAL:	Furnished By: *	Manufacturer: *	Type: *
22	D	Single or Double? *	Inside or Outside? *	Balanced or Unbalanced? *	
23	E	Rotary Unit: *	Seal Ring Mtrl: *	Face Material: *	Shaft Packing: *
24	T	Insert: *	Reversible? *	Face Material: *	
25	A	Insert Mounting: Clamped, O-Ring or Press Fit? *			
26	I	Gland: *	Plain? *	Carbon Throttle Bushing? *	
27	L	Gland Stuffing Box Machined & Tapped for: *		Dead End Lub.? *	Circulating Lub.? *
28	S	Flushing Seal Faces with Discharge Bypass? *		Quenching? *	Vent & Drain? *
29		Flushing Seal Faces with External Fluid? *		Auxilliary Stuffing Box Required? *	
30		Weight of Pump: * lbs.	Weight of Base: * lbs.	Weight of Driver: * lbs.	Shipping Weight: * lbs.
31	M	Casing & Covers: **D. I.**	Shaft: **316 SS**	Casing wear Rings: *	Shaft Sleeves: *
32	T	Impeller: **316 SS**	Lantern Rings: *	Impeller Wear Rings: *	Stuffing Box Bushings: *
33	L	Glands: *	Gaskets: *		
34		Furnished By: **Vendor**	Elec. or Steam Turbine? **Elec.**	Direct, Gear, V-Belt or Rope?	**V-belt**
35		ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:	Mfr.:
36		Mounted By: **Vendor**	Enclosure: **TEFC**	Mounted By:	Model:
37	D	Speed: * rpm	Service Factor: *	Horsepower: HP	Water Rates: Lbs/Hr
38	R	Volts: **480**	Temp. Rise: *	Speed rpm	Vacuum (if any):
39	I	Phase: **3**	Insulation: *	Inlet Steam Press.:	Inlet Steam Temp.:
40	V	Cycles: **60**	Frame: *	Normal: psig	Normal: deg. F
41	E	Nominal Size * HP	Est. BHP Req'd: **3** HP	Max.: psig	Max.: deg F
42	R	SPEED REDUCERS:	Mfr.:	Backpressure: psig	
43		Ratio:	Model:	Nozzles / Size / Rating	Facing / Location
44		Integral or Separate?	Class:	Inlet	
45				Exhaust	
46		See Driver Specification No.:			
47	T	Performance Curve? *	Certified?	M	Serial Number:
48	E	Curve No.:		I	Outline Drawing Number:
49	S	Hydrotest?	Pressure: psig	S	Cross Section Drawing Number:
50	T	Witness Testing?	Shop Inspection?	C	
51		**1. Vendor to verify correct pump model no. and motor horsepower.**			
52		**2. Vendor shall clearly state any exceptions to the requirements outlined in this data sheet.**			
53	N	**3. Vendor to provide air release valve with pump.**			
54	O	**4. Vendor to tap pump suction and discharge for the installation of pressure gauges.**			
55	T	**5. Pump and associated instrumentation shall be provided with stainless steel I.D. tags.**			
56	E	**6. Pump shall be constructed such that the entire rotating assembly of the pump (impeller, shaft,**			
57	S	**and bearings) may be removed from the pump without removing the pump casing from the**			
58		**baseplate or disconnecting the attached piping.**			
59		**7. Vendor to complete information marked *.**			
60		**8. Seismic design to Kentucky Category E, Ss=2.56 g, S1=0.78 g**			

SHAW ENVIRONMENTAL, INC.	TABLE OF CONTENTS	PUMP SPECIFICATION		SHAW SPEC. NO. 122064-P108
	NO	BY	DATE	REV.
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SHEET	1 OF 1
PROJECT NAME	C-400 SOIL VAPOR & GWTS
JOB NO.	122064
LOCATION	PADUCAH, KY
BY / APPR / DATE	TDS / SES / 1/9/07

PROJ: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS
AREA: C-400 CLEANING BLDG
TAG NO.: P-108
EQUIP: LIQUID TCE PUMP

1	C	Manufacturer: **Gorman-Rupp or approved equal**		Model No.: *	
2	O	No. of Units: **1 (One)**		Normal Flow : **0.78 gpm**	Discharge Press: 42 ft
3	N	Liquid Pumped: **Liquid TCE**		Max. Flow at P.T.: **2 gpm**	Suction Press: 34 ft
4	D	Pumping Temp.: **32 -70 °F**	Sp. Gr. @ P.T.: **1.4**	Viscosity @ P.T.: **1** cp	Suction Press: 15 psia
5	T	Differential Press.: psi	Differential Head: **9** Ft.	Fluid pH	NPSH Available: **6** Ft.
6	N	Discharge Press.@ Norm:	Discharge Press. @ Max: **50 ft H_2O**		NPSH Required (Water): * Ft.
7	S	Type: **Centrifugal pump**		Location: **Outdoors @ T-105**	
8		Horizontal or Vertical Arrangement? **Horizontal**		Single or Double Suction?	**Single**
9	C	CW OR CCW Direction of Rotation Facing Pump Coupling:		Case Design Press.: psig	Max. Allow. W.P.: psig
10	O	Number of Stages: **1**	Speed: * rpm	Shut-off Press.: PSIG	Vol. Eff. @ Rating: %
11	N	BARREL: *	Split? *	Horizontal?	Vertical?
12	S	IMPELLER: *	Type: *	Max. Diameter: * In.	Min. Diameter: * In.
13	T	Actual Imp. Dia.: * In.	Vent and Drain Tapped? *	Thrust Bearing Type: *	Radial Bearing Type: *

		Nozzles	Size	Rating	Facing	Location		
14	R	Nozzles	Size	Rating	Facing	Location	Bearing Lub. Type: *	
15	U	Suction	*	*	*	*	Oiler? *	Oiler Type: *
16	C	Discharge	*	*	*	*	Coupling Mfr.: *	Coupling Model: *
17	T	Vents	*	*	*	*	Baseplate? *	Type Baseplate: *
18	I	Drains	*	*	*	*	Water Cooling: Csng, Stffg Bx, Brgs, Pdstl, Glnd or none? *	
19	O	Cooling H2O	*	*	*	*	Total Water Req'd: * gpm	Smothering Gland? *

20	N	Stuffing Box Lubrication: Oil, Grease or None?		Type Packing: *	Seal Oil Connection? *
21		MECHANICAL SEAL:	Furnished By: *	Manufacturer: *	Type: *
22	D	Single or Double? *	Inside or Outside? *	Balanced or Unbalanced? *	
23	E	Rotary Unit: *	Seal Ring Mtrl: *	Face Material: *	Shaft Packing: *
24	T	Insert: *	Reversible? *	Face Material: *	
25	A	Insert Mounting: Clamped, O-Ring or Press Fit? *			
26	I	Gland: *	Plain? *	Carbon Throttle Bushing? *	
27	L	Gland Stuffing Box Machined & Tapped for: *		Dead End Lub.? *	Circulating Lub.? *
28	S	Flushing Seal Faces with Discharge Bypass? *		Quenching? *	Vent & Drain? *
29		Flushing Seal Faces with External Fluid? *		Auxilliary Stuffing Box Required? *	
30		Weight of Pump: * lbs.	Weight of Base: * lbs.	Weight of Driver: * lbs.	Shipping Weight: * lbs.
31	M	Casing & Covers: **D. I.**	Shaft: **316 SS**	Casing wear Rings: *	Shaft Sleeves: *
32	T	Impeller: **316 SS**	Lantern Rings: *	Impeller Wear Rings: *	Stuffing Box Bushings: *
33	L	Glands: *	Gaskets: *		
34		Furnished By: **Vendor**	Elec. or Steam Turbine? **Elec.**	Direct, Gear, V-Belt or Rope? **V-belt**	
35		ELECTRIC MOTOR:	Mfr.: *	STEAM TURBINE:	Mfr.:
36		Mounted By: **Vendor**	Enclosure: **TEFC**	Mounted By:	Model:
37	D	Speed: * rpm	Service Factor: *	Horsepower: HP	Water Rates: Lbs/Hr
38	R	Volts: *	Temp. Rise: *	Speed rpm	Vacuum (if any):
39	I	Phase: *	Insulation: *	Inlet Steam Press.:	Inlet Steam Temp.:
40	V	Cycles: *	Frame: *	Normal: psig	Normal: deg. F
41	E	Nominal Size **1** HP	Est. BHP Req'd: **1** HP	Max.: psig	Max.: deg F
42	R	SPEED REDUCERS:	Mfr.:	Backpressure: psig	

				Nozzles	Size	Rating	Facing	Location
43		Ratio:	Model:	Nozzles	Size	Rating	Facing	Location
44		Integral or Separate?	Class:	Inlet				
45				Exhaust				
46		See Driver Specification No.:						

47	T	Performance Curve? *	Certified?	M	Serial Number:
48	E	Curve No.:		I	Outline Drawing Number:
49	S	Hydrotest?	Pressure: psig	S	Cross Section Drawing Number:
50	T	Witness Testing?	Shop Inspection?	C	

51		**1. Vendor to verify correct pump model no. and motor horsepower.**
52		**2. Vendor shall clearly state any exceptions to the requirements outlined in this data sheet.**
53	N	**3. Vendor to provide air release valve with pump.**
54	O	**4. Vendor to tap pump suction and discharge for the installation of pressure gauges.**
55	T	**5. Pump and associated instrumentation shall be provided with stainless steel I.D. tags.**
56	E	**6. Pump shall be constructed such that the entire rotating assembly of the pump (impeller, shaft,**
57	S	**and bearings) may be removed from the pump without removing the pump casing from the**
58		**baseplate or disconnecting the attached piping.**
59		**7. Vendor to complete information marked *.**
60		**8. Seismic design to Kentucky Category E, Ss=2.56 g, S1=0.78 g**

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SHAW ENVIRONMENTAL, INC

TANK SPECIFICATION

SHAW SPEC. NO.	122064-T-100
SHEET	1 OF 1
PROJECT NAME	C-400 SOIL VAPOR
JOB NO.	122064
LOCATION	PADUCAH, KY

NO	BY	DATE	REV.
0	WRC	9/23/10	AS BUILT

BY	APPR	DATE
WRC		9/7/10

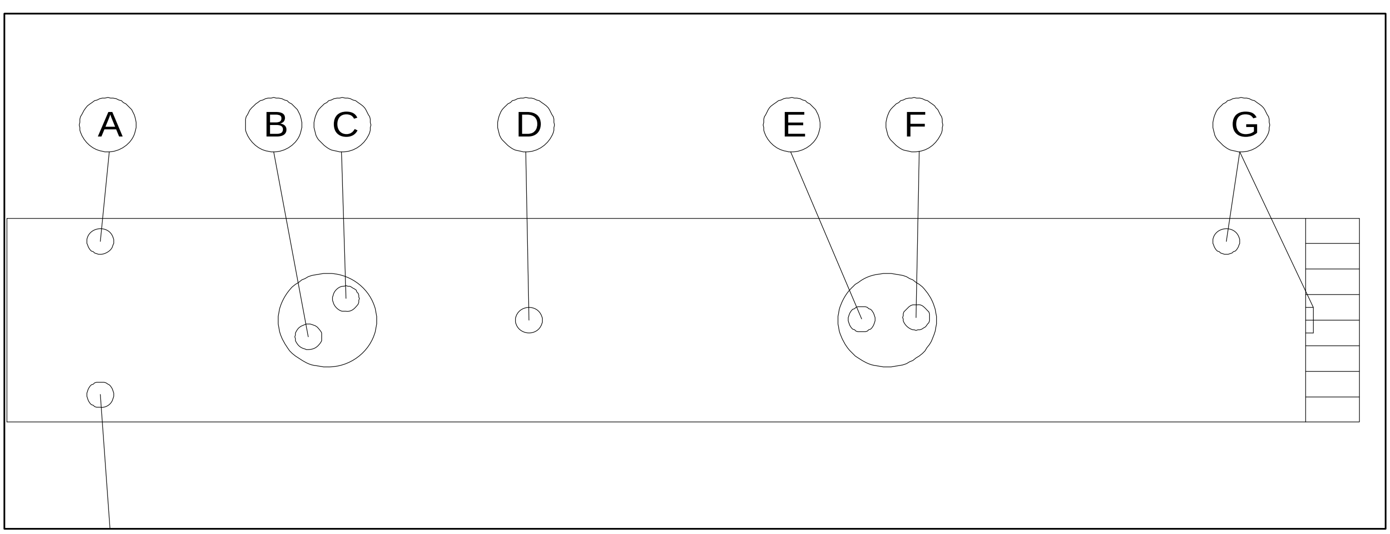
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**
AREA NAME:
TAG NO.: **T-100**
EQUIP. NAME: **Feed Surge Tank**

	Total Volume: 17,640 gal	Field Erected? NO	No. Units: 1(One)
	Operating Pressure, in WC	ATM	
	Operating Temperature, deg F	40 - 200	
	Operating Time, hrs/day	24 continuous	
	Contents Lethal?	No	
	Design Pressure, in WC	ATM	
D	Design Temperature, deg F	200	
E	Vessel Content:	Treated groundwater	
S	Liquid Density (lb/cu.ft.) at standard	62.3	
I	Top	FLAT	
G	Shell / Heads Corr. Barrier, inches		
N	Shell / Head Joint Efficiency, %		
	Code:	Stamp:	
	Radiograph:	Stress Relieve:	
D	National Board No.		
A	Type Supports: None, Self-supporting		
T	Insulation: None		
A	Fireproofing: None		
	Sandblast: Yes	Paint: Yes 09900	
	MANHOLE: Hinged? Yes	Davited? No	Other:
	Handrail clips: Yes	Stairs: Yes	Insul. Rings:
	Pipe Supports: None	Seismic Design: Kentucky Category E	
	Wind Load: 90 mph	Seismic Ss=2.56 g, S1=0.78g	
	Weight Empty: 34,000 lbs	Weight Full of Water: lbs	

	Item	Thickness	Mat'l	Mat'l - Min Quality
	Shell	3/8"		Carbon Steel
M	Heads	3/8"		Carbon Steel
A	Length	37'-6"		
T	Width	8'-0"		
E	Height	11'-8"		
R	Nozzle Necks	*		Carbon Steel
I	Flanges	*		Carbon Steel
A	Coupling			
L	M.H. Cover			
S	Supports			
	Bolts/Studs			SA-193 B7/SA-194-2
	Nuts			SA-193 B7/SA-194-2
	Gaskets			EPDM

	Service	Mark	No	Size	Rating	Face
N	Pressure Relief	A	1	4""	150#	RF
O	Pump	B	1	4""	150#	RF
Z	Pump Discharge	C	2	3"	150#	RF
Z	Spare	D	1	4"	150#	RF
L	Vapor Vent	E	1	4"	150#	RF
E	Well Field Inlet	F	1	3"	150#	RF
	Level	G	2	4"	150#	RF
S	CT Blowdown	H	1	4"	150#	RF
C						
H						
E						
D						
U						
L						
E						

1: Vendor to complete information marked *
Seismic Ss=2.56 g, S1=0.78g
Nozzle orientation to be specified in detailed engineering
All nozzles to have 6" projection



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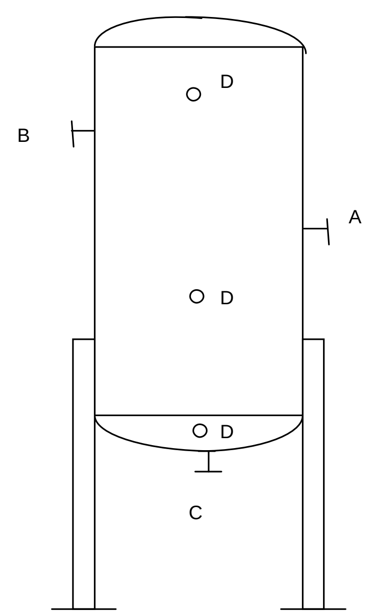
	B / TDS / 7/07/08 / for internal review		PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	2		JOB NO. **122064**
AREA NAME: **C-400 CLEANING BLDG**			LOCATION **PADUCAH, KY**
TAG NO.: **T-101**	3		BY TDS / APPR SES / DATE **7/07/08**
EQUIP NAME: **LIQUID/VAPOR SEPARATOR 1**			

1		Total Volume: * FT3	Field Erected? NO		No. Units 1			
2		Operating Pressure, PSIA	10 in Hg vacuum or 9.8 psia					
3		Operating Temperature, deg F	203					
4		Design Pressure, PSIG	full vacuum to 5 psig					
5		Design Temperature, deg F	300					
6		Gas Type	Air and Water Vapor					
7		Gas Density (lb/cu.ft.) at flow	0.0354					
8	**D**	Gas Specific Gravity						
9	**E**	Gas Max. Flow Rate (ACFM)	4200					
10	**S**	Liquid Type	Water					
11	**I**	Liquid Holding Volume (gallons)	125					
12	**G**	Liquid Density (lb/cu.ft.) at standard	62.3					
13	**N**	Liquid Specific Gravity						
14		Liquid Load (lb/hr)	500					
15		Liquid Viscosity (cp)	1					
16	**D**	Hydrostatic Test, PSIG	*					
17	**A**	Shell	Heads Corr. Barrier, inches	NONE	NONE			
18	**T**	Shell	Head Joint Efficiency, %	85	85			
19	**A**	Code: ASME Section VIII	Stamp: YES					
20		Radiograph: PER CODE	Stress Relieve: PER CODE					
21		National Board No. N/A						
22		Type Supports: THREE (3) LEGS						
23		Insulation: NONE						
24		Fireproofing: NONE						
25		Sandblast: *	Paint: *					
26		MANHOLE: Hinged? NO	Davited? NO	Other: HANDLE				
27		Platform Clips: NO	Ladder Clips: NO	Insul. Rings: NO				
28		Pipe Supports: None						
29		Wind Load: 90 mph	Seismic Design: Kentucky Category E					
30		Weight Empty: * Lbs	Weight Full of Water: * Lbs					
31		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality			
32		Shell	*		Carbon Steel			
33	**M**	Heads	*		Carbon Steel			
34	**A**	Lining	N/A					
35	**T**	Diameter	36"					
36	**E**	Height	*					
37	**R**	Nozzle Necks			Carbon Steel			
38	**I**	Flanges			Carbon Steel			
39	**A**	Coupling			Carbon Steel			
40	**L**	M.H. Cover						
41	**S**	Supports	Three (3)		A-36			
42		Bolts/Studs			SA-193 B7/SA-194-2			
43		Nuts			SA-193 B7/SA-194-2			
44		Gaskets			Nitrile			
45	**N**	Service	Mark	No.	Size	Rating	Face	Type
46	**O**	Inlet	A	1	10"	Note 3	RF	Flg.
47	**Z**	Outlet	B	1	10"	Note 3	RF	Flg.
48	**Z**	Drain	C	1	3"	Note 3	RF	Flg.
49	**L**	Instrument Taps	D	4	1"		NPT	Coupling
50	**E**							
51	**S**	NOTES:						
52		1. Vendor to complete information marked "*".						
53		2. Vendor to provide lid with two handles.						
54		3. 1/4" flat flange, match 150# bolt pattern						
55		4. Seismic Ss=2.56 g, S1=0.78g						



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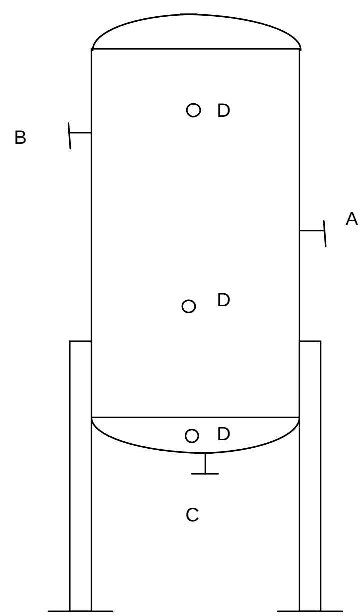
Nozzle orientation to be specified in detailed engineering

SHAW ENVIRONMENTAL, INC.	**LIQUID/VAPOR SEPARATOR**				SHAW SPEC. NO. **122064-T102**
	NO	BY	DATE	REV.	SHEET 1 OF 1
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	B	TDS	7/07/08	for internal review	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
AREA NAME: **C-400 CLEANING BLDG**	2				JOB NO. **122064**
TAG NO.: **T-102**	3				LOCATION **PADUCAH, KY**
EQUIP NAME: **LIQUID/VAPOR SEPARATOR 2**					BY TDS / APPR SES / DATE **7/07/08**

1		Total Volume: * FT3	Field Erected? NO		No. Units 1		
2		Operating Pressure, PSIA	10 in Hg vacuum or 9.8 psia				
3		Operating Temperature, deg F	105				
4		Design Pressure, PSIG	full vacuum to 5 psig				
5		Design Temperature, deg F	300				
6		Gas Type	Air and Water Vapor				
7		Gas Density (lb/cu.ft.) at flow	0.0455				
8	**D**	Gas Specific Gravity					
9	**E**	Gas Max. Flow Rate (ACFM)	3093				
10	**S**	Liquid Type	Water				
11	**I**	Liquid Holding Volume (gallons)	*				
12	**G**	Liquid Density (lb/cu.ft.) at standard	62.3				
13	**N**	Liquid Specific Gravity	1				
14		Liquid Load (lb/hr)	5000				
15		Liquid Viscosity (cp)	1				
16	**D**	Hydrostatic Test, PSIG	*				
17	**A**	Shell	Heads Corr. Barrier, inches	NONE	NONE		
18	**T**	Shell	Head Joint Efficiency, %	85	85		
19	**A**	Code: ASME Section VIII	Stamp: YES				
20		Radiograph: PER CODE	Stress Relieve: PER CODE				
21		National Board No. N/A					
22		Type Supports: THREE(3) LEGS					
23		Insulation: NONE					
24		Fireproofing: NONE					
25		Sandblast: YES	Paint: YES				
26		MANHOLE: Hinged? NO	Davited? NO	Other: HANDLE			
27		Platform Clips: NO	Ladder Clips: NO	Insul. Rings: NO			
28		Pipe Supports: None					
29		Wind Load: 90 mph	Seismic Design: Kentucky Category E				
30		Weight Empty: * Lbs	Weight Full of Water: * Lbs				
31		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality		
32		Shell	*		Carbon Steel		
33	**M**	Heads	*		Carbon Steel		
34	**A**	Lining	N/A				
35	**T**	Diameter	24"				
36	**E**	Height	*				
37	**R**	Nozzle Necks			Carbon Steel		
38	**I**	Flanges			Carbon Steel		
39	**A**	Coupling			Carbon Steel		
40	**L**	M.H. Cover					
41	**S**	Supports	Three (3)		A-36		
42		Bolts/Studs			SA-193 B7/SA-194-2		
43		Nuts			SA-193 B7/SA-194-2		
44		Gaskets			Nitrile		

		Service	Mark	No.	Size	Rating	Face	Type
45	**N**	Service	Mark	No.	Size	Rating	Face	Type
46	**O**	Inlet	A	1	6"	150#	RF	Flg.
47	**Z**	Outlet	B	1	6"	150#	RF	Flg.
48	**Z**	Drain	C	1	3"	150#	RF	Flg.
49	**L**	Instrument Taps	D	4	1"		NPT	Coupling
50	**E**							
51	**S**	NOTES:						
52		1. Vendor to complete information marked "*".						
53		2. Vendor to provide lid with two handles.						
54		3. 1/4" flat flange, match 150# bolt pattern						
55		4. Seismic Ss=2.56 g, S1=0.78g						



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Nozzle orientation to be specified in detailed engineering

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SHAW ENVIRONMENTAL, INC	**TANK SPECIFICATION**				SHAW SPEC. NO. **122064-T103**
	NO	BY	DATE	REV.	SHEET 1 OF 1
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	A	TDS	1/17/07	for internal review	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
AREA NAME: **C-400 CLEANING BLDG**	2				JOB NO. **122064**
TAG NO.: **T-103**	3				LOCATION **PADUCAH, KY**
EQUIP. NAME: **AIR STRIPPER EFFLUENT TANK**					BY TDS / APPR SES / DATE **1/9/07**

1		Total Volume: 1,500 gal	Field Erected? NO	No. Units 1(One)
2		Operating Pressure, in. w.c.	Atmospheric	
3		Operating Temperature, deg F	60 - 200	
4		Operating Time, hrs/day	24 continuous	
5		Contents Lethal?	No	
6		Design Pressure, psi	Atmospheric	
7	**D**	Design Temperature, deg F	210	
8	**E**	Vessel Content:	Treated Groundwater	
9	**S**	Liquid Density (lb/cu.ft.) at standard	62.3	
10	**I**	Top	Closed, Dished	
11	**G**	Shell / Heads Corr. Barrier, inches		
12	**N**	Shell / Head Joint Efficiency, %		
13		Code:	Stamp:	
14		Radiograph:	Stress Relieve:	
15	**D**	National Board No.		
16	**A**	Type Supports: None, Self-supporting		
17	**T**	Insulation: None		
18	**A**	Fireproofing: None		
19		Sandblast: Yes	Paint: Yes	
20		MANHOLE: Hinged? No	Davited? No	Other:
21		Platform Clips: No	Ladder Clips: No	Insul. Rings:
22		Pipe Supports: None		
23		Wind Load: 90 mph	Seismic Design: Kentucky Category E	
24		Weight Empty: * lbs	Weight Full of Water: * lbs	

		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
26		Shell	*		Carbon Steel
27	**M**	Heads	*		Carbon Steel
28	**A**	Lining			
29	**T**	I.D.	6 ft.		
30	**E**	Height	7 ft.		
31	**R**	Nozzle Necks	*		Carbon Steel
32	**I**	Flanges	*		Carbon Steel
33	**A**	Coupling			Carbon Steel
34	**L**	M.H. Cover			Carbon Steel
35	**S**	Supports	Self-supprting		
36		Bolts/Studs			SA-193 B7/SA-194-2
37		Nuts			SA-193 B7/SA-194-2
38		Gaskets			

		Service	Mark	No.	Size	Rating	Face	Type
39		Service	Mark	No.	Size	Rating	Face	Type
40	**N**	Inlet - upper Side	A	2	4"			
41	**O**	Outlet - lower Side	B	1	4"			
42	**Z**	Manway - top	C	1	18"			
43	**Z**	Vent - top	D	1	4"			
44	**L**	Drain - lower side	E	1	4"			
45	**E**		F					
46			G					
47	**S**		H					
48	**C**		J					
49	**H**		K					
50	**E**		L					
51	**D**		M					
52	**U**		N					
53	**L**		P					
54	**E**							

Nozzle orientation to be specified in detailed engineering

55 NOTE: Vendor to complete information marked *

56 Seismic Ss=2.56 g, S1=0.78g

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SHAW ENVIRONMENTAL, INC	TANK SPECIFICATION				SHAW SPEC. NO. 122064-T104
	NO	BY	DATE	REV.	SHEET 1 OF 1
	A	TDS	1/17/07	for internal review	PROJECT NAME C-400 SOIL VAPOR & GWTS
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS	2				JOB NO. 122064
AREA NAME: C-400 CLEANING BLDG	3				LOCATION PADUCAH, KY
TAG NO.: T-104					BY TDS / APPR SES / DATE 1/9/07
EQUIP. NAME: HOT GROUNDWATER TANK					

1		Total Volume: 550 gal	Field Erected? NO		No. Units 1(One)
2		Operating Pressure, in. w.c.		Atmospheric	
3		Operating Temperature, deg F		60 - 150	
4		Operating Time, hrs/day		24 continuous	
5		Contents Lethal?		No	
6		Design Pressure, psi		Atmospheric	
7	D	Design Temperature, deg F		200	
8	E	Vessel Content:		Treated groundwater	
9	S	Liquid Density (lb/cu.ft.) at standard		62.3	
10	I	Top		Closed, Dished	
11	G	Shell	Heads Corr. Barrier, inches		
12	N	Shell	Head Joint Efficiency, %		
13		Code:		Stamp:	
14		Radiograph:		Stress Relieve:	
15	D	National Board No.			
16	A	Type Supports:	None, Self-supporting		
17	T	Insulation:	None		
18	A	Fireproofing:	None		
19		Sandblast:	Yes	Paint: Yes	
20		MANHOLE:	Hinged? No	Davited? No	Other:
21		Platform Clips: None		Ladder Clips: None	Insul. Rings:
22		Pipe Supports:	None		
23		Wind Load:	90 mph	Seismic Design: Kentucky Category E	
24		Weight Empty:	* lbs	Weight Full of Water: * lbs	

25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
26		Shell	*		Carbon Steel
27	M	Heads	*		Carbon Steel
28	A	Lining			
29	T	I.D.	4 ft.		
30	E	Height	6 ft.		
31	R	Nozzle Necks	*		Carbon Steel
32	I	Flanges	*		Carbon Steel
33	A	Coupling			
34	L	M.H. Cover			
35	S	Supports	Self-supprting		
36		Bolts/Studs			SA-193 B7/SA-194-2
37		Nuts			SA-193 B7/SA-194-2
38		Gaskets			RUBBER

39		Service	Mark	No.	Size	Rating	Face	Type
40	N	Inlet - upper Side	A	1	4"		RF	Flanged
41	O	Outlet - lower Side	B	1	4"		RF	Flanged
42	Z	Manway - top	C	1	18 "			
43	Z	Vent - top	D	1	4			
44	L	Drain - lower side	E	1	4			
45	E		F					
46			G					
47	S		H					
48	C		J					
49	H		K					
50	E		L					
51	D		M					
52	U		N					
53	L		P					
54	E							
55		NOTE: Vendor to complete information marked *						
56		Seismic Ss=2.56 g, S1=0.78g						

Nozzle orientation to be specified in detailed engineering

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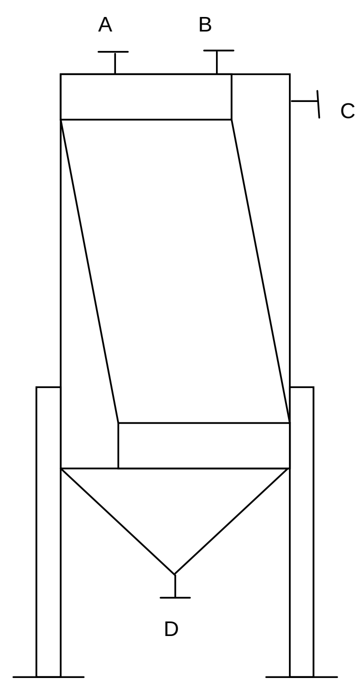
SHAW ENVIRONMENTAL, INC.	OIL/WATER SEPARATOR				SHAW SPEC. NO 122064-T105
	NO	BY	DATE	REV.	SHEET 1 OF 1
	A	TDS	1/17/07	for internal review	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	2				JOB NO. **122064**
AREA NAME: **C-400 CLEANING BLDG**					LOCATION **PADUCAH, KY**
TAG NO.: **T-105**	3				BY TDS / APPR SES / DATE **1/9/07**
EQUIP NAME: **DNAPL SEPARATOR**					

No.		Item	Value		
1		Total Volume: * FT3	Field Erected? NO	No. Units: 1	
2		Operating Pressure, PSIG	ATM		
3		Operating Temperature, deg F	180		
4		Design Pressure, PSIG	ATM		
5		Design Temperature, deg F	220		
6		Fluid 1 Type	Liquid TCE		
7		Fluid 1 Density (lb/cu.ft.)	*		
8	D	Fluid 1 Specific Gravity	1.4		
9	E	Fluid 1 Max. Flow Rate (gpm)	8		
10	S	Fluid 2 Type	Groundwater		
11	I	Fluid 2 Flowrate (gpm)	80		
12	G	Fluid 2 Density (lb/cu.ft.)	62.3		
13	N	Fluid 2 Specific Gravity	1		
14					
15		Top:	Closed, flat		
16	D	Hydrostatic Test, PSIG	*		
17	A	Shell	Heads Corr. Barrier, inches	NONE	NONE
18	T	Shell	Head Joint Efficiency, %	85	85
19	A	Code: ASME Section VIII	Stamp: NO		
20		Radiograph: PER CODE	Stress Relieve: PER CODE		
21		National Board No. N/A			
22		Type Supports: LEGS			
23		Insulation: NONE			
24		Fireproofing: NONE			
25		Sandblast: YES	Paint: YES		
26		MANHOLE: Hinged? NO	Davited? NO	Other:	
27		Platform Clips: NO	Ladder Clips: NO	Insul. Rings: NO	
28		Pipe Supports: None			
29		Wind Load: 90 mph	Seismic Design: Kentucky Category E		
30		Weight Empty: * Lbs	Weight Full of Water: * Lbs		

No.		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
31		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
32		Shell	*		Carbon Steel
33	M	Heads	*		Carbon Steel
34	A	Lining	N/A		
35	T	Diameter	*		
36	E	Height	*		
37	R	Nozzle Necks			Carbon Steel
38	I	Flanges			Carbon Steel
39	A	Coupling			Carbon Steel
40	L	M.H. Cover			
41	S	Supports	Legs		A-36
42		Bolts/Studs			SA-193 B7/SA-194-2
43		Nuts			SA-193 B7/SA-194-2
44		Gaskets			nitrile rubber

No.		Service	Mark	No.	Size	Rating	Face	Type
45	N	Service	Mark	No.	Size	Rating	Face	Type
46	O	Groundwater Inlet	A	1	4"	150#	RF	Flg.
47	Z	Condensate Inlet	B	1	3"	150#	RF	Flg.
48	Z	Water Outlet	C	1	4"	150#	RF	Flg.
49	L	DNAPL Outlet	D	1	3"	150#	RF	Flg.
50	E							
51	S	NOTES:						
52		1. Vendor to complete information marked "*".						
53		2. Vendor to provide lid with two handles.						
54		3. 1/4" flat flange, match 150# bolt pattern						
55		4. Seismic Ss=2.56 g, S1=0.78g						



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Nozzle orientation to be specified in detailed engineering

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SHAW ENVIRONMENTAL, INC				**TANK SPECIFICATION**	SHAW SPEC. NO. **122064-T106**
	NO	BY	DATE	REV.	SHEET 1 OF 1
	A	TDS	1/17/07	for internal review	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**	2				JOB NO. **122064**
AREA NAME: **C-400 CLEANING BLDG**					LOCATION **PADUCAH, KY**
TAG NO.: **T-106**	3				BY TDS / APPR SES / DATE **1/9/07**
EQUIP. NAME: **AIR STRIPPER FEED TANK**					

1		Total Volume: 1,500 gal	Field Erected? NO	No. Units 1(One)			
2		Operating Pressure, in. w.c.		Atmospheric			
3		Operating Temperature, deg F		60 - 200			
4		Operating Time, hrs/day		24 continuous			
5		Contents Lethal?		No			
6		Design Pressure, psi		Atmospheric			
7	**D**	Design Temperature, deg F		210			
8	**E**	Vessel Content:		Groundwater			
9	**S**	Liquid Density (lb/cu.ft.) at standard		62.3			
10	**I**	Top		Closed, Dished			
11	**G**	Shell	Heads Corr. Barrier, inches				
12	**N**	Shell	Head Joint Efficiency, %				
13		Code:		Stamp:			
14		Radiograph:		Stress Relieve:			
15	**D**	National Board No.					
16	**A**	Type Supports:	None, Self-supporting				
17	**T**	Insulation:	None				
18	**A**	Fireproofing:	None				
19		Sandblast:	Yes	Paint: Yes			
20		MANHOLE:	Hinged? No	Davited? No	Other:		
21		Platform Clips: None	Ladder Clips: None	Insul. Rings:			
22		Pipe Supports:	None				
23		Wind Load:	90 mph	Seismic Design: Kentucky Category E	Seismic Ss=2.56 g, S1=0.78g		
24		Weight Empty:	* lbs	Weight Full of Water: * lbs			
25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality		
26		Shell	*		Fiberglass Reinforced Epoxy		
27	**M**	Heads	*		Fiberglass Reinforced Epoxy		
28	**A**	Lining					
29	**T**	I.D.	6 ft.				
30	**E**	Height	7 ft.				
31	**R**	Nozzle Necks	*		Fiberglass Reinforced Epoxy		
32	**I**	Flanges	*		Fiberglass Reinforced Epoxy		
33	**A**	Coupling			Fiberglass Reinforced Epoxy		
34	**L**	M.H. Cover			Fiberglass Reinforced Epoxy		
35	**S**	Supports	Self-supprting				
36		Bolts/Studs					
37		Nuts					
38		Gaskets					

		Service	Mark	No.	Size	Rating	Face	Type
39		Service	Mark	No.	Size	Rating	Face	Type
40	**N**	Inlet - upper Side	A	1	4"			
41	**O**	Outlet - lower Side	B	1	4"			
42	**Z**	Manway - top	C	1	18 "			
43	**Z**	Vent - top	D	1	2 "			
44	**L**	Drain - lower side	E	1	2 "			
45	**E**		F					
46			G					
47	**S**		H					
48	**C**		J					
49	**H**		K					
50	**E**		L					
51	**D**		M					
52	**U**		N					
53	**L**		P					
54	**E**							

Nozzle orientation to be specified in detailed engineering

55 1. Vendor to complete information marked *

56 2. Resin selected to be compatible with groundwater and TCE at 1,100 ppm concentration.

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SHAW ENVIRONMENTAL, INC	TANK SPECIFICATION			SHAW SPEC. NO. 122064-T107
	NO	BY	DATE	REV.
	A	TDS	1/17/07	for internal review
	2			
	3			

SHEET 1 OF 1

PROJECT NAME: C-400 SOIL VAPOR & GWTS

JOB NO.: 122064

LOCATION: PADUCAH, KY

BY	APPR	DATE
TDS	SES	1/9/07

PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS
AREA NAME: C-400 CLEANING BLDG
TAG NO.: T-107
EQUIP. NAME: LIQUID TCE STORAGE TANK

1		Total Volume: 7,000 gal	Field Erected? NO		No. Units 1(One)			
2		Operating Pressure, in. w.c.		Atmospheric				
3		Operating Temperature, deg F		60 - 100				
4		Operating Time, hrs/day		24 continuous				
5		Contents Lethal?		No				
6		Design Pressure, psi		Atmospheric				
7	D	Design Temperature, deg F		150				
8	E	Vessel Content:		Liquid TCE				
9	S	Liquid Density (lb/cu.ft.) at standard		91				
10	I	Top		Closed, Dished				
11	G	Shell	Heads Corr. Barrier, inches					
12	N	Shell	Head Joint Efficiency, %					
13		Code:		Stamp:				
14		Radiograph:		Stress Relieve:				
15	D	National Board No.						
16	A	Type Supports:	None, Self-supporting					
17	T	Insulation:	None					
18	A	Fireproofing:	None					
19		Sandblast:	No	Paint: None				
20		MANHOLE:	Hinged? Yes	Davited? No	Other:			
21		Platform Clips: No	Ladder Clips: Yes		Insul. Rings:			
22		Pipe Supports:	None					
23		Wind Load:	90 mph	Seismic Design: Kentucky Category E				
24		Weight Empty:	* lbs	Weight Full of Water: * lbs				
25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality			
26		Shell	*		Carbon Steel			
27	M	Heads	*		Carbon Steel			
28	A	Lining						
29	T	I.D.	10 ft.					
30	E	Height	12 ft.					
31	R	Nozzle Necks	*		Carbon Steel			
32	I	Flanges	*		Carbon Steel			
33	A	Coupling	*		Carbon Steel			
34	L	M.H. Cover						
35	S	Supports	Self-supporting					
36		Bolts/Studs			SA-193 B7/SA-194-2			
37		Nuts			SA-193 B7/SA-194-2			
38		Gaskets			RUBBER			
39		Service	Mark	No.	Size	Rating	Face	Type
40	N	Inlet - upper side	A	2	4"			
41	O	Outlet - lower side	B	2	4"			
42	Z	Manway - top	C	1	18"			
43	Z	Vent - top	D	1	4"			
44	L	Drain - lower side	E	1	4"			
45	E	Instrument Taps	F	4	1"		NPT	Coupling
46			G					
47	S		H					
48	C		J					
49	H		K					
50	E		L					
51	D		M					
52	U		N					
53	L		P					
54	E							
55		NOTE: Vendor to complete information marked *						
56		Seismic Ss=2.56 g, S1=0.78g						

Nozzle orientation to be specified in detailed engineering

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SHAW ENVIRONMENTAL, INC

TANK SPECIFICATION

SHAW SPEC. NO.	122064-T108
SHEET	1 OF 1
PROJECT NAME	C-400 SOIL VAPOR & GWTS
JOB NO.	122064
LOCATION	PADUCAH, KY

BY	APPR	DATE
TDS	SES	11/26/07

NO	BY	DATE	REV.
A	TDS	11/26/07	for internal review
2			
3			

PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS**
AREA NAME: **C-400 CLEANING BLDG**
TAG NO.: **T-108**
EQUIP. NAME: **Condensate Sump Tank**

1		Total Volume: 1,500 gal	Field Erected? NO		No. Units 1(One)		
2		Operating Pressure, in. w.c.	Atmospheric				
3		Operating Temperature, deg F	60 - 200				
4		Operating Time, hrs/day	24 continuous				
5		Contents Lethal?	No				
6		Design Pressure, psi	Atmospheric				
7	D	Design Temperature, deg F	210				
8	E	Vessel Content:	Groundwater				
9	S	Liquid Density (lb/cu.ft.) at standard	62.3				
10	I	Top	Closed, Dished				
11	G	Shell	Heads Corr. Barrier, inches				
12	N	Shell	Head Joint Efficiency, %				
13		Code:	Stamp:				
14		Radiograph:	Stress Relieve:				
15	D	National Board No.					
16	A	Type Supports:	None, Self-supporting				
17	T	Insulation:	None				
18	A	Fireproofing:	None				
19		Sandblast:	Yes	Paint:	Yes		
20		MANHOLE:	Hinged? No	Davited? No	Other:		
21		Platform Clips: None	Ladder Clips: None	Insul. Rings:			
22		Pipe Supports:	None				
23		Wind Load:	90 mph	Seismic Design: Kentucky Category E			
24		Weight Empty:	* lbs	Weight Full of Water:	* lbs		

Seismic Ss=2.56 g, S1=0.78g

		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
25		Item	Thickness	Mat'l Class	Mat'l - Minimum Quality
26		Shell	*		Fiberglass Reinforced Epoxy
27	M	Heads	*		Fiberglass Reinforced Epoxy
28	A	Lining			
29	T	I.D.	3 ft.		
30	E	Height	6 ft.		
31	R	Nozzle Necks	*		Fiberglass Reinforced Epoxy
32	I	Flanges	*		Fiberglass Reinforced Epoxy
33	A	Coupling			Fiberglass Reinforced Epoxy
34	L	M.H. Cover			Fiberglass Reinforced Epoxy
35	S	Supports	Self-supprting		
36		Bolts/Studs			
37		Nuts			
38		Gaskets			

		Service	Mark	No.	Size	Rating	Face	Type
39		Service	Mark	No.	Size	Rating	Face	Type
40	N	Inlet - upper Side	A	1	2"			
41	O	Outlet - lower Side	B	1	2"			
42	Z	Manway - top	C	1	12 "			
43	Z	Vent - top	D	1	1 "			
44	L	Drain - lower side	E	1	1 "			
45	E		F					
46			G					
47	S		H					
48	C		J					
49	H		K					
50	E		L					
51	D		M					
52	U		N					
53	L		P					
54	E							

Nozzle orientation to be specified in detailed engineering

55 1. Vendor to complete information marked *
56 2. Resin selected to be compatible with groundwater and TCE at 1,100 ppm concentration.

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LATA Enviromental Services of Kentucky, LLC	COOLING TOWER SPECIFICATION				LATA SPEC. NO.
	NO	BY	DATE	REV	PAGE **1 OF 1**
	0	**JTP**	**3/2/12**	**DRAFT**	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS **AREA:** C-400 CLEANING BLDG **TAG NO.:** TBD **EQUIPMENT:** COOLING TOWER					JOB NO. **C-400 IRA** LOCATION **PADUCAH, KY** BY / APPR / DATE

Process Data:		**Process Fluid**
	Fluid:	Water
	Volumetric Flow Rate	1200 GPM
	Fluid Temp. Inlet	100 deg F
	Fluid Temp. Outlet	80 deg F
	Wet Bulb Temperature:	80 deg F
	Total Cooling Capacity	700 tons
Design Data:		
	Manufacturer:	TBD (1)
	Model:	TBD (1)
	Type:	Cooling Tower
	Housing Material:	FRP
	Fan Motor:	25 HP
	Fan Diameter:	TBD (1)
	Estimated Air Volume:	150,000 CFM
	Recirculation Pump Capacity, GPM	1,200
	Pump Differential head, ft	50
	Estimater Pump motor, HP	30
	Process Inlet	10"
	Process Outlet	10"
	Unit Dimensions:	TBD (1)
	Unit Weight (dry/wet)	TBD (1)
Ambient Conditions:		
	Equipment Location:	Outdoors
	Ambient Temp:	0 to 120 deg F
	Wind Load:	90 mph
	Seismic Design:	Kentucky Category E Seismic Ss=2.56 g, S1=0.78g

Notes:
1. Vendor to complete information marked *
2. Vendor to supply cooling water pump (w. motor control) and 200 gallon glycol-water tank.
3. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Installation Instruction, Operating/Maintenance Manual etc.
4. The vendor to include delivery schedules, and certifed shop hydrostatic test data if required. documentation.
5. Equipment shall be provided with Aluminum or stainless steel I.D. tags.

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LATA Enviromental Services of Kentucky, LLC	GLYCOL CHILLER SPECIFICATION				LATA SPEC. NO.
	NO	BY	DATE	REV	PAGE 1 OF 1
					PROJECT NAME C-400 SOIL VAPOR & GWTS
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS					JOB NO. C-400 IRA
AREA: C-400 CLEANING BLDG					LOCATION PADUCAH, KY
TAG NO.: E-102					
EQUIPMENT: Glycol Chiller					BY / APPR / DATE

Process Data:	**Process Fluid:**	**Service Fluid:**
Fluid	Air/Stream (contami w/20,000 ppmv TCE)	Ethylene Glycol 20%
Inlet Pressure	5 inch water	
Pressure Loss	*	*
Volumetric Flow Rate	2303 ACFM	* gpm
Flow In (lb/hr)	Dry Air: 4078; Steam 585; TCE 571	* lb/hr
Flow Out (lb/hr)	Dry Air: 4078; Steam 62; TCE 571	* lb/hr
Condensed (lb/hr)	Water 523 lb/hr	
Fluid Temp inlet:	138 °F	45
Fluid Temp Outlet	70 °F	60
Estimated Duty BTU/hr (Design)	742560 operating; 953,654 (design)	
Design Data:		
Manufacturer/Model:	Aerofin	
Design Temperature:	- 20 to 250 °F	50 to 200 °F
Design Pressure (psig)	- 6 to 6 lb/sq.in.	- 14.7 to 150 lb/sq.in.
Test Pressure (psig)	9 lb/sq.in.	260 ib/sq.in.
Tube Materials	Copper	
Fin Materials	Aluminum	
Housing Material	Carbon Steel	
Casing Material	Galvanized Steel	
Flange Material	1/4" Steel flat plate flange w ith matching ANSI/ASTM bolt pattern	
Mist Eliminator	None	
Tube Circuit Type	Trapped	
Gas Flow Detection	Right Hand Horizontal	
Process Inlet	10" flanged, 1/4" steel plate with bolt pattern matching ANSI	
Process Outlet	10" flanged, 1/4" steel plate with bolt pattern matching ANSI	
Service Inlet	* inch	
Service Outlet	* inch	
Unit Dimensions	*	
Unit Weight	*	
Ambient Conditions:		
Equipment Location:	Outdoors	
Ambient Temp:	0 to 120 deg F	
Wind Load:	90 mph	
Seismic Design:	Kentucky Category E	Seismic Ss=2.56 g, S1=0.78g

SHAW ENVIRONMENTAL, INC.	**AIR COMPRESSOR SPECIFICATION**				SHAW SPEC. NO. Z-901
	NO	BY	DATE	REV	PAGE **1 OF 1**
	A	**TDS**	**1/17/07**	**int review**	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS **AREA:** C-400 CLEANING BLDG **TAG NO.:** Z-901 **EQUIPMENT:** UTILITY AIR COMPRESSOR					JOB NO. **122064** LOCATION **PADUCAH, KY** BY **TDS** APPR **SES** DATE **1/9/07**

Process Data:		**Process Fluid**
	Fluid:	Compressed Air
	Flow Rate Required at Pressure:	240 scfm at 90 psig
	Min Flow Rate:	0 scfm
	Max Flow Rate:	240 scfm
	Pressure Required:	90 psig
	Air Temperature:	-15 to 105 oF
Design Data:		
	Type:	Rotary Screw
	Manufacturer:	Ingersoll Rand or Equivalent
	Model:	EP60
	Horsepower:	60 HP
	Air Flow at Max. Pressure:	244 cfm
	Full Load Pressure:	125 psig
	Size of Air Receiver:	*
	Air Receiver Configuration:	*
	Weight of Unit (lbs):	*
	Materials of Construction:	*
Ambient Conditions:		
	Equipment Location:	Outdoors
	Ambient Temp:	-15 to 105 oF
	Wind Load:	90 mph
	Seismic Design:	Kentucky Category E Seismic Ss=2.56 g, S1=0.78g

Notes:
1. Vendor to complete information marked *
2. The system should be prewired to the extent practical prior to shipment to the owner's site. The air compressor shall include a control panel to house electrical devices such as motor starters, relays, push buttons, pilot lights, instrument displays, and other electrical apparatus and controls.
3. Vendor to supply air receiver tank and air filter.
4. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Installation Instruction, Operating/Maintenance Manual etc.
5. Vendor to provide equipment material of construction, Equipment Arrangement Plan and Elevation Drawings.
6. The vendor shall clearly state any exceptions to the requirements outlined in this data sheet and attached procurement documentation.
7. Equipment shall be provided with stainless steel I.D. tags.

SHAW ENVIRONMENTAL, INC.	AIR DRYER SPECIFICATION				SHAW SPEC. NO. Z-902
	NO	BY	DATE	REV	PAGE 1 OF 1
	A	TDS	1/17/07	int review	PROJECT NAME C-400 SOIL VAPOR & GWTS
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS AREA: C-400 CLEANING BLDG TAG NO.: Z-902 EQUIPMENT: AIR DRYER					JOB NO. 122064 LOCATION PADUCAH, KY BY TDS · APPR SES · DATE 1/9/07

Process Data:		**Process Fluid**
	Fluid:	Compressed Air
	Flow Rate Required	30 scfm
	Pressure Required:	30 psig
	Air Temperature:	-15 to 105 oF
Design Data:		
	Type:	Desiccant Air Dryer
	Manufacturer:	Ingersoll Rand or Equivalent
	Model:	TZM (0-200 cfm)
	Materials of Construction:	*
	Pre-Filter:	Yes
	Pre-Filter Model:	GP40
	After-Filter:	Yes
	After-Filter Model:	DP40
Ambient Conditions:		
	Equipment Location:	Outdoors
	Ambient Temp:	-15 to 105 oF
	Wind Load:	90 mph
	Seismic Design:	Kentucky Category E Seismic Ss=2.56 g, S1=0.78g

Notes:
1. Vendor to complete information marked *
2. The system should be prewired to the extent practical prior to shipment to the owner's site. The air dryer shall include a control panel to house electrical devices such as motor starters, relays, push buttons, pilot lights, instrument displays, and other electrical apparatus and controls.
3. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Installation Instruction, Operating/Maintenance Manual etc.
4. The vendor shall clearly state any exceptions to the requirements outlined in this data sheet and attached procurement documentation.
5. Equipment shall be provided with stainless steel I.D. tags.

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LATA Enviromental Services of Kentucky, LLC	**Emergency Generator SPECIFICATION**				LATA SPEC. NO.
	NO	BY	DATE	REV	PAGE **1 OF 1**
	0	**JTP**	**3/2/12**	**DRAFT**	PROJECT NAME **C-400 SOIL VAPOR & GWTS**
PROJECT: **C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS** **AREA:** **C-400 CLEANING BLDG** **TAG NO.:** **TBD** **EQUIPMENT:** **Emergency Generator**					JOB NO. **C-400 IRA** LOCATION **PADUCAH, KY** BY / APPR / DATE

Fundamental Ratings Data:		Parameters
	Power:	800 kW
	Voltage & Phase:	480 Volts, 3-Phase
	Frequency:	60 Hz
	Temp Rise:	150 deg C Rise
	Fuel:	#2 Diesel
	Max. Fuel Flow, gph (Lph)	TBD (1)
	Generator Size, LxWxH max in, (mm)	TBD (1)
	Generator Weight, LB (kg)	TBD (1)
Design Data:		
	Type:	TBD (1)
	Manufacturer:	TBD (1)
	Model:	TBD (1)
Options Design Data:		
	Enclosure Type Option:	Weather and Sound capability
	Desired min. run time at Full load:	24.4 hours
	Fuel Tank Capacity: gal(Liters)	TBD (1)
	Tank Location:	TBD (1)
	Fuel Tank Size: LxWxH in.(mm)	TBD (1)
	Gen w/Sound Enclosure Rating:	75 dB(A) at 23 ft.
	Overall Size, LxWxH max in, (mm)	TBD (1)
	Overall system Weight, LB (kg)	TBD (1)
Ambient Conditions:		
	Equipment Location:	Outdoors
	Ambient Temp:	-15 to 105 deg F
	Wind Load:	90 mph
	Seismic Design:	Kentucky Category E Seismic Ss=2.56 g, S1=0.78g

Notes:

1. Vendor to complete information marked *
2. The system should be prewired to the extent practical prior to shipment to the owner's site. The unit shall include a control panel to house electrical devices such as motor starters, relays, push buttons, pilot lights, instrument displays, and other electrical apparatus and controls.
3. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Installation Instruction, Operating/Maintenance Manual etc.
4. The vendor shall clearly state any exceptions to the requirements outlined in this data sheet and attached procurement documentation.
5. Equipment shall be provided with stainless steel I.D. tags.

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LATA Environmental Services of Kentucky, LLC	STEAM BOILER SPECIFICATION				LATA SPEC. NO.
	NO	BY	DATE	REV	PAGE 1 OF 1
	0	MT	3/2/2012	DRAFT	PROJECT NAME: C-400 SOIL VAPOR & GWTS
PROJECT: C-400 SOIL VAPOR & GRDWATER TREATMENT SYSTEMS					JOB NO. C-400 IRA
AREA: C-400 CLEANING BLDG.					LOCATION: PADUCAH, KY
TAG NO.: TBD					BY / APPR / DATE
EQUIPMENT: STEAM BOILER					

Process Data:	Inlet Fluid	Outlet Fluid
Fluid:	Water	Steam
Pressure (psia):	TBD(1)	TBD(1)
Volumetric Flow Rate (gpm):	TBD(1)	TBD(1)
Mass Flow Rate (lbs/hr):	107	107
Fluid Temp (deg F):	70	220

Design Data:	
Manufacturer:	TBD(1)
Model:	TBD(1)
Type:	Electric Steam Boiler
Operating Pressure (psig):	0-135
Code:	ASME
Housing Material:	TBD(1)
Heating Elements:	Incoloy
Height (in.):	70
Length (in.):	80
Depth (in.):	61
Unit Weight (lbs):	2400
Normal Water Volume (gals):	TBD(1)
Normal Steam Chamber (gals):	TBD(1)
Number of Heaters:	TBD(1)
Power per Heater (KW):	TBD(1)
Nominal Power (KW):	360
Voltage:	480 VAC
Phase:	3
Vessel Openings	TBD(1)
Water Inlet (in.):	1
Chemical Treatment (in.):	N/A
Boiler Blowdown (in.):	1
Manual Blowdown (in.):	1.25
Drain Valve (in.):	TBD(1)
Steam Outlet (in.):	2"

Ambient Conditions:		
Equipment Location:	Outdoors	
Ambient Temp:	-15 to 110 ^{o}F	
Wind Load:	90 mph	
Seismic Design:	Kentucky Category E	Seismic Ss=2.56 g, S1=0.78g

Notes:
1. Vendor to complete information marked *
2. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Installation Instruction, Operating/Maintenance Manual etc.
3. Vendor to include Delivery Schedules, and certified shop hydrostatic test data if required.
4. Equipment shall be provided with stainless steel I.D. tags.

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LATA Enviromental Services of Kentucky, LLC	EQUIPMENT SPECIFICATION				LATA SPEC. NO. SPM-PHC400-P001
	NO	BY	DATE	REV	PAGE 1 OF 1
	0	JAF	3/2/12	DRAFT	PROJECT NAME C-400 SOIL VAPOR & GWTS
PROJECT: C-400 SOIL VAPOR & GROUNDWATER TREATMENT SYSTEMS **AREA:** C-400 CLEANING BLDG **TAG NO.:** TBD **EQUIPMENT:** Soil Vapor VOC Recovery System Carbon Regen System					JOB NO. C-400 IRA LOCATION PADUCAH, KY BY / APPR / DATE

Process Data:	**Process Fluid**			
Fluid:	Saturated Vapor from Soil Vacuum Extraction			
Volumetric Flow Rate	1300 Standard Cubic Feet per Minute (SCFM) (dry basis)			
Min. Flow Rate	TBD (1)			
Max Flow Rate	TBD (1)			
Fluid Temperature:	70-103 deg F will be cooled to 70-100 deg F before entering Treatment System			
Fluid pH:	Acidic			
Fluid Specific Gravity:				
Air Temperature:	0 to 120 deg F			
Fluid Composition:		Influent Concentration (ppmv)	Effluent Conc. (ppmv)	Required Percent Removal
Organics:	Trichloroethene	10,000	15	99.85
	Vinyl Chloride	Unknown	15	TBD (1)
Design Data:				
Manufacturer:	TBD (1)			
Model:	TBD (1)			
Design Pressure				
Materials of Construction:	316L Stainless Steel (wetted parts)			
System Sound Rating, dBA	TBD (1) - while operating			
Skid Weight, lbs.	TBD (1)			
Ambient Conditions:				
Equipment Location:	Outdoors			
Ambient Temp:	0 to 120 deg F			
Wind Load:	90 mph			
Seismic Design:	Kentucky Category E	Seismic Ss=2.56 g, S1=0.78g		

Notes:
1. Vendor to complete information marked *
2. The system should be prewired to the extent practical prior to shipment to the owner's site. The unit shall include a control panel to house electrical devices such as motor starters, relays, push buttons, pilot lights, instrument displays, and other electrical apparatus and controls.
3. Vendor to include Technical Manual, Spare Part List, Factory Certified Test Data, Cut Sheets, Installation Instruction, Operating/Maintenance Manual etc.
4. The vendor shall clearly state any exceptions to the requirements outlined in this data sheet and attached procurement documentation.
5. Equipment shall be provided with Aluminum or stainless steel I.D. tags.
6. The vendor's electrical design, materials, and installation shall comply with LATA Specification No. SPM-PHC400-P001, Soil Vapor VOC Recovery System.