DOE/LX/07-2437&D1

Compilation of Meeting Summaries and White Papers (2017-2018)

A Product of the Paducah Gaseous Diffusion Plant Site Groundwater Modeling Working Group

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A Product of the Paducah Gaseous Diffusion Plant Site Groundwater Modeling Working Group

Date Issued—December 2019

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Task Order DE-EM0004895

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CONTENTS

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ACRONYMS

AIP	Agreement in Principal
AT123D	Analytical Transient 1-, 2-, 3-Dimensional Simulation of Waste Transport in the Aquifer System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
COPC	chemical or radionuclide of potential concern
DAF	dilution attenuation factor
DCE	dichloroethene
DNAPL	dense nonaqueous phase liquid
DOE	U.S. Department of Energy
EIC	Environmental Information Center
EMP	Environmental Monitoring Plan
EPA	U.S. Environmental Protection Agency
FFA	Federal Facility Agreement
FFS	focused feasibility study
foc	fraction of organic carbon
FRNP	Four Rivers Nuclear Partnership
FS	feasibility study
FY	fiscal year
HQ	headquarters
K_d	distribution coefficient
Koc	organic carbon partition coefficient
KDEP	Kentucky Department for Environmental Protection
KY	Kentucky
MCL	maximum contaminant level
MW	monitoring well
MWG	Modeling Working Group
NAL	no action level
NE	northeast
NW	northwest
OREIS	Oak Ridge Environmental Information System
OU	operable unit
PEGASIS	PPPO Environmental Geographic Analytical Spatial Information System
PGDP	Paducah Gaseous Diffusion Plant
PZ	piezometer
RESRAD	RESidual RADioactivity (model)
RG	soil remediation goal
RGA	Regional Gravel Aquifer
RI	remedial investigation
RMD	Risk Methods Document
ROD	record of decision
SESOIL	Seasonal Soil Model
SI	site investigation
SSL	soil screening level
SW	southwest
SWMU	solid waste management unit
TCE	trichloroethene
TOC	total organic carbon

TVA	Tennessee Valley Authority
UCRS	Upper Continental Recharge System
VC	vinyl chloride
VOC	volatile organic compound

INTRODUCTION

The purpose of this document is to present the meeting summaries and select white papers from the Paducah Groundwater Modeling Working Group (MWG) completed between September 2017 and December 2018. The meeting summaries and white papers as finalized by the MWG are included here for historical information to promote program consistency over time and facilitate succession planning. Below is a listing of information contained within this compilation.

- September 19, 2017 Meeting Summary
- December 13, 2017 Meeting Summary
- January 25, 2018 Meeting Summary
  - Continuous Regional Gravel Aquifer Water Level Monitoring at the Paducah Site
  - Measurement of Hydraulic Conductivity in the Regional Gravel Aquifer Using Monitoring Wells at the Paducah Site
  - Assessment of Sitewide Groundwater Flow Model Using Data from the Northeast Plume Optimization Project
- April 12, 2018 Meeting Summary
- July 10, 2018 Meeting Summary
- September 18, 2018 Meeting Summary
- October 3, 2018 Meeting Summary
- Revised Evaluation of TCE Trends in MW460

Organizations participating in the production of this document and their affiliations are DOE, EPA Region 4, Commonwealth of Kentucky Energy and Environment Cabinet, and Commonwealth of Kentucky Radiation Health Branch.

Notes from MWG meetings held in 2016 and in January and March 2017, are presented in Appendix A of *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model,* DOE/LX/07 2415&D2. One white paper drafted by the MWG was a Dilution Attenuation Factor (DAF)/Soil Screening Level (SSL) White Paper, discussed during the December 13, 2017 meeting. The final version of this white paper can be found in Appendix E of *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant Paducah, Kentucky Volume 1. Human Health* DOE/LX/07-0107&D2/R9/V1.

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GROUNDWATER MODELING WORKING GROUP
MEETING SUMMARY—SEPTEMBER 19, 2017

Noman Ahsanuzzaman ✓	Eva Davis ✓	Ron Kent
Brian Begley ✓	Ken Davis✓	Al Laase
Ben Bentkowski ✓	Dave Dollins✓	Kelly Layne ✓
Rich Bonczek ✓	Chad Drummond ✓	Mac McRae ✓
Gaye Brewer ✓	Stefanie Fountain ✓	Brad Montgomery
Stephanie Brock	LeAnne Garner ✓	Todd Powers ✓
Martin Clauberg ✓	Nathan Garner	Bruce Stearns✓
Bryan Clayton	Steve Hampson ✓	Tracy Taylor ✓
Julie Corkran ✓	Craig Jones	Denise Tripp✓
Jana Dawson ✓	Chris Jung ✓	

✓ indicates member was present.

1. Call for Issues from Groundwater Modeling Working Group (MWG) Members

- Introductions were made.
- It was noted during the meeting that Four Rivers Nuclear Partnership (FRNP) will be the Paducah Deactivation and Remediation Contract, transitioning in October 2017.

2. Status of Meeting Minutes, Modeling Report Comments, and Errata

- Modeling report has been acknowledged by EPA and KY.
- Previous 2017 meeting minutes can be considered final.
- DOE will write e-mail (sent 9/26/2017) to the team to acknowledge the MWG considers the minutes final.
- Because there will be no edits to the two sets of minutes (1/20/2017 and 3/3/2017) included in the report; nor will there be addition of minutes from 5/31/2017, that previously were not included, an errata for the Groundwater Modeling Report is not needed.

3. Identification of Data Needs

- Discussion was held regarding what we will use the model for. Upcoming projects include the C-400 Complex, review of the water policy box, enhanced bioremediation at SWMU 211-A, and the possible on-site waste disposal cell.
- The model is needed for interpreting groundwater flow and groundwater/surface water interaction.
- Discussion included whether we should concentrate on a near-field model, but it was pointed out that groundwater/surface water interaction and boundary conditions would be a far-field model.
- The scope of this MWG will need to closely interact with other projects—primarily environmental monitoring, but also the upcoming projects mentioned above.

- Some of these data needs could inform more than one planned activity and should be discussed in relation to the FFA. Conversely, different planned activities could require different aspects and scope of the data needs.

- Northeast (NE) Plume transect well information is not included in current model.

- Priority of recommendations should be ranked to identify importance and interdependencies, and then we can apply cost consideration.

- MW106A and MW426 were discussed northwest of the SW plume as having recently elevated concentrations (see table of results below). These locations are outside the general groundwater flow path. Additionally, there are multiple other wells between the SW plume and the wells near the water policy box that do not indicate a direct connection. TCE concentrations have dropped since 2016.

	Maximum TCE (µg/L)	
Date	**MW106A**	**MW426**
2/10/2015	4.96	
2/12/2015		1U
5/12/2015	4.88	
5/13/2015		1U
5/27/2015	4.67	
6/9/2015		0.3J
8/11/2015	4.12	1U
11/16/2015	4.06	1U
2/10/2016	4.77	
2/11/2016		0.31J
5/10/2016	4.51	
5/11/2016		1U
8/15/2016	5.18	5.05
11/16/2016	5.4	5.78
2/8/2017		0.66J
2/14/2017	5.35	
5/5/2017		1.89
5/16/2017	4.24	
8/28/2017	4	
8/29/2017		0.55J

U indicates the result was not detected by the laboratory.
J indicates the result was estimated below the reporting limit by the laboratory.

- MW146, NW of the leading edge of the NW plume was discussed as having had a concentration near 5 ppb TCE during one sampling event (4.82 µg/L on 11/14/2016) where prior results have been nondetect. This location is outside the general groundwater flow path. The near 5 ppb TCE values are lower upon more current sampling.

- An overall/long-term groundwater strategy should be developed.

- The items above, including anomalies and related observations, will be integrated into discussions and assessments of groundwater control.

ID	**Recommendations** (from *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations")	**Data Collection Interdependency/ Potential Projects**	**Discussion**
1	To reduce uncertainty at the contact area between the Terrace Gravel and the UCRS in the vicinity of the southern model boundary, additional monitoring well installation may be considered to collect water level and soil boring information.	SWMU 211-A&B	Information collected during SWMU 211-A and -B actions could inform this item.
2	Additional slug test performed on a selection of appropriate monitoring wells will define hydraulic conductivity better across the model domain. Future discussions should include selecting an appropriate slug test method and criteria for selecting test wells.		DOE will put together a proposal regarding which wells would be beneficial for slug (or other method to obtain hydraulic conductivity data) testing. Higher hydraulic conductivity [e.g., as in the Lower Regional Gravel Aquifer (RGA)] is problematic for slug tests. Pulse testing may be better suited for higher hydraulic conductivity (may be more expensive) and requires wells in certain locations relative to the test well(s) to perform. Slug tests could address some of the comments on the model and help with model calibration and/or validation. Testing in areas modeled as higher hydraulic conductivity would provide greater benefit. DOE agreed to work with interested parties in the MWG to evaluate methods to assess hydraulic conductivity. This item may not be as high a priority as other items.
3	To quantify the volumetric rates at which water enters and exits streams, efforts may be made to gage flows in various portions of BC and LBC to determine where and in what quantities water enters and exits the creeks and to coordinate the stream gauging event with a sitewide water level synoptic measurement event.	Sitewide water level synoptic – (Dependent on ID #7)	DOE will look into creek gauging, but a source of funding will likely need to be identified. Manual measurements versus weirs in the creek were discussed. See also ID #8.
4	Evaluation of a more accurate method to quantify Terrace underflow to the RGA is recommended.		This topic was not discussed specifically; see ID #1.
5	The hydraulic connection of the RGA to the Ohio River and the nature of river bank storage remain important aquifer parameters potentially justifying further study to support the model and to assess the impact of transient conditions. Continuous RGA water level records are recommended over a period of a year in the vicinity of the Ohio River and along a transect of wells extending back to the PGDP industrial area.	See also ID #12 and #16.	Did not previously have a transient model. DOE will look at making a plan to record continuous water level data from wells along a NE plume transect for over several seasons, potentially to be included in data to be available in fiscal year (FY) 19.

ID	**Recommendations** (from *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations")	**Data Collection Interdependency/ Potential Projects**	**Discussion**
6	To evaluate changes in post closure site operation that may affect anthropogenic recharge in the plant area, monitoring and documentation (including dates) of the enacted utility optimization program (performed by others) are recommended.	See also ID #11 and #17.	Still in same place with respect to anthropogenic recharge until switched to municipal utilities. DOE will evaluate synoptic water levels collected more than once per year. Is there a way to better quantify water use now?—The problem has gotten less difficult, but still very difficult to get arms around it for a full understanding.
7	To evaluate groundwater flow patterns and to verify the occurrence of the inferred groundwater divide within the plant area, increased water level measurement events conducted during different seasons, in addition to annual events (conducted in September for the last three years), are recommended. The water level measurements should be synoptic and collected over a relatively short duration, ideally within one or two days. These measurements will provide information regarding seasonal variation and may be considered for use as calibration targets in a subsequent model update.	Stream gauging – ID #3 Synoptic event at higher river stage – ID #15	A recommendation was made for taking more synoptic water elevation measurements and that KY AIP could assist.
8	If possible, measurement of the water level elevation at Metropolis Lake should be included in the sitewide water level synoptic event. Consideration also should be given to characterizing the thickness and hydraulic conductivity of the lake bottom sediments if the lake is to be simulated using river boundary condition in future modeling efforts.		Water level of the lake proposed to be recorded during one of the synoptic water level events (requires reference point). KDEP has taken the action to see if there is an elevation reference for the lake. (completed 10/9/2017) Hydraulic conductivity of lake bottom sediments is a common model unknown (because it is difficult to collect and not necessarily useful). Incorporation of this unknown into the model will need to be decided, but likely will be addressed as a boundary condition. Noman discussed pilot points were being over used.
9	Assessing water level and water quality data collected from the newly installed transect of monitoring wells located east of C-400 Building is recommended. This assessment will facilitate better understanding of the groundwater elevation contours and flow directions that indicate an apparent groundwater divide near the new transect monitoring wells. This apparent groundwater divide is a key feature of the current model calibration.	See also ID #12.	NE plume data needs to be incorporated into model; including the NE plume wells in a sitewide synoptic event (they were included in the latest sitewide synoptic water level measurements). DOE to develop proposal for the following: 1. Use synoptic information now, predicting what should be out there. A white paper may be prepared to document the results. 2. A stress period may be run for the model after NE optimization hydraulic assessment tests of extraction wells and calibrate against it. A mini-report would be used to "confirm" the current model prediction and used to evaluate if further refinements of the model may be needed.

ID	**Recommendations** (from *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations")	**Data Collection Interdependency/ Potential Projects**	**Discussion**
			3. To obtain transient data, use of data loggers for an approximate 1-year period will be considered. Note: Adding hydraulic conductivities for the NE wells would be a change to the model. The question was posed at the meeting about whether the effort was warranted at this time.
10	To understand the groundwater flow north of the site better, the TVA monitoring system data should be compiled and verified (especially datums) for use in future models.		See ID #19. Following the meeting, (on 9/26/2017) KY provided information regarding the TVA monitoring system.
11	Two of the main water supply systems and the storm water and HPFW piping were included in the model as discreet recharge zones based on site information. Assessment of the remaining water supply systems in the plant area, which include the recirculating cooling water and waste heat system, the sanitary water system, and the plant (nonsanitary) water system, is recommended to evaluate potential for contribution to anthropogenic recharge.		See ID #6.
12	Anthropogenic recharge rates are estimated over a wide range of values. As with most groundwater models, the model configuration and calibrated input parameters are not a unique solution. It is recommended that continuous water level recorders be deployed in select monitoring wells/piezometers within the plant area to assess recharge better and its impact on nearby water levels.	See also ID #5	See ID #9.
13	Installation of piezometers equipped with continuous water level monitors beneath several of the large buildings would define the thickness of the sub-slab gravel base and the temporal water level fluctuations beneath several of the large buildings better.		This topic was not discussed specifically; see ID #5 and ID #9.
14	Flow rate in the McNairy Formation is negligible compared to the RGA because the hydraulic conductivity is 2 to 3 orders of magnitude lower than in the RGA; however, the McNairy Formation may be significant for DNAPL source accumulation and contaminant transport. Future transport models based on the 2016 flow model will need to consider potential mass flux from the McNairy to the RGA resulting from back diffusion.		This topic was not discussed.
15	The Olmsted Locks and Dam are scheduled to be operational in 2018. At that time, the lowest Ohio River stage at PGDP will be the upper pool height of the dam, 302 ft amsl. Seasonally low river stages at PGDP effectively will be increased 7 ft to 12 ft. Future groundwater modeling should consider evaluation of the calibrated model using a synoptic data set collected under steady conditions at the higher river stage anticipated to start in 2018.	Sitewide water level synoptic – ID #7	This topic was not discussed.
16	The groundwater system in the PGDP Hydrologic Basin is in a transient state for much of the year, except in dry periods typically experienced in the fall. The model simulates steady state conditions and is calibrated to periods with relatively low river stage. Validation simulations indicate that during higher Ohio River stages the Northwest Plume discharges to LBC and flows west parallel to the creek. This is consistent with early plume depictions, based on water quality data, showing the plume paralleling LBC (Figure 4.5 of DOE 2010). Consideration of transient seasonal conditions at high Ohio River stages should be considered in the use of the model for	Continuous water level data collection across model domain – ID #5	This topic was not discussed specifically; see ID #5.

ID	**Recommendations** (from *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations")	**Data Collection Interdependency/ Potential Projects**	**Discussion**
	evaluating remedial strategies.		
17	A Water Balance Study to identify significant sources of anthropogenic recharge in the model domain may provide a better understanding of key components of anthropogenic recharge and reduce uncertainty in recharge estimates for future model updates.		See ID #6. KY stated that a water balance study should not be interpreted as "all or nothing" and that conducting some of the study could also reduce uncertainty.
18	Recharge related to the process building roof drains is poorly understood. Future model efforts should compile available information regarding the chronology of roof drain repair to understand temporal variability better and reduce uncertainty in recharge estimates.		This topic was not discussed.
19	Installation of additional monitoring wells, located inside and outside of the plants industrial area would reduce uncertainty regarding groundwater flow direction, contaminant distribution, and potential source areas for future model updates.	Projects upcoming that would allow collection of data: C-400, SWMU 211-A&B. See also ID #10.	There are relationships between this item and others that we have discussed today. The group should be looking further out, beyond this FY. Inputs to be considered: Wells near Metropolis Lake Road, new TVA wells, and TVA infrastructure that recently have been installed.
20	Conducting tracer tests in the vicinity of the apparent groundwater divide located east of the C-400 Building to refine understanding of groundwater flow in this area should be considered for future model update efforts.		This topic was not discussed specifically; see ID #6.

ID	**Additional Recommendations**	**Data Collection Interdependency/ Potential Projects**	**Discussion**
21	Evaluate Effects of Northeast Plume Containment System and Northwest (NW) Plume Groundwater System.	See also ID #9	NE System is new and needs to be integrated. NW System data indicate an area of anomaly/uncertainty. • Discussion of 2016 Plume Maps: MW460 data—two hypotheses for the data include 1) EWs may not be capturing the plume; 2) plume may be migrating. • KY has noted potential bypass of NW System during review of annual reports for several years. • Consideration of a change in pumping rates was discussed as a potential to help understand what is happening at MW460; however, need to be careful not to mobilize the core plume/sources. DOE is preparing a path forward to address this item and will present to the MWG.
22	Evaluate the status of the Water Policy Box.		This item is part to the overall site groundwater monitoring programs; FRNP has a task to evaluate the water policy box.
23	Determination for "groundwater contaminant migration under		This topic was not discussed

ID	Additional Recommendations	Data Collection Interdependency/ Potential Projects	Discussion
	control" based on Government Performance and Results Act environmental indicators.		specifically; see bullets above table.

Color code for data needs:

Additional Monitoring Well (MW)/Piezometer (PZ) Installation	Desktop Studies
Field Testing Using Existing MWs/PZs	Incorporation of Available/Existing Data
New Field Testing	Modeling

4. Proposed FY 2018 Schedule

Actions from discussion above and Item 7 below have been added to this schedule with dates for completion proposed.

Quarterly Meeting (September) (face-to-face meeting)	9/19/2017
Develop Draft FY 2018 Schedule	9/19/2017
Submit FY 2018 Schedule	10/19/2017
E-mail acknowledgement that the MWG considers the minutes to be final	11/20/2017
MWG concurs with FY 2018 Schedule	11/20/2017
MWG meeting to discuss DAF/SSL white paper	12/13/2017*
Submit proposal regarding transect of RGA water levels	1/4/2018
Submit proposal regarding which wells would be beneficial for slug testing	1/4/2018
KY report to MWG whether there is a marker to use at Metropolis Lake (Complete)	1/11/2018
Determination for synoptic water levels collected more than once per year	1/11/2018
Determination for synoptic water level at Metropolis Lake Road	1/11/2018
Submit proposal for use of NE transect wells into model	1/11/2018
Quarterly Meeting (December-January)	1/11/2018
Submit draft DAF/SSL white paper (See Item 7)	2/12/2018
Comments due for DAF/SSL white paper	3/12/2018
Submit recommendation for MW460 high TCE concentration	4/12/2018
Quarterly Meeting (March-April)	4/12/2018
MWG concur with DAF white paper to be included in Risk Methods Document (RMD) (Note: Entire RMD is scheduled for submission to Risk Assessment Working Group on 4/17/2018)	4/12/2018
Quarterly Meeting (June)	6/26/2018
Quarterly Meeting (September)	9/18/2018

Quarterly meetings will be Web/teleconference 8:00 a.m.–11:00 a.m. (Central), 9:00 a.m.–12:00 p.m. (Eastern)

* scheduled following the MWG meeting

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

5. Feedback on Earthcon Presentation

- Environmental Monitoring Plans (EMPs) document the sampling that is planned at the site, which includes compliance monitoring and additional environmental surveillance monitoring. The PGDP EMP is not a primary document required by the FFA, therefore, DOE does not scope the Plan with KY and EPA. KY noted that, although the Department requests copies of the EMP to support their AIP planning activities, it is often not provided by DOE until late in the 2Q of the FY. DOE noted that the EMP is typically final and available in the fall of each year and can be shared with the regulators. Optimization of sampling can be discussed based on the Earthcon recommendations, as long as the reallocation of sampling (frequency of sampling events and breadth of analysis) will not result in excessive cost increases.

- Recommendations for sampling frequency can be made through MWG.

- Sampling frequencies for some wells may be reduced (DOE to propose), keeping in mind that reduction also may cause us to miss potential anomalies in the sentinel wells (e.g., MW106A, MW426, and MW146). A potential reduction in sampling frequencies was suggested closer to the source zones, unless they are regulatory and/or CERCLA project required. High results around C-400 or other source zones should be anticipated and are expected to continue until specific source actions are implemented.

- FRNP likely will look at new monitoring strategies.

6. Poll MWG Members/Open Discussion

- EPA is including additional personnel in group so that they can include input from MWG discussions into FFA Projects and vice-versa.

- Groundwater meetings would be a good time to discuss anomalous results, objective information.

GROUNDWATER MODELING WORKING GROUP MEETING NOTES—DECEMBER 13, 2017

Noman Ahsanuzzaman ✓
Brian Begley ✓
Ben Bentkowski ✓
Rich Bonczek ✓
Gaye Brewer ✓
Stephanie Brock
Martin Clauberg ✓
Bryan Clayton
Julie Corkran
Jana Dawson
Eva Davis
Ken Davis ✓
Dave Dollins ✓
Stefanie Fountain
Tim Frederick ✓
LeAnne Garner ✓
Nathan Garner ✓
Steve Hampson
Jeri Higginbotham ✓
Chris Jung ✓
Kelly Layne
Jerri Martin ✓
Mac McRae ✓
Bobette Nourse
Todd Powers ✓
Bruce Stearns ✓
Tracy Taylor ✓
Denise Tripp ✓

✓ indicates member was present.

1. Site-Specific DAFs and Site-Specific SSLs Presentation

Attached, as Attachment 1.

2. Feedback

Verify fraction of organic carbon (foc) values used in SESOIL vs AT123D (UCRS vs RGA). LeAnne will send documentation of available measurements (empirical data) of site-specific variables used in DAF calculations (including foc and porosity) to the group. Site-specific inputs could be facility-wide or project- (e.g., C-720 area) specific, depending on the parameter.
Noman had comments on DAF in August. These comments should be revisited in this white paper.

Guidance suggesting DAF should be 1 is from Appendix E (p. E-5) of EPA's Soil Screening Guidance Technical Basis Document:
"The saturated zone and transport module is based on the following assumptions:

- The aquifer is uniform and initially contaminant-free…."

Ben and Noman are looking into EPA's official interpretation that the above guidance directs implementation of DAF greater than 1 only above an uncontaminated aquifer.

Discussion was held regarding fluxes being additive, but concentrations are not additive. Requiring the use of a DAF of 1 makes the assumption that the contaminant is within the aquifer. However, it was stated that DAF calculation is not based on concentration.

In the SSL equation, Kd and DAF dominate the calculation.
Denise is providing requested information about infiltration and hydraulic conductivity from the calibrated model for SWMU 1 and the C-720 area.

White paper would present a model for developing site-specific DAF and SSLs using SW Plume FFS (Attachment 2). The model would not contain SW Plume-specific information, but would use project-specific information, as available.

White paper is due to the MWG 2/12/18. Rich asked for acknowledgement from EPA on the MWG FY 2018 Schedule. The schedule is not binding, but gives the working group members an idea of upcoming submittals. Ben said he would pass this on to Julie.

Highlighting indicates an action item, for follow-up.

Attachment 1

SITE-SPECIFIC DAFs AND SITE-SPECIFIC SSLs

AT THE PADUCAH SITE

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IDENTIFICATION OF THE PROBLEM

- During the September 2017 FFA Managers meeting, it was decided that the MWG would develop a white paper for inclusion in the Risk Methods Document to provide guidance on development of site-specific soil screening levels (SSLs) and site-specific dilution attenuation factors (DAFs) to be implemented when scoping projects. After e-mail exchange, it was decided the white paper will present a brief history section concerning the historical use of DAFs and SSLs at the Paducah Site, including the DAF of 58 from Soils OU (DOE 2013).

SSL AND DAF EQUATIONS

$$SSL = C_w \left(K_d + \left(\frac{\theta_w + \theta_a \times H'}{\rho_b} \right) \right)$$

C_w → MCL or NAL × DAF

$$DAF = 1 + \frac{Kid}{IL}$$

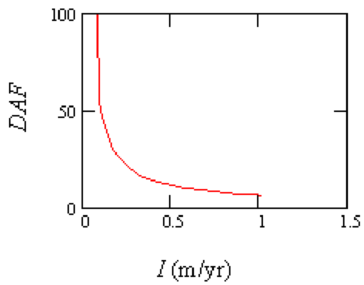
Equations from EPA's Soil Screening Guidance.

VARIABLE	EXPLANATION
C_w	target soil leachate concentration (mg/L) target soil leachate concentration (nonzero MCLG, MCL, or HBL) × a dilution factor
K_d	soil-water partition coefficient (L/kg) for organics: = $K_{oc} \times f_{oc...}$(f_{oc}=0.2%)
θ_w	water-filled soil porosity (L /L)
θ_a	air-filled soil porosity (L /L)
ρ_b	dry soil bulk density (kg/L)
H'	dimensionless Henry's law constant

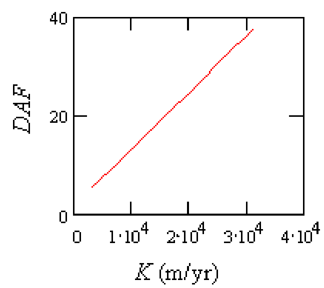
VARIABLE	EXPLANATION
i	gradient (m/m)
d	mixing zone depth (m)
I	infiltration rate (m/yr)
L	length of area of concern parallel to ground water flow (m)
K	aquifer hydraulic conductivity (m/yr)

DAF SENSITIVITY TO INPUT VALUES

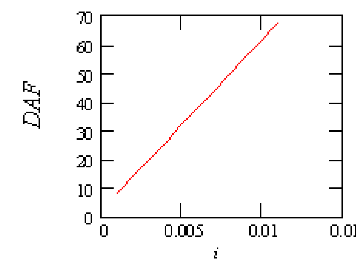
DAF sensitivity is inversely proportional to infiltration rate, I



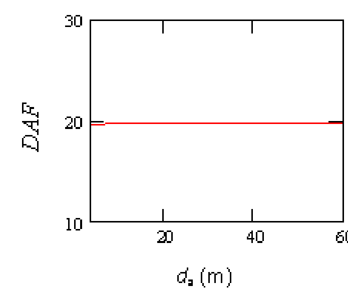
DAF sensitivity is slightly less than linear with respect to conductivity, K



DAF sensitivity is slightly less than linear with respect to gradient, i



When aquifer thickness is ≥ 3.4 m, aquifer thickness has no effect on the DAF.



New Jersey Department of Environmental Protection 2013. *Development of a Dilution-Attenuation Factor for the Impact to Ground Water Pathway*, Version 2.0, November.

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HISTORY OF SSL AND DAF USE AT PADUCAH SITE

- 1996 USEPA *Soil Screening Guidance: Technical Background Document* → generic SSLs.
  - Tables provided by DOE in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant* (2010) as preliminary remediation goals (PRGs) for protection of groundwater (DAF of 1 and 20).
- Subsequent site Risk Methods Documents (2013 – 2017).
  - Table 3.2, "Modeling Matrix for Groundwater, Surface Water, and Biota," → <u>use of DAFs and SSLs for screening during investigative phases</u>

    "Value to be used for initial scoping, use dilution attenuation factor (DAF) of 1 for SSLs unless site-specific values are available."
  - Appendix A provides SSLs* for significant COPCs.

*SSL values based on DAF of 1 taken from RAIS. SSLs for radionuclides calculated using equations provided.

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HISTORY OF SSL AND DAF USE AT PADUCAH SITE (CONTINUED)

- Many site RIs screened media analyses against background and risk-based screening levels from the site Risk Methods Document.
  - SWMU 2 Data Summary Interpretation Report (1997)
  - WAG 6 RI (1998)
  - WAG 27 RI (1999)
- Other site RIs screened media analyses against EPA-derived SSLs using a DAF of 20.
  - WAGs 9 & 11 Site Evaluation (1999)
  - WAG 28 RI (2000)

HISTORY OF SSL AND DAF USE AT PADUCAH SITE (CONTINUED)

- SWMUs 7 & 30 RI (1998) used EPA SSLs at a DAF of 1 to screen COPCs prior to fate and transport modeling using SESOIL.
- WAG 3 RI Report (2000) used EPA SSLs at a DAF of 20 to screen COPCs prior to fate and transport modeling using MEPAS.
- SW Plume SI Report (2007) provided SSL 1 and SSL 20 values for VOCs.

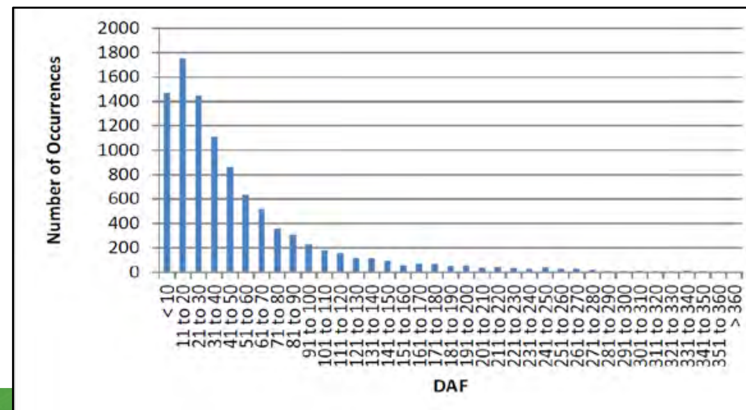
HISTORY OF SSL AND DAF USE AT PADUCAH SITE (CONTINUED)

- Follow-on SW Plume FFS (2011)—for Oil Landfarm and C-720 area—used deterministic modeling (SESOIL/AT123D) and site-specific values to evaluate remediation goals for protection of groundwater for TCE and its break-down products (Appendix C.3).
  - Calculated a DAF of 59
  - Calculated cleanup goals of 0.073 and 0.075 mg/kg for TCE at SWMU 1 and C-720, respectively (using MCL of 5 μg/L as cleanup standard)
  - Site-specific values shown in Tables C.9 and C.10
  - Remediation goals in Tables C.13 and C.16
- Calculated cleanup goals (e.g., 0.073 and 0.075 mg/kg for TCE at SWMU 1 and C-720, respectively) are presented in the ROD.

http://www.ffspaducah.com/public-documents/SW%20Plume%20FFS%20Revised%20D2/PPPO-02-1167406-11B%20Revised%20SW%20Plume%20FFS%20D2.pdf

HISTORY OF SSL AND DAF USE AT PADUCAH SITE (CONTINUED)

- Soils OU RI Report (DOE 2013) http://paducaheic.com/Search.aspx?accession=env 1.A-00358
  – Remediation Goal SSLs (Sections C1.1.2—C1.2.1)
  – DAF = 58 (Sections C2—C2.2)
    - Based on site-specific distribution of parameters from SW Plume SI Report (2007) [from Attachment F2; also shown in Appendix E of the 2017 Risk Methods Document (starting on page E-168)].
    - Soils OU-specific length of source area and aquifer thickness.
    - Crystal Ball® was used to generate 10,000 individual K, horizontal i, I, and d values which were used as input to the DAF calculation. Note that the probabilistic mean (52) DAF value is similar to the deterministic mean DAF value of 58 (Section C2.2).
      – Average = 52
      – Median = 33
      – Minimum = 3
      – Maximum = 366
      – Most frequent = 11 to 20



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SSL AND DAF EQUATIONS

$$SSL = C_w\left(K_d + \left(\frac{\theta_w + \theta_a \times H'}{\rho_b}\right)\right)$$

C_w = MCL or NAL × DAF

VARIABLE	EXPLANATION
C_w	target soil leachate concentration (mg/L) target soil leachate concentration (nonzero MCLG, MCL, or HBL) × a dilution factor
K_d	soil-water partition coefficient (L/kg) for organics: = $K_{oc} \times f_{oc\ldots}(f_{oc}$=0.2%)
θ_w	water-filled soil porosity (L /L)
θ_a	air-filled soil porosity (L /L)
ρ_b	dry soil bulk density (kg/L)
H’	dimensionless Henry's law constant

$$DAF = 1 + \frac{Kid}{IL}$$

VARIABLE	EXPLANATION
i	gradient (m/m)
d	mixing zone depth (m)
I	infiltration rate (m/yr)
L	length of area of concern parallel to ground water flow (m)
K	aquifer hydraulic conductivity (m/yr)

Equations from EPA’s Soil Screening Guidance.

SITE-SPECIFIC INPUTS VS DEFAULT VALUES

Key COPC	Site-Specific DAF	Site-Specific Kd L/kg	Site-Specific SSL mg/kg or pCi/g	Default DAF	Default Kd L/kg	Default SSL[f] mg/kg or pCi/g
TCE	59[a]	7.52E-02[a]	7.30E-02[a]	20[d]	1.21E-01[c]	3.58E-02[d]
1,1-DCE	59[a]	5.20E-02[a]	1.30E-01[a]	20[d]	6.36E-02[c]	5.02E-02[d]
cis-1,2-DCE	59[a]	2.88E-02[a]	6.00E-01[a]	20[d]	7.92E-02[c]	4.12E-01[d]
trans-1,2-DCE	59[a]	3.04E-02[a]	1.08E+00[a]	20[d]	7.92E-02[c]	6.26E-01[d]
Vinyl chloride	59[a]	1.52E-02[a]	3.40E-02[a]	20[d]	4.34E-02[c]	1.38E-02[d]
Tc-99	58[f]	2.00E-01[b]	2.12E+01[e]	20[d]	2.00E-01[d]	1.52E-01[d]
U-238	58[f]	6.68E+01[b]	2.64E+02[e]	20[d]	6.68E+01[d]	8.04E-01[d]

a DOE 2011. *Revised Focused Feasibility Study for Solid Waste Management Units 1, 211A, and 211B Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0362&D2, U.S. Department of Energy, Paducah, KY, May, for SWMU 1 area, using site-specific foc.

b DOE 2003. *Risk and Performance Evaluation of the C-746-U Landfill at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2041&D2/R1, U.S. Department of Energy, Paducah, KY, November. http://paducaheic.com/Search.aspx?accession=I-05306-0086

c RAIS 2017. https://rais.ornl.gov/, accessed November 27, using Koc x foc where foc is 0.2% .

d DOE 2017. *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant Paducah, Kentucky Volume 1. Human Health*, DOE/LX/07-0107&D2/R8/V1, U.S. Department of Energy, Paducah, KY, July.

e DOE 2013. *Soils Operable Unit Remedial Investigation Report at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0358&D2/R1, U.S. Department of Energy, Paducah, KY, February.

f SSL is based on MCL for the organics and resident NAL for the radionuclides.

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CONSENSUS ON MOVING FORWARD

- As stated in the 2017 Risk Methods Document, SSLs and DAFs are agreed upon during project scoping and are used throughout the project.
- We propose using Appendix C.3 of the SW Plume FFS (included as part of this package) to use as "how-to."
- Sources of information:
  - Parameter distributions prepared for the SW Plume SI Report, documented in the current Risk Methods Document (Appendix E)
  - Target GW concentrations are MCL or Residential NAL
  - Kd
    - SW Plume SI Report (DOE 2006) http://paducaheic.com/Search.aspx?accession=I-04610-0041 (beginning on p F2-15)
    - Risk and Performance Evaluation of the C-746-U Landfill (DOE 2003) (for environmental media, Table 4.5) http://paducaheic.com/Search.aspx?accession=I-05306-0086
    - WDA RI/FS Work Plan (DOE 2011) (for environmental media, Table C1.3) http://paducaheic.com/Search.aspx?accession=env 1.A-00072

Attachment 2

Appendix C, Section C.3, of the *Revised Focused Feasibility Study for Solid Waste Management Units 1, 211A, and 211B Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0362&D2, U.S. Department of Energy, Paducah, KY, May 2011.

C.3 SESOIL AND AT123D MODELING AND DAF CALCULATIONS

SESOIL and AT123D modeling were coupled to determine the effects of systematic reductions of SWMU 1 and C-720 Building soil contaminant concentrations on underlying RGA groundwater quality for UCRS biodegradation half-lives ranging from 5 to 50 years. Of primary interest is the time required for RGA groundwater contaminant concentrations to drop below MCLs. Table C.4 summarizes the site parameters used for SWMU 1 and the C-720 Building SESOIL modeling. The chemical-specific parameters used in the SESOIL modeling for each contaminant of concern (COC) included solubility in water, organic carbon partition coefficient (K_{oc}), Henry's Law constant, distribution coefficient (K_d), diffusion coefficients in air and water, and, for TCE, degradation rate constant are presented in Table C.5. K_d values for TCE; *cis*- and *trans*-1, 2-DCE; VC, and 1,1-DCE were derived using the following relationship.

$K_d = K_{oc} \times f_{oc}$

where: K_d is the distribution coefficient,
K_{oc} is the organic carbon partition coefficient, and
f_{oc} is the fraction of organic carbon for source area soils.

Table C.4. Soil Parameters Used in SESOIL Modeling of SWMU 1 and the C-720 Building Area[a]

Input Parameter	SWMU 1	C-720 Building	Source
Soil type	Silty clay	Silty clay	PGDP site-specific
Bulk density (g/cm^3)	1.46	1.46	Laboratory analysis
Percolation rate (cm/year)	11	11	PGDP calibrated model
Intrinsic permeability (cm^2)	1.65E-10	1.65E-10	Calibrated
Disconnectedness index	10	10	Calibrated
Porosity	0.45	0.45	Laboratory analysis
Depth to water table (m)	16.76	18.29	Site specific (to RGA) based on field observation
Organic carbon content (f_{oc}) (%)	0.08	0.09	Laboratory analysis
Frendlich equation exponent	1	1	SESOIL default value

[a] Parameter values from the Southwest Plume SI Report (DOE 2007).
PGDP = Paducah Gaseous Diffusion Plant
RGA = Regional Gravel Aquifer

Table C.5. Chemical-Specific Parameters of the Contaminants of Concern Used in SESOIL Modeling[a]

Contaminant of Concern	Mol. Wt. (MW) (g/gmol)	Solubility in water (mg/L)	Diffusion in air (cm2/s)	Diffusion in water (m2/hr)	Henry's Constant (atm.m3/mol)	K_{oc} (L/kg)	K_d[b] (L/kg) SWMU 1	K_d[b] (L/kg) C-720	Degradation Half Life[c] (years)
Trichloroethene	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	0.0846	5, 25, 50
cis-1,2-dichloroethene	97	3,500	0.07	4.07E-06	0.00408	36	0.0288	0.0324	infinite
trans-1,2-dichloroethene	97	6,300	0.07	4.28E-06	0.00938	38	0.0304	0.0342	infinite
Vinyl chloride	63	2,760	0.11	4.43E-07	0.0270	19	0.0152	0.0171	infinite
1,1-dichloroethene	97	2,250	0.09	3.74E-06	0.0261	65	0.0520	0.0585	infinite

[a] Parameter values from the Southwest Plume SI Report (DOE 2007).
[b] K_d of an organic compound depends on the soil's organic carbon content (f_{oc}) and compound's organic carbon partition coefficient (K_{oc}).
[c] Half-life refers to the time it takes for a contaminant to lose half of its mass due to biodegradation.

The UCRS f_{oc} used for SWMU 1 and C-720 were 0.08% and 0.09%, respectively. The mechanisms and rates of TCE biodegradation within the UCRS have not yet been substantively assessed; consequently, a range of degradation rates (5, 25, and 50 years) was used in this assessment to determine the effects of degradation on overall remedy time frames. For conservatism, it was assumed that the remaining COCs (*cis*-DCE, *trans*-DCE, VC, and 1,1-DCE) did not undergo biodegradation. An effort to utilize mole percentages for daughter products was not performed to verify the half-lives calculated for TCE.

Based on the vertical distribution of soil contamination at C-720 and SWMU 1, 10-ft-thick SESOIL model layers were to simulate contaminant movement in the upper portions of the UCRS. Thinner 1-ft layers were used in the vicinity of the UCRS/RGA contact to limit the potential for numerical issues. For better source representation of vertical contaminant distributions and to improve the flux mass balance, the SWMU 1 and C-720 source zones were divided into 10 and 11 layers, respectively. Tables C.6 and C.7 summarize average contaminant concentrations and layer thickness for the two source areas.

Table C.6. Summary of Source Term Characteristics for SWMU 1[a]

Layer	Depth (ft)	Average (mg/kg)	Area (ft^2)	Volume (ft^3)	Mass[b] (g)
		Trichloroethene			
Layer 1	00–10	7.59	4,375	43,750	13,723
Layer 2	10–20	110.8	3,125	31,250	143,177
Layer 3	20–30	17.6	6,250	62,500	45,503
Layer 4	30–40	13.0	5,625	56,250	30,283
Layer 5	40–50	13.6	5,625	56,250	31,516
Layer 6–9	50–54	5.74	7,500	30,000	7,119
Layer 10	54–55	5.74	7,500	7,500	1,780
		Total Mass			273,068
		cis-1,2-Dichloroethene			
Layer 1	00–10	6.00	4,375	43,750	10,852
Layer 2	10–20	0.046	3,125	31,250	59
Layer 3	20–30	0.086	6,250	62,500	222
Layer 4	30–40	1.7	5,625	56,250	3,953
Layer 5	40–50	1.0	5,625	56,250	2,326
Layer 6–9	50–55	0.02	7,500	30,000	29
Layer 10	54–55	0.02	7,500	7,500	7
		Total Mass			17,449
		trans-1,2-Dichloroethene			
Layer 1	00–10	16.0	4,375	43,750	28,940
Layer 2	10–20	1.5	3,125	31,250	1,938
Layer 3	20–30	1.5	6,250	62,500	3,876
Layer 4	30–40	0.6	5,625	56,250	1,395
Layer 5	40–50	1.4	5,625	56,250	3,256
Layer 6–9	50–55	0.00	7,500	30,000	0
Layer 10	54–55	0.00	7,500	7,500	0
		Total Mass			39,405
		Vinyl chloride			
Layer 1	00–10	0.7	4,375	43,750	1,266
Layer 2	10–20	0.0033	3,125	31,250	4
Layer 3	20–30	0.088	6,250	62,500	227

Table C.6. Summary of Source Term Characteristics for SWMU 1[a] (Continued)

Layer	Depth (ft)	Average (mg/kg)	Area (ft^2)	Volume (ft^3)	Mass[b] (g)
Layer 4	30–40	0.012	5,625	56,250	28
Layer 5	40–50	0.0095	5,625	56,250	22
Layer 6–9	50–55	0.02	7,500	30,000	22
Layer 10	54–55	0.02	7,500	7,500	6
		Total Mass			1,576
		1,1-Dichloroethene			
Layer 1	00–10	0.01	500	5,000	2
Layer 2	10–20	0.00	0	0	0
Layer 3	20–30	0.04	1,000	10,000	17
Layer 4	30–40	0.04	1,600	16,000	26
Layer 5	40–50	0.03	2,800	28,000	29
Layer 6–9	50–55	0.06	850	3,400	8
Layer 10	54–55	0.06	850	850	2
		Total Mass			84

[a] Layer concentrations from the Southwest Plume SI Report (DOE 2007).
[b] Mass calculated using an average bulk density of 1.46 g/cm^3.

Table C.7. Summary of Source Term Characteristics for the C-720 Building Area Source[a]

Layer	Depth (ft)	Average (mg/kg)	Area (ft^2)	Volume (ft^3)	Mass[b] (g)
		Trichloroethene			
Layer 1	00–10	2.96	7,500	75,000	9,185
Layer 2	10–20	6.37	7,500	75,000	19,751
Layer 3	20–30	11.9	15,000	150,000	73,900
Layer 4	30–40	1.55	6,875	68,750	4,393
Layer 5	40–50	1.20	6,875	68,750	3,411
Layer 6–10	50–55	0.10	6,875	34,375	142
Layer 11	55–60	0.00	6,875	34,375	0
		Total Mass			110,684
		cis-1,2-Dichloroethene			
Layer 1	00–10	3.2	7,500	75,000	9,922
Layer 2	10–20	0.75	7,500	75,000	2,326
Layer 3	20–30	0.019	15,000	150,000	118
Layer 4	30–40	0.052	6,875	68,750	148
Layer 5	40–50	0	6,875	68,750	0
Layer 6–10	50–55	0.00	6,875	34,375	0
Layer 11	55–60	0.00	6,875	34,375	0
		Total Mass			12.513
		trans-1,2-Dichloroethene			
Layer 1	00–10	0	7,500	75,000	0
Layer 2	10–20	0.4	7,500	75,000	1,240
Layer 3	20–30	0	15,000	150,000	0
Layer 4	30–40	0	6,875	68,750	0

Table C.7. Summary of Source Term Characteristics for the C-720 Building Area Source[a] (Continued)

Layer	Depth (ft)	Average (mg/kg)	Area (ft^2)	Volume (ft^3)	Mass[b] (g)
Layer 5	40–50	0	6,875	68,750	0
Layer 6–10	50–55	0.00	6,875	34,375	0
Layer 11	55–60	0.00	6,875	34,375	0
		Total Mass			1,240
		Vinyl chloride			
Layer 1	00–10	0.4	7,500	75,000	1,240
Layer 2	10–20	0.4	7,500	75,000	1,240
Layer 3	20–30	0	15,000	150,000	0
Layer 4	30–40	0	6,875	68,750	0
Layer 5	40–50	0	6,875	68,750	0
Layer 6–10	50–55	0.00	6,875	34,375	0
Layer 11	55–60	0.00	6,875	34,375	0
		Total Mass			2,481
		1,1-Dichloroethene			
Layer 1	00–10	0.0	0	0	0
Layer 2	10–20	0.0	0	0	0
Layer 3	20–30	0.0	0	0	0
Layer 4	30–40	0.18	5,600	56,000	417
Layer 5	40–50	0.0305	15,000	150,000	189
Layer 6–10	50–55	0.0020	2,150	10,750	1
Layer 11	55–60	0.0020	2,150	10,750	1
		Total Mass			611

[a] Layer concentrations from the Southwest Plume SI Report (DOE 2007).
[b] Mass calculated using an average bulk density of 1.46 g/cm^3.

Using the listed parameters as input, SESOIL calculated temporal groundwater contaminant concentrations in the UCRS at the HU3/HU4 contact, which were used as input for AT123D. Additional AT123D input parameters are summarized in Table C.8.

Table C.8. Hydrogeologic Parameters Used in AT123D Modeling[a]

Input Parameter	SWMU 1	C-720 Building	Source
Bulk density (kg/m^3)	1,670	1,670	Laboratory analysis
Effective porosity	0.3	0.3	PGDP sitewide model calibrated value
Hydraulic conductivity (m/hour)	16.2	16.2	Average value from Tables C.7 and C.8
Hydraulic gradient	0.0004	0.0004	PGDP sitewide model calibrated value
Aquifer thickness	9.14 m 30 ft	9.14 m 30 ft	Site average
Longitudinal dispersivity (m)	1.5	1.5	
Density of water (kg/m^3)	1,000	1,000	Default
Fraction of organic carbon (%)	0.02	0.02	Laboratory analysis
Well screen length (m)	3	3	Assumed a 10 ft well screen mixing zone

[a] Parameter values from the Southwest Plume SI Report (DOE 2007).

DAF calculations were performed to determine the maximum allowable UCRS soil concentrations that are protective of RGA groundwater quality. The DAF was calculated using the following equation:

$$DAF = 1 + \frac{Kid}{IL}$$

Where:

i = gradient (m/m)
d = mixing zone depth (m)
I = infiltration rate (m/yr)
L = length of area of concern parallel to groundwater flow (m)
K = aquifer hydraulic conductivity (m/yr)

The equation for calculating the aquifer mixing zone depth, d:

$$d = \left(0.0112\, L^2\right)^{0.5} + d_a \left\{1 - e^{\left[\frac{(-L\,I)}{(K\,i\,d_a)}\right]}\right\}$$

Where:

d_a = aquifer thickness (m)

The first term, d_{av}, estimates the depth of the mixing due to vertical dispersivity along the length of the groundwater flow path:

$$d_{av} = \left(0.0112\, L^2\right)^{0.5}$$

The second term, d_{iv}, estimates the depth of mixing due to the downward velocity of infiltrating water:

$$d_{iv} = d_a \left\{1 - e^{\left[\frac{(-L\,I)}{(K\,i\,d_a)}\right]}\right\}$$

Input parameters for the DAF calculations are summarized in Table C.9 and Table C.10 from the Site Investigation (SI) Report (DOE 2007) for SWMU 1 and C-720, respectively. The effective aquifer hydraulic conductivity for the RGA/HU4 stratigraphic sequence (0.45 cm/s, 1.42E+05 m/yr) was calculated as the arithmetic average of the RGA hydraulic conductivity (0.53 cm/s, 9.14 m thickness) and HU4 hydraulic conductivity (0.001 cm/s, 1.5 m thickness). The DAF, the amount by which UCRS groundwater contamination can expect to be diluted beneath the source areas, was calculated to be 59 for both SWMU 1 and C-720.

Table C.9. SWMU 1 Parameter Values for Calculation of the DAF

Parameter	Value	Description
L	17.04	L corresponds to the square root of the source area (Table F.28, DOE 2007) and is the length of the source area parallel to groundwater flow.
d_a	9.14	Aquifer thickness (m) Table F.34 SI Report
I	0.1054	Infiltration rate (m/yr) 10.54 cm/yr SESOIL net recharge rate to groundwater
K	1.42E+05	Aquifer hydraulic conductivity (m/yr) average of silty sand (5 ft) at 10^{-3} cm/s and gravel (30 ft) at 0.529 cm/s from SI Table F.34
i	4.00E-04	Hydraulic gradient (m/m) Table F.34 SI Report

Table C.10. C-720 Parameter Values for Calculation of the DAF

Parameter	Value	Description
L	37.3	L corresponds to the square root of the source area (Table F.28, DOE 2007) and is the length of the source area parallel to the groundwater flow.
d_a	9.14	Aquifer thickness (m) Table F.34 of SI Report (DOE 2007)
I	0.1054	Infiltration rate (m/yr) 10.54 cm/yr SESOIL net recharge rate to groundwater
K	1.42E+05	Aquifer hydraulic conductivity (m/yr) Average of silty sand (5 ft) at 10^{-3} cm/s and gravel (30 ft) at 0.529 cm/s from SI Report Table F.34 (DOE 2007)
i	4.00E-04	Hydraulic gradient (m/m) Table F.34 SI Report (DOE 2007)

SWMU 1 Results

Remedial technologies under consideration at SWMU 1 are the following:

· Deep Soil Mixing with Enhancements
· Large Diameter Auger Excavation with Deep *In Situ* Treatment
· *In Situ* Thermal Treatment
· Long-term Monitoring
· Enhanced *In Situ* Bioremediation

For modeling purposes, we assumed that the treatment technologies do not materially alter UCRS hydrologic properties (except for excavation). Thus, the soil properties within SESOIL were not altered in the evaluation simulations. Soil excavation will change UCRS soil properties because a column of soil will be removed to within approximately 10 ft of the HU3/HU4 contact, and the excavated soil will be replaced by sand, a more permeable material. It needs to be acknowledged that changing the hydraulic conductivity profile within SESOIL to reflect the higher hydraulic of the emplaced sand relative to the native UCRS resulted in an error message that the configuration produced near zero soil moisture and the simulation could not be completed. To overcome this limitation, it was assumed that the hydraulic conductivity of the emplaced media was the same as the original UCRS. In addition, the excavation scenario assumed that contamination in the excavated portion of soil column is zero rather than a percentage decline from the original contaminant concentration levels. Native soil contamination concentrations below the excavated material were simulated at original concentrations and as incremental declining percentages from the original contaminant concentration levels.

Table C.11 combines the TCE average concentration profile presented by layer in Table C.6, with the expected removal percentage presented in Table C.1 to yield expected posttreatment concentrations by layer.

Table C.11. Expected Posttreatment Average TCE Concentrations by Layer for SWMU 1

Layer/Depth(ft)	Average TCE Conc. (mg/kg)	Post-DSM TCE Conc. (mg/kg)	Post-LDA TCE Conc. (mg/kg)	Post-ERH TCE Conc. (mg/kg)	Post-EISB TCE Conc. (mg/kg)
	Percentage Removal	***91%***	***100%/0%***	***98%***	***60%***
Layer 1/00-10	7.59	0.68	0	0.15	3.04
Layer 2/10-20	110.8	9.97	0	2.22	44.3
Layer 3/20-30	17.6	1.58	0	3.52	7.04
Layer 4/30-40	13.0	1.17	0	2.60	5.20
Layer 5/40-50	13.6	1.17	6.8	2.72	5.44
Layer 6–9/50-54	5.74	0.52	5.74	0.11	2.30
Layer 10/54-55	5.74	0.52	5.74	0.11	2.30
Total Mass (lbs)	601	54	20	12	240

Conc. = concentration
DSM = deep soil mixing
EISB = enhanced *in situ* bioremediation
ERH = electrical resistance heating
LDA = large diameter auger

Figure C.3 summarizes AT123D modeling results as percent soil contaminant reduction versus years to reach the TCE MCL for RGA groundwater at the SWMU boundary for a range of biological half-lives. The figure can be used to assess the expected performance of the various proposed remedial technologies (Table C.12). Evaluation shows that, with the exception of thermal treatment with five-year TCE biological half-life, many decades will pass after UCRS soil remediation before RGA water quality will drop below the TCE MCL of 5 µg/L.

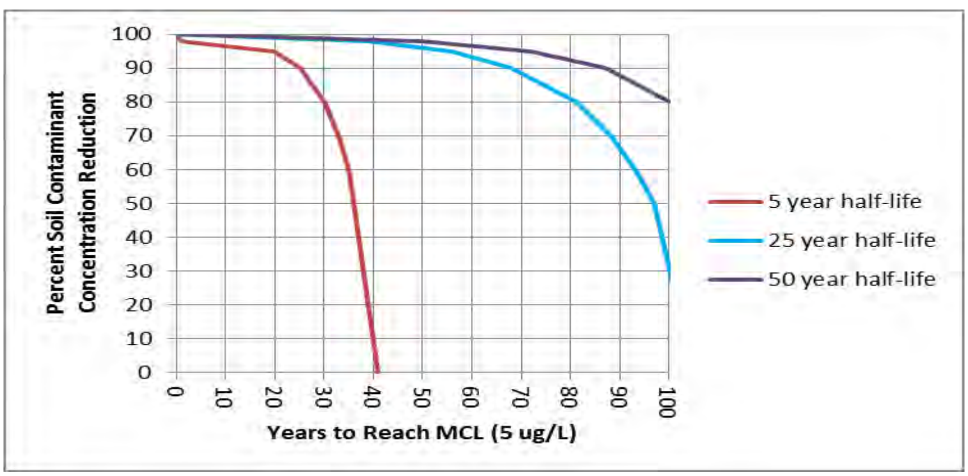

Figure C.3. Time Required for Residual TCE Mass from SWMU 1 to Reach MCL (5 µg/L) in RGA

Table C.12. Expected Time Frames to Reach TCE MCL in the RGA at SWMU 1

Remedial Alternative	Expected Reduction in Soil Contaminant Concentrations, %	Years to reach MCL in RGA Groundwater, 5-Year Half-Life	Years to reach MCL in RGA Groundwater, 25-Year Half-Life	Years to reach MCL in RGA Groundwater, 50-Year Half-Life
Deep Soil Mixing with Enhancements	91	25	68	87
Large Diameter Auger Excavation with Deep *In Situ* Treatment	100 in excavated column, 0 in native soils	15	38	50
In Situ Thermal Treatment	98	1	39	50
Enhanced *In Situ* Bioremediation	60	35	93	> 100
Long-term Monitoring	0	41	> 100	> 100

Figure C.4 shows AT123D simulation results for Large Diameter Auger Excavation with Deep *In Situ* Treatment. The results listed in Table C.12 are based on SESOIL runs having varying biodegradation rates (5-, 25-, and 50-year half-lives) where contamination was removed (assumed zero) to a depth of approximately 10 ft above the HU3/HU4 contact. Removing contaminated soil and replacing it with clean sand significantly reduces the time to achieve the TCE MCL in RGA groundwater. For a 25-year biological half-life and no remediation, time to reach TCE MCL in the RGA is reduced from > 100 years (long-term monitoring) to 38 years. If the remaining TCE soil contaminant concentrations beneath the sand column are reduced via *in situ* treatment, the time to reach the TCE MCL is reduced further.

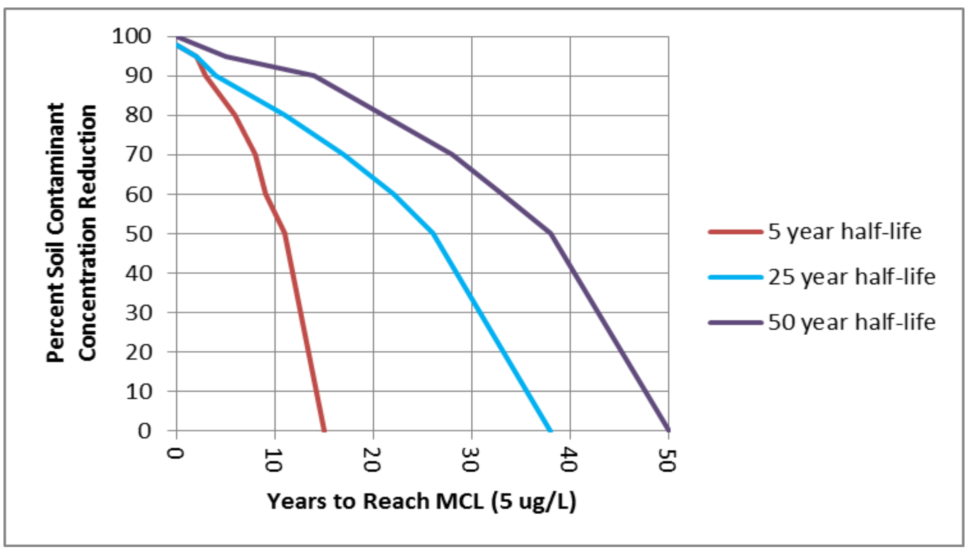

Figure C.4. Time Required for Residual TCE Mass from SWMU 1 to Reach MCL (5 µg/L) in RGA for Large Diameter Auger Excavation

The same procedure described above was used to evaluate SWMU 1 soil contaminants other than TCE. 1,1-DCE and VC were not included in the graph because UCRS soil concentrations are so low that concentrations reduce to MCLs in RGA groundwater without remediation (as a function of dilution). Different from the TCE simulations, however, was the assumption that biodegradation does not occur. In essence, the results are worst case, and time to reach MCLs in RGA groundwater likely will be shorter than the predicted times. Figure C.5 shows that minimal reduction in soil contaminant concentrations is required to rapidly drop expected RGA contaminant concentrations below MCLs. This is because the initial contaminant soil concentrations are less than the initial TCE soil contaminant concentrations and, with the exception of VC, the MCLs for the contaminants are higher than the TCE MCL.

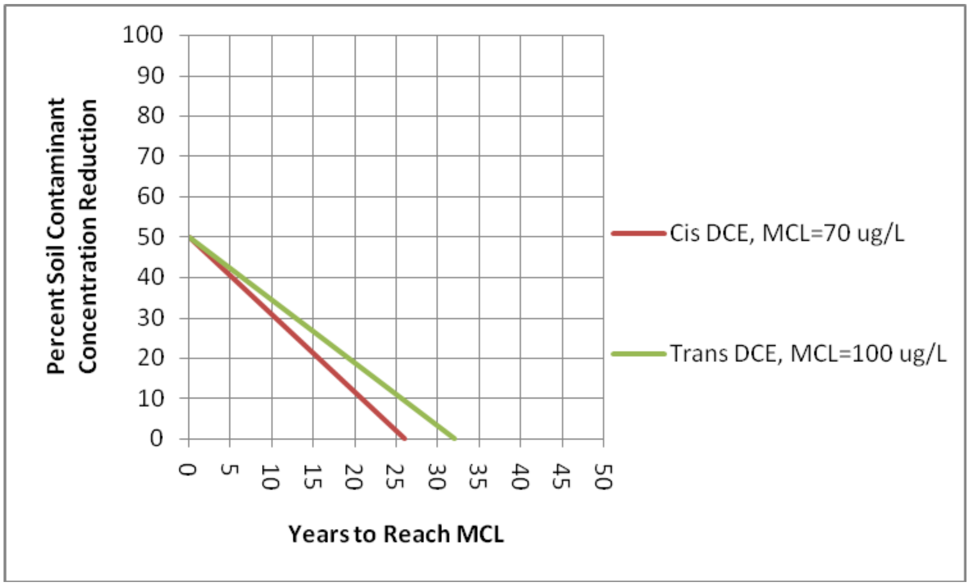

Figure C.5. Time Required for Residual *cis*-DCE and *trans*-DCE Mass from SWMU 1 to Reach MCLs in RGA

Required UCRS soil contamination concentrations to be protective of RGA groundwater quality were calculated using the following equation:

$$RG = \frac{(MCL)\times(C_s)}{C_{gw}}$$

Where:

RG = soil remediation goal (mg/kg)
MCL = MCL for the COC (µg/L)
C_s = soil concentration (mg/kg)
C_{gw} = groundwater concentration based on a unit soil concentration (µg/L)

If unit soil contaminant concentrations are used in SESOIL, then the equation simplifies this to:

$$RG = \frac{(MCL)}{C_{gw}}$$

Table C.13 presents the allowable UCRS groundwater contaminant concentrations and bulk average soil contaminant remediation goals (RGs) for SWMU 1 to be protective of RGA groundwater quality.

Table C.13. SWMU 1 Soil Remediation Goals for Groundwater Based on a DAF

COC	Leachate Concentration at HU3/HU4 (µg/L)	Groundwater Concentration (µg/L)[a]	MCL (µg/L)	Soil RG for units above HU4 (mg/kg)
Trichloroethene (5-yr UCRS half-life)	295	5	5	0.085
Trichloroethene (25-yr UCRS half-life)	295	5	5	0.080
Trichloroethene (50-yr UCRS half-life)	295	5	5	0.073
1,1-Dichloroethene	413	7	7	0.130
cis-1,2-Dichloroethene	4,130	70	70	0.600
trans-1,2-Dichloroethene	5,900	100	100	1.080
Vinyl chloride	118	2	2	0.034

[a] DAF = 59

C-720 Building Results

Remedial technologies under consideration at C-720 NE and SE sources are as follows:

- *In Situ* Thermal Treatment
- *In Situ* Jet Chemical Source Treatment
- *In Situ* Soil Flushing with Dual-Phase Extraction
- Long-term Monitoring

In general, the treatment technologies considered at C-720 minimally, if at all, alter UCRS hydrologic properties. Thus, the soil properties within SESOIL were not altered in the evaluation simulations.

Table C.14 combines the TCE average concentration profile presented by layer in Table C.7 with the expected removal percentage presented in Table C.1 to yield expected posttreatment concentrations by layer.

Table C.14. Expected Posttreatment Average TCE Concentrations by Layer for C-720

Layer/Depth(ft)	Average TCE Conc. (mg/kg)	Post-LAI TCE Conc. (mg/kg)	Post-MPE TCE Conc. (mg/kg)	Post-ERH TCE Conc. (mg/kg)
Percentage Removal		***90%***	***95%***	***98%***
Layer 1/00-10	2.96	0.30	0.15	0.15
Layer 2/10-20	6.37	0.64	0.32	2.22
Layer 3/20-30	11.9	1.19	0.6	3.52
Layer 4/30-40	1.55	0.16	0.08	2.60
Layer 5/40-50	1.20	0.12	0.06	2.72
Layer 6–10/50-55	0.10	0.01	0.005	0.11
Layer 11/55-60	0.00	0.00	0.00	0.00
Total Mass (lbs)	243	24	12	2

Conc. = concentration
ERH = electrical resistance heating
LAI = liquid atomized injection
MPE = multiphase extraction (with soil flushing)
TCE = trichloroethene

Figure C.6 summarizes the C-720 SE source AT123D modeling results as percent soil contaminant reduction versus years to reach the TCE MCL for RGA groundwater at the SWMU boundary for a range of biological half-lives. As with SWMU 1, the figure can be used to assess the expected performance of the various proposed remedial technologies at C-720 (Table C.15). Simulation results suggest that application of *In Situ* Thermal Treatment and *In Situ* Soil Flushing with Multiphase Extraction will rapidly reduce RGA TCE concentrations to below the MCL for a TCE 5-year biological half-life. For the remaining technologies at a TCE 5-year half-life and all technologies for 25- and 50-year half-lives, decades will be required after application for RGA TCE concentrations to drop below the MCL.

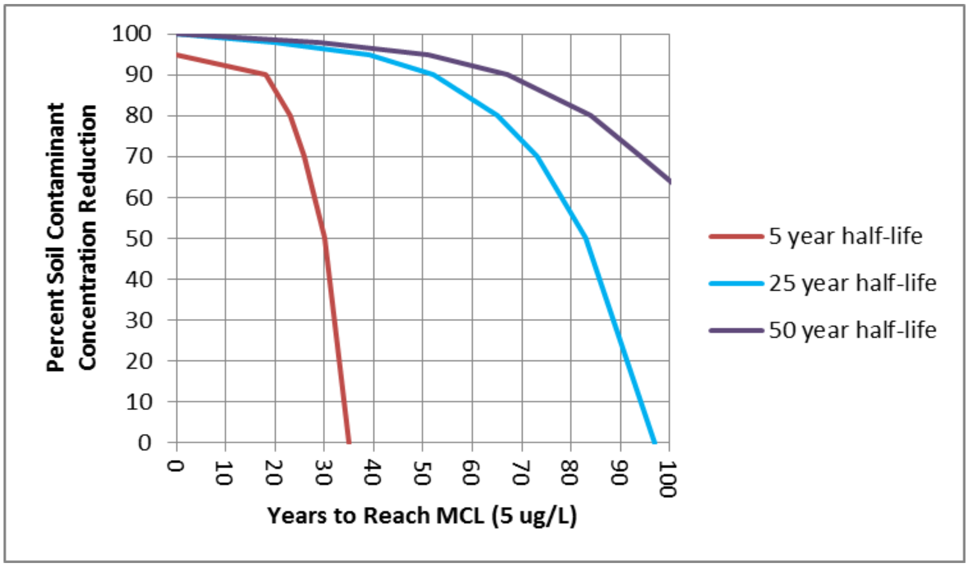

Figure C.6. Time Required for Residual TCE Mass from C-720 to Reach MCL (5 µg/L) in RGA

Table C.15. Expected Time Frames to Reach TCE MCL in the RGA at C-720

Remedial Alternatives	Expected Reduction in TCE Soil Concentrations, %	Years to reach MCL in RGA Groundwater, 5-Year Half-Life	Years to reach MCL in RGA Groundwater, 25-Year Half-Life	Years to reach MCL in RGA Groundwater, 50-Year Half-Life
In Situ ERH Treatment	98	0	20	29
In Situ LAI Source Treatment	90	18	52	67
In Situ Soil Flushing with MPE	95	0	39	51
Long-term Monitoring	0	35	97	>100

ERH = electrical resistance heating
LAI = liquid atomized injection
MPE = multiphase extraction

AT123D simulation results for C-720 soil contaminants other than TCE show that minimal reductions in *cis*-DCE and VC soil contaminant concentrations are required to rapidly drop expected RGA contaminant concentrations below MCLs (Figure C.7). Results for *trans*-DCE and 1,1-DCE are not shown because the initial preremediation concentrations are sufficiently low so that the contaminants do not negatively impact RGA water quality.

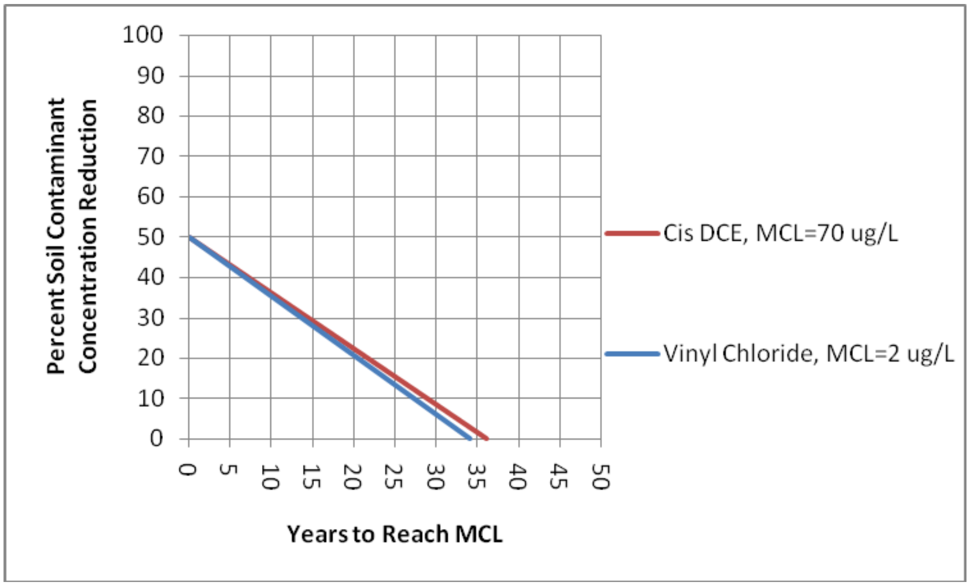

Figure C.7. Time Required for Residual *cis*-DCE, *trans*-DCE, and VC Mass from C-720 to Reach MCLs in RGA

As with SWMU 1, required UCRS soil contamination concentrations to be protective of RGA groundwater quality were calculated (DAF) for all of the C-720 soil contaminants (Table C.16).

Table C.16. C-720 Soil Remediation Goals for Groundwater Based on a DAF

COC	Leachate Concentration at HU3/HU4 (µg/L)	Groundwater Concentration (µg/L)[a]	MCL (µg/L)	Soil RG for units above HU4 (mg/kg)
Trichloroethene (5-yr UCRS half-life)	295	5	5	0.092
Trichloroethene (25-yr UCRS half-life)	295	5	5	0.083
Trichloroethene (50-yr UCRS half-life)	295	5	5	0.075
1,1-Dichloroethene	413	7	7	0.137
cis-1,2-Dichloroethene	4,130	70	70	0.619
trans-1,2-Dichloroethene	5,900	100	100	5.29
Vinyl chloride	118	2	2	0.450

[a] DAF = 59

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GROUNDWATER MODELING WORKING GROUP
MEETING SUMMARY—JANUARY 25, 2018

Noman Ahsanuzzaman ✓	Jana Dawson	Jeri Higginbotham ✓
Brian Begley ✓	Eva Davis ✓	Chris Jung ✓
Ben Bentkowski ✓	Ken Davis ✓	Kelly Layne
Rich Bonczek ✓	Dave Dollins ✓	Mac McRae ✓
Gaye Brewer	Bruce Ford	Bobette Nourse ✓
Stephanie Brock	Stefanie Fountain	Todd Powers ✓
Martin Clauberg ✓	LeAnne Garner ✓	Bruce Stearns ✓
Bryan Clayton	Nathan Garner	Tracy Taylor ✓
Julie Corkran	Steve Hampson ✓	Denise Tripp ✓

✓ indicates member was present.

1. Call for Issues from Groundwater Modeling Working Group (MWG) Members

2. Status of Previous Meeting Summary

Comments received from KY and EPA, incorporated as shown. The previous meeting summary is to be sent out separately, following the meeting. If no comments are received, they will be considered final.

3. Remaining FY 2018 Schedule

Submit proposal regarding transect of RGA water levels (Submitted)	1/4/2018
Submit proposal regarding which wells would be beneficial for slug testing (Submitted)	1/4/2018
KY report to MWG whether there is a marker to use at Metropolis Lake (Complete)	1/11/2018
Determination for synoptic water levels collected more than once per year	1/11/2018
Determination for synoptic water level at Metropolis Lake	1/11/2018
Submit proposal for use of NE transect wells into model (Submitted)	1/11/2018
Quarterly Meeting (December-January)	1/25/2018
Comments due to Ken for white paper	2/1/2018
Submit draft DAF/SSL white paper	2/12/2018
Submit revised draft white papers	2/19/2018
Comments due for DAF/SSL white paper	3/12/2018
Submit recommendation for MW460 high TCE concentration	4/12/2018
Quarterly Meeting (March-April)	4/12/2018
MWG concur with DAF white paper to be included in Risk Methods Document (RMD) (Note: Entire RMD is scheduled for submission to Risk Assessment Working Group on 4/17/2018)	4/12/2018
Quarterly Meeting (June)	6/26/2018
Quarterly Meeting (September)	9/18/2018

Quarterly meetings will be Web/teleconference 8:00 a.m.–11:00 a.m. (Central), 9:00 a.m.–12:00 p.m. (Eastern)

* scheduled following the MWG meeting

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

LeAnne will send out place holder calendar invitations.

Ben will check on an EPA acknowledgement of Working Group schedule.

4. DAF/SSL White Paper

- During the September 2017 FFA Managers meeting, it was decided that the MWG would develop a white paper for inclusion in the Risk Methods Document providing guidance on development of site-specific soil screening levels (SSLs) and site-specific dilution attenuation factors (DAFs) to be implemented when scoping projects.

- A kick-off meeting for this white paper was held December 13, 2017. The white paper will include a brief history section concerning the historical use of a DAF of 58 for the Soils Operable Unit. A proposed "model" for determining site-specific DAFs and SSLs was presented. Items for follow-up are

  1. LeAnne will send documentation of available measurements (empirical data) of site-specific variables used in DAF calculations to the group.
  2. Ben and Noman are looking into EPA's official interpretation that the guidance directs implementation of DAF only above an uncontaminated aquifer.
  3. Denise is providing requested information about infiltration and hydraulic conductivity from the calibrated model for SWMU 1 and the C-720 area.

  LeAnne will be sending Items 1 and 3 within this bullet to the group. (They are included as Attachment 1 to this Meeting Summary.)
  Ben will be talking to EPA SMEs at HQ on Friday, January 26, and will be sending information regarding Item 2 within this bullet.

  The draft paper will be sent to the MWG for review on February 12. Comments must be received by March 12, to support the completion of the 2018 RMD.

5. Proposal Regarding Transect of RGA Water Levels

- The *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations" stated that the hydraulic connection of the RGA to the Ohio River and the nature of river bank storage remain important aquifer parameters potentially justifying further study to support the model and to assess the impact of transient conditions. Continuous RGA water level records are recommended over a period of a year in the vicinity of the Ohio River and along a transect of wells extending back to the PGDP industrial area.

- Draft white paper was submitted 1/4/2018.

- Comments or feedback from the group following Ken's presentation of the paper include the following.

  — Noman recommends adding MW476 so that vertical gradient also can be monitored. MWs 146 and 147 similarly could be used to monitor vertical gradient. (MW 476 is more important than MW147 because of its proximity to Metropolis Lake.)

  — Consideration has to be given to well accessibility (e.g., one of the wells in a well pair is in a private resident's front yard).

  — Denise recommends that MW473/MW474 might be a better choice than MW475/MW476 because of their location with respect to the plume.

  — The number of available data loggers (continuous pressure transducers) is a potential limit to the selection of wells for continuous monitoring.

- Recommendations from this white paper will be presented to DOE management regarding resources.

- Suggested changes to wells include moving data collection from MW199 to MW489/490.

- MW353 is beneficial because of its location in the plume divide.

- In general, the group agreed with the recommended approach. The continuous water level records provide better information than just synoptic water levels. Additional justification can be made and added to the white paper for presentation to management.

- MWG members agreed to provide their comments by 2/1/2018 in writing to Ken. Ken will provide a revised draft for a quick review by 2/19/2018. Additional comments provided on the 2/19/2018 will be integrated into a final paper by March for discussion with DOE management. These dates have been added to the schedule.

6. Determination for Synoptic Water Levels Collected More than Once per Year

- The *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations" stated that to evaluate changes in post closure site operation that may affect anthropogenic recharge in the plant area, monitoring and documentation (including dates) of the enacted utility optimization program (performed by others) are recommended.

- In the September 2017 quarterly meeting, DOE agreed to evaluate whether to collect synoptic water levels more than once per year.

- MWG recommendation can be made to inform Environmental Monitoring Plan revisions.

- Discussion for synoptic water levels collected more than once per year has been postponed to April 2018 meeting.

7. Proposal Regarding Which Wells Would Be Beneficial for Slug Testing

- The *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations" stated that additional slug test performed on a selection of appropriate monitoring wells will define hydraulic conductivity better across the model domain. Future discussions should include selecting an appropriate slug test method and criteria for selecting test wells.

- In the September 2017 quarterly meeting, DOE agreed to put together a proposal regarding which wells would be beneficial for slug (or other method to obtain hydraulic conductivity data) testing.

- Draft white paper submitted 1/4/2018.

- Comments or feedback from the group following Ken's presentation of the paper include the following.

  - Slug testing can be applicable where RGA hydraulic conductivity is less than 200 ft/day.
  - Group is comfortable in general with the conclusions presented in the paper.
  - Model used hydraulic conductivities from pumping tests, not slug test.

- Written comments can be provided by 2/1/2018.
- This topic will be revisited in September.

8. KY Report to MWG Whether there Is a Marker to Use at Metropolis Lake

- KY reported that there is no marker for use at Metropolis Lake.
- Fluctuation of water levels at the lake would be beneficial to have.
- DOE will investigate what option(s) is available to establish a water level gauge at the April 2018 quarterly meeting.

9. Determination for Synoptic Water Level at Metropolis Lake Road

- This action was for determination for synoptic water levels at Metropolis Lake, not Metropolis Lake Road.
- The *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations" stated that, if possible, measurement of the water level elevation at Metropolis Lake should be included in the sitewide water level synoptic event. Consideration also should be given to characterizing the thickness and hydraulic conductivity of the lake bottom sediments if the lake is to be simulated using river boundary condition in future modeling efforts.
- Since there is no marker for use at Metropolis Lake, should these measurements be attempted?
- Topic will be revisited at the next meeting.

10. Proposal for Use of Northeast Plume Transect Wells into Model

- The *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, Section 8.2, "Recommendations" stated that assessing water level and water quality data collected from the newly installed transect of monitoring wells located east of C-400 Building is recommended. This assessment will facilitate better understanding of the groundwater elevation contours and flow directions that indicate an apparent groundwater divide near the new transect monitoring wells. This apparent groundwater divide is a key feature of the current model calibration.
- In the September 2017 quarterly meeting, DOE agreed to look at making a plan to record continuous water level data from wells along a NE plume transect for over several seasons, potentially to be included in data to be available in fiscal year (FY) 19.
- In the September 2017 quarterly meeting, DOE agreed to develop a proposal.
- Draft white paper due to be submitted 1/11/2018 (e-mail from LeAnne was dated 1/10/2018).
- Comments or feedback from the group following Ken's presentation of the paper include the following.

- NE Plume transect wells increase our confidence in the model; but would likely not change the model.
- Rejected water level data was due to measurements being out of line with others nearby. Measurements out of line likely due to measurement errors, rejected approximately 10 %.

- Additional comments can be addressed at the April 2018 meeting.

11. Poll MWG Members/Open Discussion

- LeAnne will send out all 3 white papers with this meeting summary. They are included as Attachments 2–4.

- Vapor Intrusion information may be discussed at the April 2018 meeting.

- C-400 scoping may be discussed at the April 2018 meeting.

ATTACHMENT 1
Groundwater Modeling Working Group
Follow-up to DAF Meeting (December 13, 2017)

Highlighted items are excerpts from the December 13, 2017 meeting summary.
LeAnne will send documentation of available measurements (empirical data) of site-specific variables used in DAF calculations [including fraction of organic carbon (foc) and porosity] to the group.

The Southwest Plume Focused Feasibility Study (FFS) that was discussed in our meeting references the Southwest Plume Site Investigation (SI) Report D2/R1 (June 2007). The SI Report D2/R1 was not previously available on the EIC website. It now is available at the following location:
https://eic.pad.pppo.gov/Search.aspx?accession=ENV 1.A-01477

Appendix E of the Risk Methods Document reprints an excerpt of Appendix F, Attachment 2 of the 2007 D2/R1 SI Report (the Risk Methods Document incorrectly references the 2006 D2 SI Report). That text states the following:

"**Organic Carbon Content:** Site-specific data were available for the organic carbon content of the UCRS. The site-specific organic carbon contents measured earlier were assumed to representative of that expected in the UCRS at each source area. Summary statistics for the site-specific data are in Table F.2.3. A set of 138 results was available. The coefficient of variation was estimated as 66%, and the skewness was estimated as 4.3. Given the coefficient of variation and skewness, a log-normal distribution was assumed. The organic carbon content was assumed not correlated to any other parameter. The summary statistics for the values output by Crystal Ball are in Table F.2.4. …

Table F.2.3. Statistics of variable inputs used in Monte Carlo sampling for SESOIL modeling (see Table F.45)

Input Parameter	Statistics	Unit	SWMU 1	C-720 Building	Remark
Vertical Hydraulic Conductivity[a]	Minimum	cm/sec	1.00E-08	1.00E-08	DOE 1997a, DOE 1997b
	Likeliest	cm/sec	1.64E-05	1.64E-05	DOE 1997a, DOE 1997b
	Maximum	cm/sec	2.00E-04	2.00E-04	[b]DOE 1997a, DOE 1997b
	Standard Deviation	cm/sec	5.52E-05	5.52E-05	DOE 1997a, DOE 1997b
	Count	#	13	13	DOE 1997a, DOE 1997b
	Coefficient of Variation	cm/sec	336.49	336.49	DOE 1997a, DOE 1997b
	Skew	-	3.60	3.60	DOE 1997a, DOE 1997b
	Maximum	cm/sec	3.20E-05	3.20E-05	[c,d]Recharge-specific (to RGA) calibration
	Distribution	-	Triangular	Triangular	See Section 4.0, Intrinsic Permeability
	Correlation Pair	-	None	None	None
	Correlation Coefficient	-	NA	NA	NA
Organic Carbon Content	Minimum	%	2.48E-02	2.48E-02	Site-specific (to PGDP) field data
	Likeliest	%	8.01E-02	8.01E-02	Site-specific (to PGDP) field data
	Maximum	%	4.55E-01	4.55E-01	Site-specific (to PGDP) field data
	Standard Deviation	%	5.27E-02	5.27E-02	Site-specific (to PGDP) field data
	Count	#	138	138	Site-specific (to PGDP) field data
	Coefficient of Variation	%	65.82	65.82	Site-specific (to PGDP) field data
	Skew	-	4.30	4.30	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	None	None	See Section 4.0, Organic Carbon Content
	Correlation Coefficient	-	NA	NA	NA

…
[a] Field observation was available for vertical hydraulic conductivity. Therefore, intrinsic permeability was estimated from vertical hydraulic conductivity.
[b] The maximum from DOE 1997a and DOE 1997b was judged to be high and was re-estimated through calibration.

[c] The maximum was estimated through calibration to a recharge of 22 cm/yr (DOE 2000).
[d] The value selected for probabilistic method.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, *Environmental Degradation Rates*, Lewis Publishers, Inc. Chelsea, MI, 1991.
LMES (Lockheed Martin Energy Systems) 1997. *Evaluation of Natural Attenuation Processes for Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/EM-113.
DOE, 1997a. *Ground-Water Conceptual Model for the Paducah Gaseous Diffusion Plant Paducah, Kentucky,* DOE/OR/06-1628&D0, August.
DOE, 1997b. *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Grouping 22 at the PGDP Paducah, Kentucky,* DOE/OR/07-1549&D1, February.
DOE 2000. *Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant Paducah, Kentucky,* DOE/OR/07-1857&D1, July."

"**Effective Porosity:** Site-specific data were available for the porosity of the RGA; therefore, the effective porosity was estimated from the porosity using a conversion value of 81% taken from DOE 1999. [In that report, an effective porosity of 0.30 and a porosity of 0.37 were reported (i.e., 0.30/0.37 = 0.81 or 81%).] The data were assumed applicable to the RGA at each source area and along the contaminant flow paths. A set of 28 results was available. The minimum, maximum, and most likely values selected for porosity were 27, 54, and 39%. The coefficient of variation was estimated as 15%, and the skewness was estimated as 0.43. Given the coefficient of variation and skewness, a normal distribution was assumed. Additionally, the porosity was assumed correlated to the hydraulic conductivity and the hydraulic gradient. The correlation coefficients were assumed as 0.20 and -0.20 for correlating the porosity to the hydraulic conductivity and to the hydraulic gradient, respectively. Summary statistics for the values output by Crystal Ball® and the resulting effective porosity values used in runs for AT123D modeling are provided in Table F.2.9. A histogram of the effective porosity values is in Fig. F.2.22[1]. Note that only a histogram of effective porosity is presented because effective porosity and not porosity was the value input into AT123D.

[1] Future groundwater modeling efforts at PGDP will utilize 35% as a practical upper-bound for effective porosity values."

The analytical data supporting this is available on PEGASIS. Results can be seen by selecting samples collected between 2/1/1998 and 5/1/1998 and the analyte "Total Organic Carbon (TOC)."

Vertical hydraulic conductivity values are found in DOE 1997a, attached, and DOE 1997b, at the following link: https://eic.pad.pppo.gov/Search.aspx?accession=I-02910-0031

Reports containing empirical data are the following.

Porosity. WAG 6 RI Report, Appendix H, https://eic.pad.pppo.gov/Search.aspx?accession=I-00810-0050 (part b, beginning on page 433 of the pdf).

Organic Carbon.
Results of the Site Investigation, Phase II, https://eic.pad.pppo.gov/Search.aspx?accession=I-02400-0224 (part b, pages 301, 302, and 306 of the pdf).
WAG 27 RI Report, https://eic.pad.pppo.gov/Search.aspx?accession=I-03910-0021 (part a, pages 401 and 407 of the pdf).
Southwest Plume SI Report D2/R1, summarized above. See also https://eic.pad.pppo.gov/Search.aspx?accession=ENV 1.A-01477
(part D, pages 150, 153, 169, 172, 223, 321, 324, and 337 of the pdf).

Ben and Noman are looking into EPA's official interpretation that the above guidance [i.e., EPA's Soil Screening Guidance Technical Basis Document] directs implementation of DAF only above an uncontaminated aquifer.

Denise is providing requested information about infiltration and hydraulic conductivity from the calibrated model for SWMU 1 and the C-720 area.
Information follows.

Model Parameters in the SWMU 1 and C-720 Areas

2016 Sitewide Groundwater Model

SWMU1 (Oil Landfarm Area) and C-720 Area Location Map

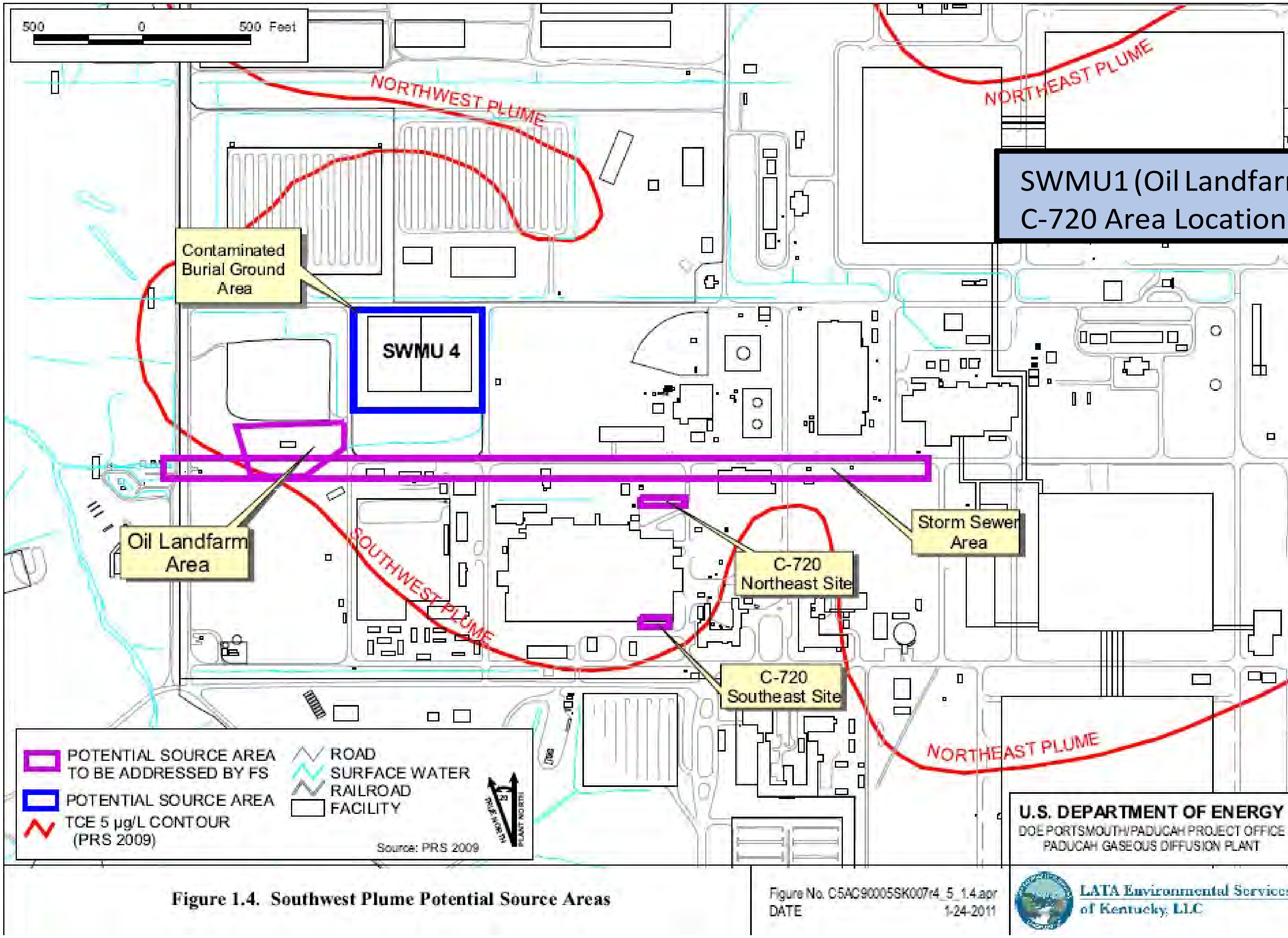
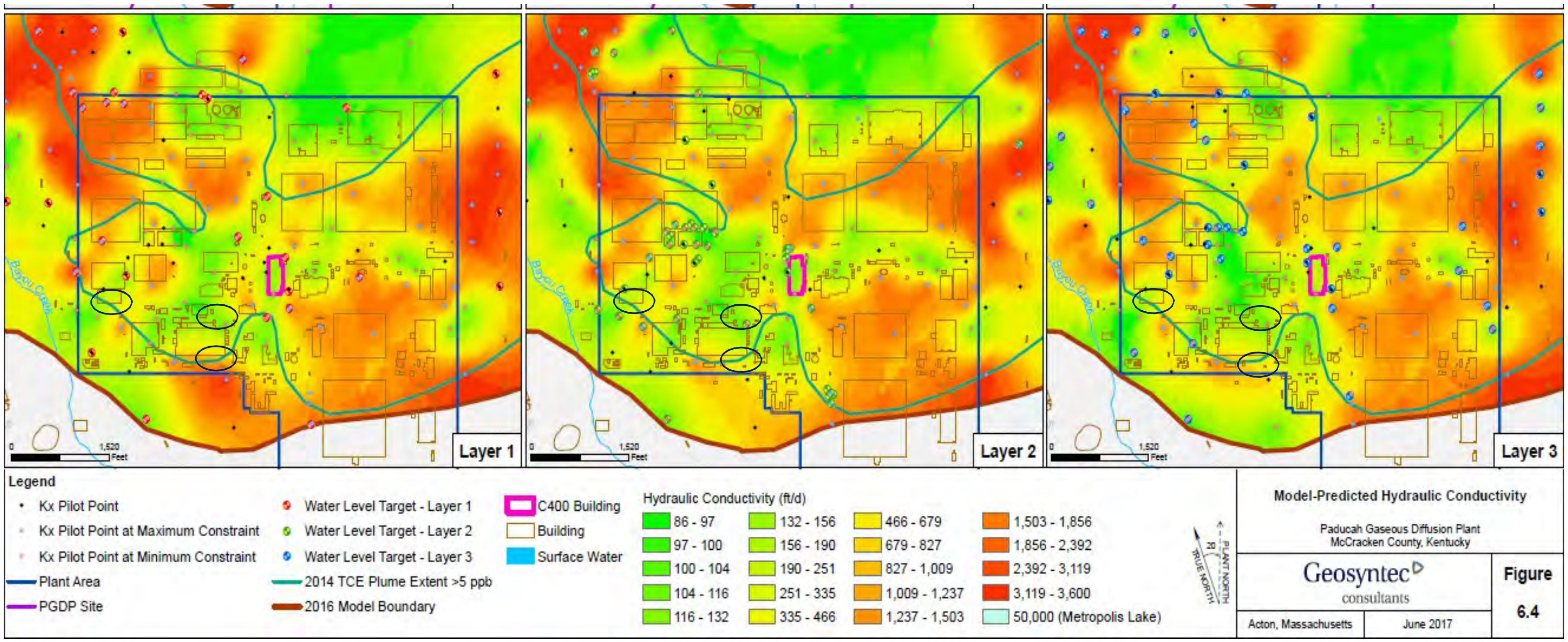
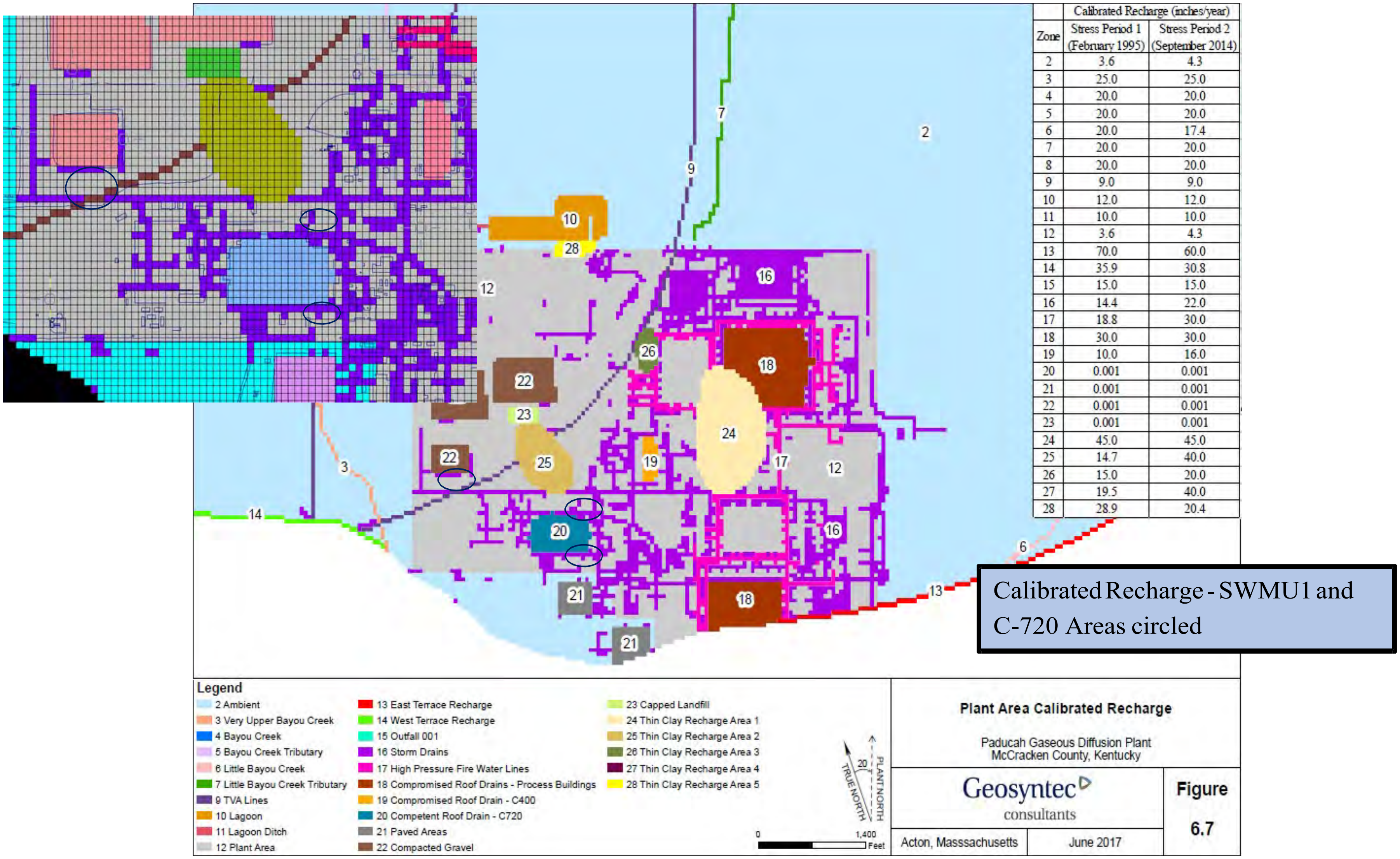


Figure 1.4. Southwest Plume Potential Source Areas

Model Hydraulic Conductivity – SWMU1 and C-720 areas circled



DRAFT



Zone	Calibrated Recharge (inches/year) Stress Period 1 (February 1995)	Stress Period 2 (September 2014)
2	3.6	4.3
3	25.0	25.0
4	20.0	20.0
5	20.0	20.0
6	20.0	17.4
7	20.0	20.0
8	20.0	20.0
9	9.0	9.0
10	12.0	12.0
11	10.0	10.0
12	3.6	4.3
13	70.0	60.0
14	35.9	30.8
15	15.0	15.0
16	14.4	22.0
17	18.8	30.0
18	30.0	30.0
19	10.0	16.0
20	0.001	0.001
21	0.001	0.001
22	0.001	0.001
23	0.001	0.001
24	45.0	45.0
25	14.7	40.0
26	15.0	20.0
27	19.5	40.0
28	28.9	20.4

Recharge

- SWMU 1: primarily Zone 12 (Plant Area) - Recharge = 3.6 (SP1) and 4.3 (SP2) inch/yr
- C-720 Northeast: primarily Zone 12 (Plant Area) - Recharge = 3.6 (SP1) and 4.3 (SP2) inch/yr
- C-720 Southeast: primarily Zone 16 (Storm Drains) - Recharge = 14.4 (SP1) and 22 (SP2) inch/yr

Hydraulic Conductivity

- SWMU 1: Layers 1, 2 and 3 – 150 to 400 ft/day
- C-720 Northeast: Layers 1, 2 and 3 – 100 to 300 ft/day
- C-720 Southeast: Layer 1 - 720 to 880 ft/day, Layers 2 and 3 – 400 to 500 ft/day

Continuous Regional Gravel Aquifer Water Level Monitoring at the Paducah Site

This document is approved for public release per review by:

FRNP Classification Support 2-14-18
Date

CONTINUOUS REGIONAL GRAVEL AQUIFER WATER LEVEL MONITORING AT THE PADUCAH SITE

Hydraulic connection of the Regional Gravel Aquifer (RGA) to the Ohio River and the nature of river bank storage remain important aquifer parameters requiring further study to improve the model of groundwater flow in the RGA and to assess the impact of transient Ohio River conditions. The *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model* (DOE 2017) included a recommendation for collection of continuous RGA water level records over a period of one year in the vicinity of the Ohio River and in transect extending back to the Paducah Site industrial area to improve understanding of both parameters. This white paper documents a recommendation to place pressure transducer/data logger instrumentation in existing Paducah Site[1] groundwater monitoring wells (MWs) near the Ohio River and in groundwater MWs more distal to the Ohio River to collect the relevant data.

Three criteria apply to the selection of groundwater MWs for the study:

- Spatial: located on or near the Paducah Site and extending to near the Ohio River,
- Depth: screened in the RGA, and
- Accessibility: not committed to landfill groundwater compliance monitoring.

The Paducah Site currently maintains 245 RGA MWs and piezometers that are available for water level measurements and are not committed to landfill groundwater compliance monitoring. The groundwater MWs are located within U.S. Department of Energy (DOE) property and adjacent West Kentucky Wildlife Management Area, Tennessee Valley Authority, and private properties (Figure 1).

TRANSIENT TRENDS

Over the preceding five years, the annual change in the stage of the lower Ohio River near the Paducah Site has ranged from 31.1 ft (2014) to 42.7 ft (2016). Figure 2 provides hydrographs for the Ohio River near the Paducah Site for the years 2014 and 2016. The hydrographs are characterized by low and steady river stage during summer months and higher and variable river stage during fall, winter, and spring months. Flood events provide yearly water level spikes that impact water levels in the RGA near the Ohio River (see Figure 3).

Water levels in the RGA in the vicinity of the Paducah Site exhibit a yearly cycle of high and low stage, nearly synchronous and correlative with the overall stage of the Ohio River. The annual peak of the RGA water levels typically is delayed compared to Ohio River stage, and the delay increases with distance from the Ohio River.[2] Figure 3 provides Ohio River[i] and RGA hydrographs along a transect extending from MW152, located approximately 4,000 ft from the Ohio River, back to the Paducah Site (MW71,

[1] References in this report to the Paducah Site generally mean the property, programs, and facilities at or near Paducah Gaseous Diffusion Plant for which DOE has ultimate responsibility. The Paducah Site is located in a generally rural area of McCracken County, Kentucky, 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River. The plant is on a 3,556-acre DOE site comprised of the following: 628 acres within a fenced security area, approximately 809 acres located outside the security fence, 133 acres in acquired easements, and the remaining 1,986 acres licensed to the Commonwealth of Kentucky as part of the West Kentucky Wildlife Management Area.

[2] The delay in the annual peak of RGA water level is due to gain and loss of storage: it is not due to transmission of kinetic energy.

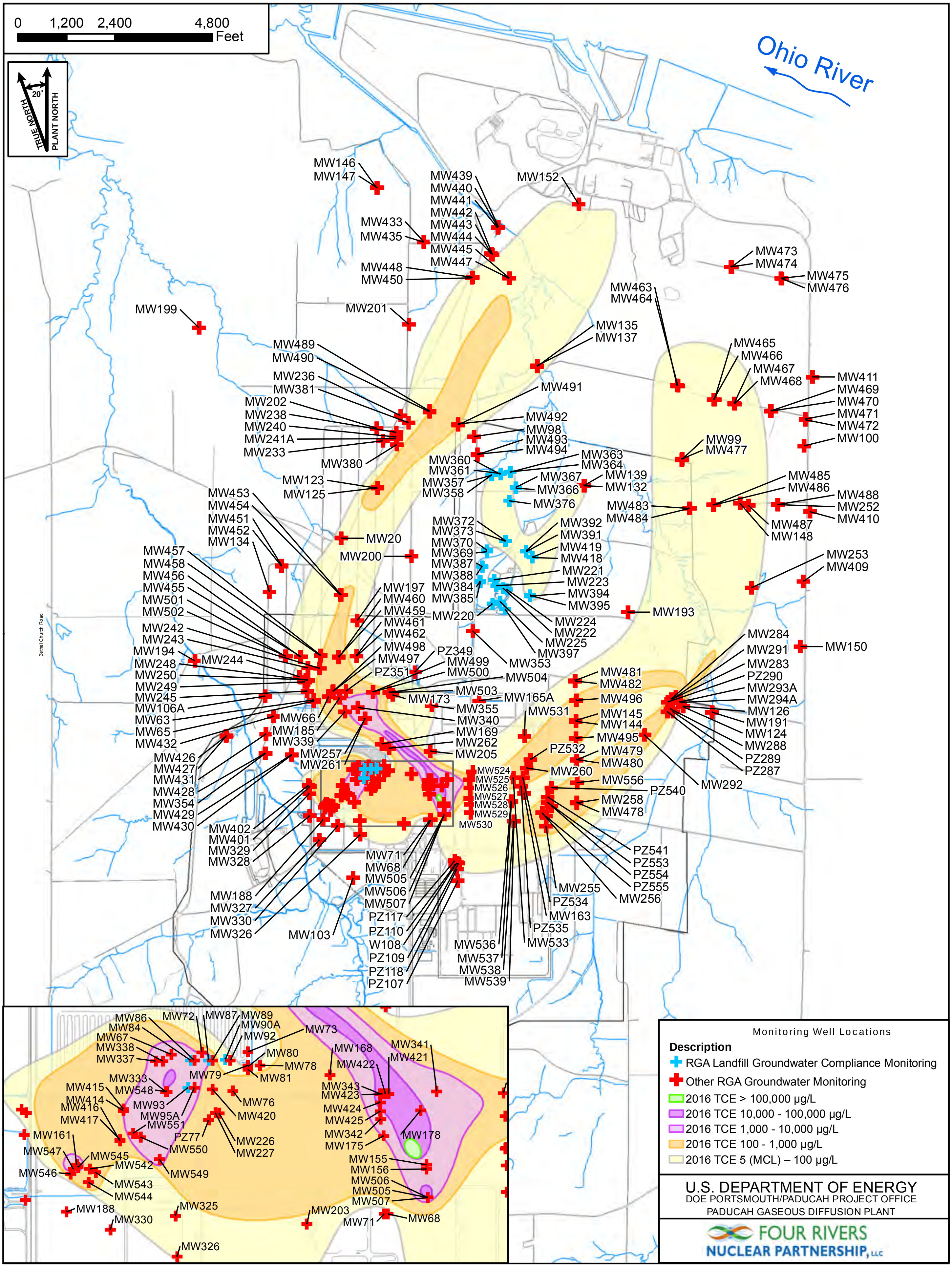


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Figure 1. RGA Monitoring Wells with TCE Groundwater Plume Shown

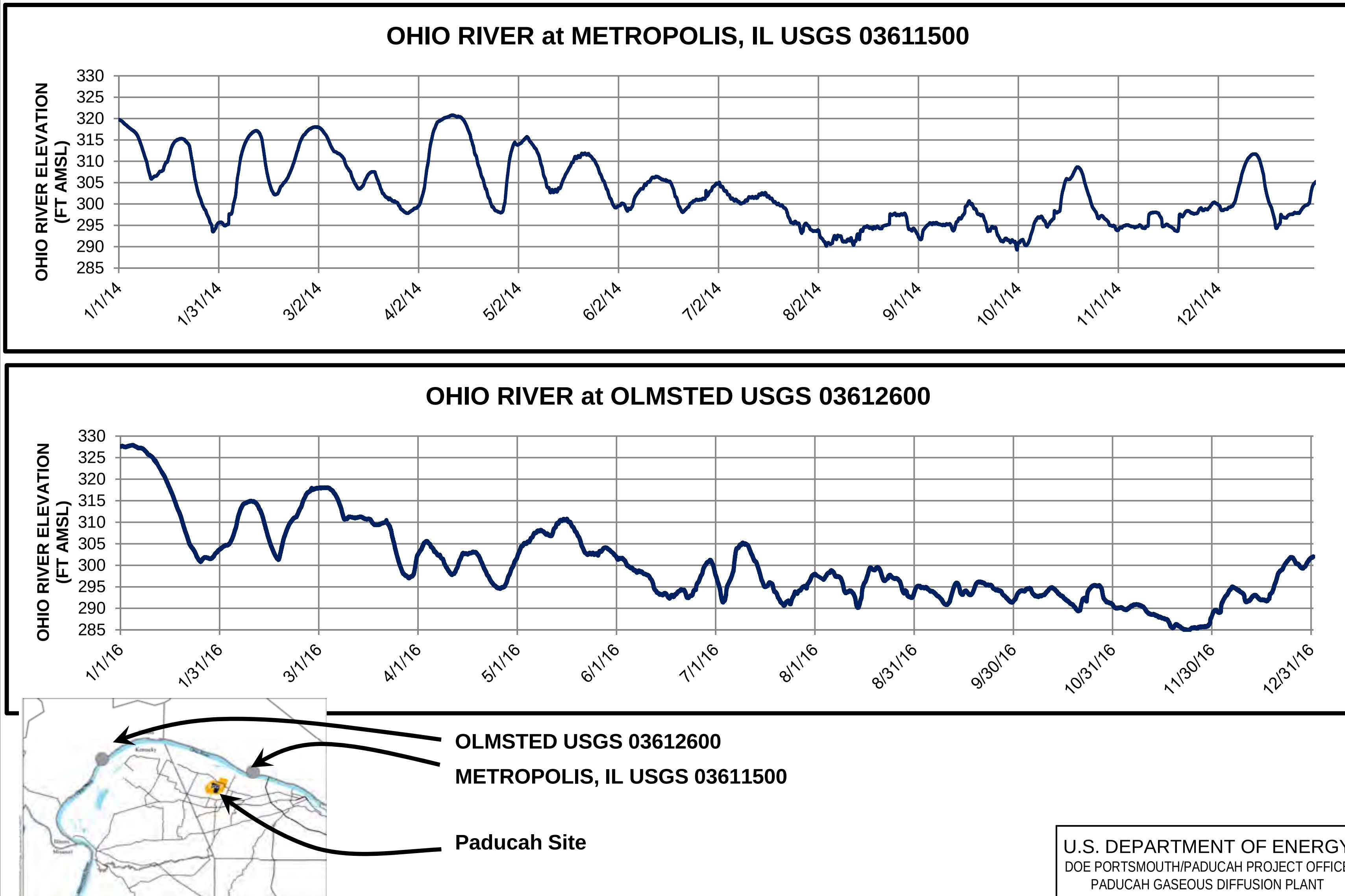

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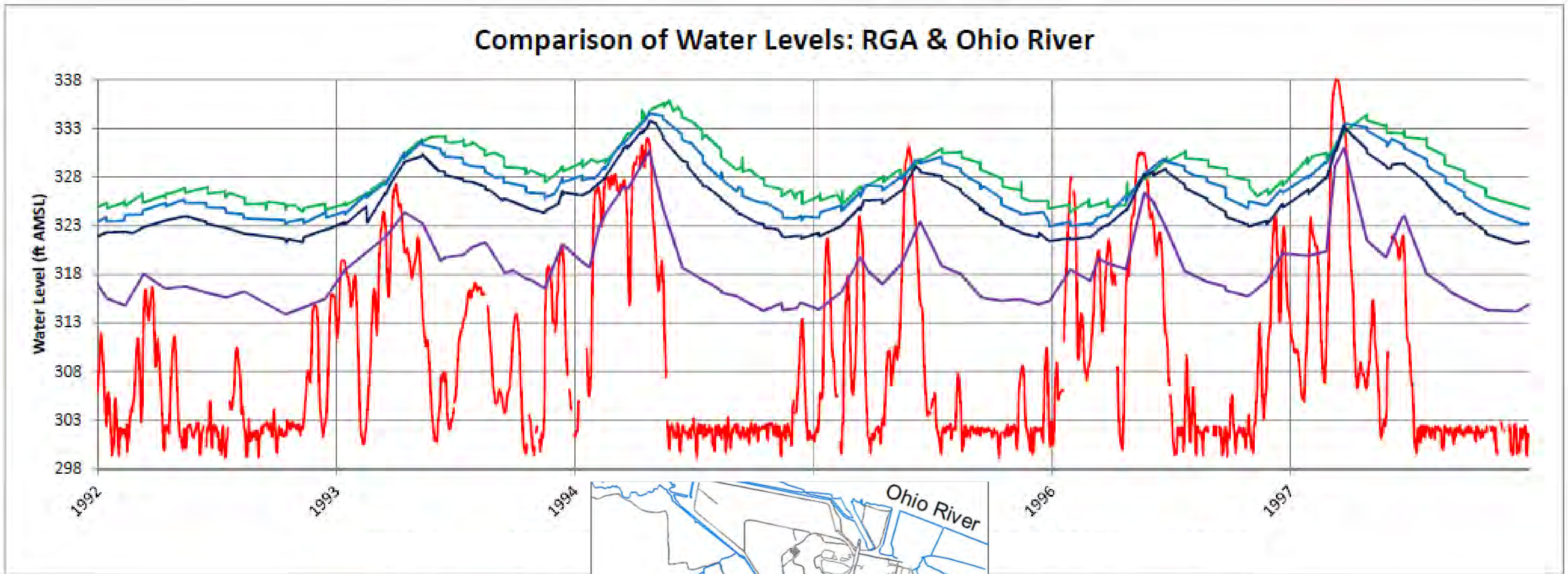
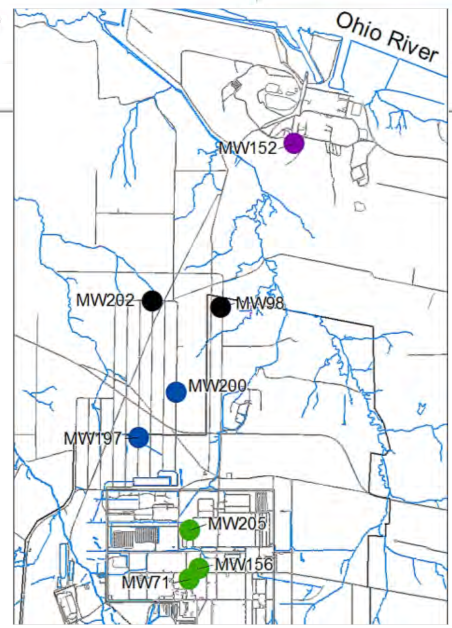
Figure 2. Ohio River Hydrographs Near the Paducah Site for Calendar Years 2014 and 2016





MW71 & MW156 & MW205 — MW197 & MW200 — MW98 & MW202 — MW152 — Ohio River

- Groundwater monitoring well located ~4,000 ft from Ohio River
- Groundwater monitoring wells located ~10,000 ft from Ohio River
- Groundwater monitoring wells located ~13,500 to 15,000 ft from Ohio River
- Groundwater monitoring wells located in Paducah Site limited area (~18,000 to 20,000 ft from Ohio River)

The Ohio River hydrograph represents water level measurements by the U.S. Geological Survey for the *Ohio River at Paducah, Kentucky* (station USGS 03611000). The U.S. Army Corps of Engineers Locks and Dam Number 52, located between Paducah, Kentucky (upstream) and the PGDP (downstream) maintains a low Ohio River stage of approximately 302 ft amsl at Paducah, Kentucky. Ohio River stage less than 302 ft amsl near PGDP is not represented on the hydrograph. The Ohio River stage declines to as low as 290 ft amsl (as measured by station USGS 03611500, *Ohio River at Metropolis, Illinois*, for the years 2010 through 2015).

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Figure 3. Transect of Ohio River and RGA Hydrographs, 1992 through 1997

MW156, and MW205; located 18,000 to 20,000 ft from the Ohio River), for the time period 1992 through 1997, including instantaneous water level measurements (different days) in multiple adjacent MWs wells to simulate a near-continuous water level record[3].

MONITORING WELL SELECTION

The Model Working Group proposes two transects of wells, one each along the central axis of the Northeast and Northwest TCE Plumes, and two wells located in the groundwater divide between the plumes.

Relative Location	Northeast Plume Transect			Northwest Plume Transect			Central	
	Monitoring Well	Screened Interval[1]		Monitoring Well	Screened Interval		Monitoring Well	Screened Interval
North	MW473	LRGA		MW152	LRGA			
	MW474	LRGA		MW445	MRGA			
	MW465	MRGA		MW491	MRGA			
	MW485	MRGA		MW459	URGA		MW353	MRGA
South	MW145	LRGA		MW262	LRGA		MW71	URGA

[1]URGA = Upper RGA (elevation 320 to 305 ft amsl), MRGA = Middle RGA (elevation 305 top 295 ft amsl), LRGA = Lower RGA (elevation 295 to 250 ft amsl)

Where RGA well clusters were present at a desired monitoring location in the two plume transects, the shallower well was selected, to best monitor for anthropogenic impact on the water levels. In the case of the northern-most location of the Northeast Plume transect, both available RGA wells were included to monitor for transient vertical hydraulic gradients in the vicinity of Metropolis Lake.

In addition to monitoring longitudinal trends along the axis of the plume from near the Ohio River to the Paducah Site area, continuous water level records for these monitoring wells will addresses Ohio River bank storage impacts to the RGA (MW152, MW473, and MW474) and variable anthropogenic contribution in the industrial sector of the Paducah site (MW145 and MW262), as well as trends in the groundwater divide between the two TCE plumes (MW71 and MW353). Water level measurements in each of these groundwater MWs as part of the annual synoptic water level data set demonstrate that these groundwater MWs are in good hydraulic connection with the RGA and will provide area-representative water level trends.

Figure 4 maps the locations of the proposed groundwater MWs to be included in this RGA water level monitoring network. A start of continuous water level monitoring in 2018 would provide for a year's record prior to operation of the Olmsted Locks and Dam, now projected to commence in 2020. Once the Olmsted Locks and Dam are operational, the low river stage near the Paducah Site will be increased 7 ft to 12 ft, reducing the range of the annual Ohio River stage flux and reducing the benefit of the continuous water level record. The "before Olmsted" data will provide a best basis for assessment of the storativity of the RGA and bank storage near the Ohio River (required for transient groundwater flow modeling).

[3] Water level measurements, as elevation, were combined in an Excel™ file for RGA well groupings: 1) MW98 and MW202; 2) MW197 and MW200; and 3) MW71, MW156, and MW205 to create water level records with sufficient measurements to graph as a hydrograph for the area represented by each of the 3 well groupings.

REFERENCES

DOE 2017. *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, DOE/LX/07-2415&D2, U.S. Department of Energy, Paducah, KY, July.

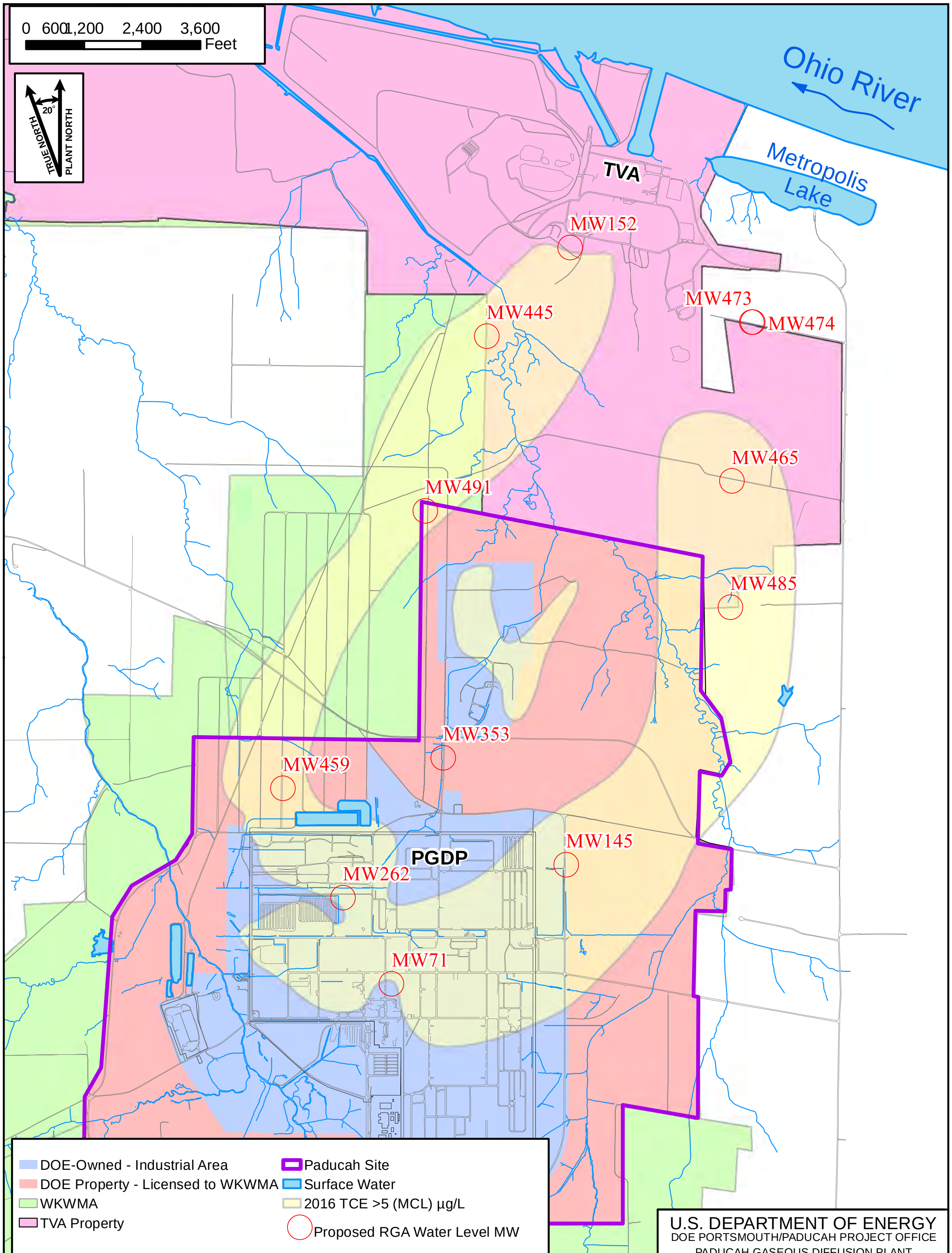

Figure 4. Candidate Continuous Water Level Monitoring Locations

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ATTACHMENT 3

Measurement of Hydraulic Conductivity in the Regional Gravel Aquifer Using Monitoring Wells at the Paducah Site

DRAFT

MEASUREMENT OF HYDRAULIC CONDUCTIVITY IN THE REGIONAL GRAVEL AQUIFER USING MONITORING WELLS AT THE PADUCAH SITE

Slug tests were performed in 29 monitoring wells (MWs) at the Paducah Site[1] as part of the Phase I and Phase II Site Investigations (CH2M HILL 1991; CH2M HILL 1992). Twenty of the slug tests were in Regional Gravel Aquifer (RGA) wells inside the Limited Area, where additional measurements of RGA hydraulic conductivity would benefit the sitewide groundwater flow model. Phase I slug test data were analyzed using the computer program SLUGCON (CH2M HILL 1985), especially adapted for confined aquifers using the Hvorslev equation (Hvorslev 1951) and appropriate shape factors. Phase II slug test data were analyzed using the computer program AQTESOLV™ (Geraghty & Miller 1985) and by the method of Bouwer and Rice (1976), developed for partially penetrating and partially screened groundwater wells in unconfined aquifers, and by the method of Cooper-Bredehoeft-Papadopulos (1967), developed to analyze groundwater wells screened in confined aquifers. Table 1 summarizes the results of the Phase I and Phase II slug test analyses.

Subsequently, the Paducah Site Environmental Restoration Program contracted with LeAnne Kilby and Dr. Cary McConnell of the University of Missouri at Rolla to perform a re-evaluation of some of the slug tests (Kilby and McConnel 1993). The reevaluation assessed the Phase I and II Site Investigations slug test data using two analytical methods, those of Hvorslev (Fetter 1988) and that of Nguyen and Pinder (1984), and also using the Well Hydraulics Interpretation Program (WHIP) (Hydro Geo Chem, Inc. 1988). Table 1 includes the reevaluation results. The reevaluation found no correlation of results between any of the slug test interpretation methods, as well as found no correlation of any of the slug test interpretation results with previous site pumping test results. Consequently, slug test results have been used only cautiously to evaluate the hydraulic conductivity of the RGA at the Paducah Site.

Slug testing was used in December 2015 and January 2016 for the Remedial Investigation of Solid Waste Management Unit 4 (DOE 2017a). Results were less than 50 ft/day ($< 1.8 \times 10^{-2}$ cm/sec), which is lower than expected for the RGA, based on prior investigations. The results may be biased by near-well conditions (e.g., the filter pack and MW bore); large in-well storage typical of MWs; and formation damage (skin damage) that was not corrected during MW development.

The Paducah Site currently has 169 RGA MWs and piezometers with well screens of 2-ft length or greater installed and maintained under various programs and within or close to the Limited Area. The *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model* (DOE 2017b) includes a recommendation to perform additional slug testing on a selection of appropriate MWs to define better the hydraulic conductivity of the RGA within the Limited Area. This white paper identifies slug test methods and criteria for selecting test wells if a program of slug testing is implemented. In addition, this white paper provides a brief summary of alternative methods that are applicable to the existing MWs to attempt to measure hydraulic conductivity of the RGA.

[1] References in this report to the Paducah Site generally mean the property, programs, and facilities at or near Paducah Gaseous Diffusion Plant for which the U.S. Department of Energy (DOE) has ultimate responsibility. The Paducah Site is located in a generally rural area of McCracken County, Kentucky, 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River. The plant is on a 3,556-acre DOE site comprised of the following: 628 acres within a fenced security area, 806 acres located outside the security fence, 133 acres in acquired easements, and the remaining 1,986 acres licensed to the Commonwealth of Kentucky as part of the West Kentucky Wildlife Management Area.

Table 1. Paducah Site Slug Test Results

Well/ Test ID	Location	Sand Pack Interval	Site Investigation Slug Test			Slug Test Reevaluation		
			Test Method*	K (cm/sec)		K (cm/sec)		
						Hvorslev	Nguyen & Pinder	WHIP
MW53 (inside Limited Area)								
MW53 RHT1	Lower RGA (LRGA)	61 - 73	DC	5.23E-02				
MW53 RHT2				3.69E-02				
MW53 RHT3				6.22E-02				
MW53 FHT1				1.06E-01				
MW53 FHT2				8.16E-02				
MW54 (inside Limited Area)								
MW54 RHT1	Upper RGA (URGA)	55 - 74	DC	2.17E-03				
MW54 RHT2				1.78E-03				
MW54 FHT1				2.54E-03				
MW54 FHT2				3.31E-03				
MW65 (inside Limited Area)								
MW65 RHT1	LRGA	85 - 94	PDD	2.51E-02				
MW65 RHT2				4.24E-02				
MW68 (inside Limited Area)								
MW68 RHT1	LRGA	95 - 109	PDD	4.67E-02		3.80E-01	7.14E+00	
MW68 RHT2				3.51E-02		3.14E-01	1.07E+00	1.37E-02
MW79 (inside Limited Area)								
MW79 RHT1	URGA	63 - 91	DC	4.14E-02		6.61E-02	2.99E-02	
MW79 RHT2				4.51E-02		6.61E-02	2.52E-02	3.24E-03
MW79 FHT1				3.45E-02		7.30E-02	5.16E-02	
MW79 FHT2				3.23E-02		7.05E-02	2.33E-02	
MW79 FHT3				3.08E-02			1.41E-02	
MW80 (inside Limited Area)								
MW80 RHT1	URGA	63 - 87	PDD	1.41E-02		1.40E-01	5.12E-02	
MW80 RHT2				3.85E-03		1.14E-01	4.13E-02	1.24E-02
MW81 (inside Limited Area)								
MW81 RHT1	URGA	63 - 87	PDD	1.03E-02		1.35E-01	2.27E-02	
MW81 RHT2				7.89E-03		1.03E-01	1.16E-03	4.80E-03
MW123 (outside Limited Area)								
MW123 RHT1	URGA	59 - 73	PDD	2.86E-04				
MW123 RHT2				2.19E-04				
MW124 (outside Limited Area)								
MW124 RHt1	LRGA	77 - 93	PDD	2.82E-03				
MW124 RHT2				2.35E-03				
*DC = displacement cylinder, PDD = pneumatic displacement device								

Table 1. Paducah Site Slug Test Results (Continued)

Well/ Test ID	Location	Sand Pack Interval	Site Investigation Slug Test		Slug Test Reevaluation		
			Test Method*	K (cm/sec)	K (cm/sec)		
					Hvorslev	Nguyen & Pinder	WHIP
MW125 (outside Limited Area)							
MW125 RHT1	LRGA	76 - 88	PDD	8.57E-03			
MW125 RHT2				7.08E-03			
MW126 (outside Limited Area)							
MW126 RHT1	URGA	52 - 65	PDD	1.80E-02			
MW126 RHT2				1.56E-02			
MW155 (inside Limited Area)							
MW155 RHT1	LRGA	82 - 95	PDD	4.76E-03	5.07E-01	1.14E-01	
MW155 RHT2				4.96E-03	6.44E-01	1.12E-01	1.59E-04
MW155 RHT3				3.53E-03	6.66E-02	8.28E-02	
MW156 (inside Limited Area)							
MW156 RHT1	URGA	61 - 75	PDD	3.31E-03			
MW156 RHT2				3.20E-03			
MW156 RHT3				3.17E-03			
MW158 (inside Limited Area)							
MW158 RHT1	LRGA	97 - 110	PDD	2.25E-04	2.90E-03	2.15E-03	1.59E-04
MW158 RHT2				2.16E-04	2.68E-03	2.94E-03	
MW159 (inside Limited Area)							
MW159 RHT1	URGA	58 - 70	PDD	3.95E-03	1.07E-01	9.96E-02	
MW159 RHT2				4.00E-03	1.10E-01	1.17E-01	
MW159 RHT3				3.93E-03	1.01E-01	7.19E-02	2.19E-03
MW161 (inside Limited Area)							
MW161 RHT1	URGA	73 - 85	PDD	2.61E-02	3.88E-01	1.29E-01	
MW161 RHT2				2.63E-02	6.29E-01	5.01E-02	
MW161 RHT3				1.76E-02	4.29E-01	2.37E-01	8.82E-03
MW163 (inside Limited Area)							
MW163 RHT1	URGA	87 - 100	PDD	4.76E-02	3.43E-01	2.21E-01	
MW163 RHT2				3.20E-02	4.36E-01	1.60E-01	
MW163 RHT3				6.13E-03	4.29E-01	1.82E-01	1.76E-02
MW165 (inside Limited Area)							
MW165 RHT1	URGA	58 - 70	PDD	7.83E-03	3.03E-01	1.51E-01	
MW165 RHT2				5.90E-03	1.45E-01	8.24E-02	3.74E-03
MW165 RHT3				5.99E-03	1.40E-01	1.76E-01	
*DC = displacement cylinder, PDD = pneumatic displacement device							

Table 1. Paducah Site Slug Test Results (Continued)

Well/Test ID	Location	Sand Pack Interval	Site Investigation Slug Test			Slug Test Reevaluation		
						K (cm/sec)		
			Test Method*	K (cm/sec)		Hvorslev	Nguyen & Pinder	WHIP
MW168 (inside Limited Area)								
MW168 RHT1	URGA	58 - 70	PDD	2.66E-04		6.90E-03	2.87E-02	2.90E-04
MW168 RHT2				4.55E-03		2.11E-01	6.64E-02	
MW169 (inside Limited Area)								
MW169 RHT1	URGA	59 - 70	PDD	5.74E-03		1.41E-01	4.46E-02	
MW169 RHT2				7.12E-03		1.37E-01	8.84E-02	2.88E-03
MW169 RHT3				7.06E-03		2.47E-03	1.17E-03	
MW175 (inside Limited Area)								
MW175 RHT1	URGA	68 - 80	PDD	3.12E-02		4.29E-01	3.14E-01	
MW175 RHT2				3.09E-02		4.58E-01	1.52E-01	
MW175 RHT3				2.95E-02		4.90E-01	1.50E-01	1.76E-03
MW178 (inside Limited Area)								
MW178 RHT1	URGA	56 - 69	PDD	2.15E-02		3.06E-01	1.41E-01	
MW178 RHT2				2.06E-02		3.43E-01	1.30E-01	
MW178 RHT3				1.89E-02		3.43E-01	1.23E-01	7.20E-03
MW188 (inside Limited Area)								
MW188 RHT1	URGA	60 - 75	PDD	5.16E-02				
MW188 RHT2				3.08E-02				
MW188 RHT3				4.56E-02				
MW191 (outside Limited Area)								
MW191 RHT1	URGA	50 - 61	PDD	2.17E-02				
MW191 RHT2				1.66E-02				
MW191 RHT3				3.02E-02				
MW193 (outside Limited Area)								
MW193 RHT1	URGA	58 - 70	PDD	8.61E-03				
MW193 RHT2				3.77E-03				
MW193 RHT3				4.11E-03				
MW194 (outside Limited Area)								
MW194 RHT1	URGA	42 - 53	PDD	1.51E-02				
MW194 RHT2				1.67E-02				
MW194 RHT3				1.70E-02				
MW197 (outside Limited Area)								
MW197 RHT1	URGA	53 - 65	PDD	2.13E-04				
MW197 RHT2				2.24E-04				
*DC = displacement cylinder, PDD = pneumatic displacement device								

Table 1. Paducah Site Slug Test Results (Continued)

Well/ Test ID	Location	Sand Pack Interval	Site Investigation Slug Test			Slug Test Reevaluation		
						K (cm/sec)		
			Test Method*	K (cm/sec)		Hvorslev	Nguyen & Pinder	WHIP
MW200 (outside Limited Area)								
MW200 RHT1	URGA	69 - 80	PDD	5.81E-03				
MW200 RHT2				5.65E-03				
MW200 RHT3				4.08E-03				
MW201 (outside Limited Area)								
MW201 RHT1	URGA	57 - 70	PDD	3.70E-05				
MW201 RHT2				3.26E-05				
MW202 (outside Limited Area)								
MW202 RHT1	URGA	72 - 85	PDD	1.43E-04				
MW202 RHT2				1.38E-04				
MW203 (inside Limited Area)								
MW203 RHT1	URGA	68 - 80	PDD	2.39E-04		1.01E-02	2.61E-02	3.39E-04
MW203 RHT2				1.95E-04		4.97E-03	8.20E-03	
*DC = displacement cylinder, PDD = pneumatic displacement device								

SLUG TEST METHOD

Slug tests consists of adding or removing a measured quantity of water from a groundwater well rapidly, followed by a quick series of water level measurements to assess the rate of water level recovery. Falling head tests involve the addition of water to a groundwater well; rising head tests involve the removal of water, either by instantaneously bailing water from the groundwater well of by displacing initially the water back into the aquifer by means of a weighted cylinder or by pneumatic displacement. The results of either test approach can be used to evaluate the transmissivity and hydraulic conductivity of an aquifer.

Slug tests offer the following advantages:

- Relatively low cost;
- Requires little time for the field test; and
- Typically, little or no water is removed from the aquifer.

Slug test disadvantages include these:

- Evaluates only a small portion of the aquifer adjacent to the groundwater well bore; and

- May be influenced strongly by the groundwater well's gravel pack material in the borehole adjacent to the well screen.

The method of slug testing selected should be based on aquifer conditions. In highly conductive aquifers like the RGA, rising head tests conducted by pneumatic displacement of water within the groundwater well and using pressure transducer measurements and a data logger are the industry standard and have proven effective at the Paducah Site.

In higher conductivity aquifers, such as the RGA, an industry standard quality control check is to repeat the test 2 or 3 times with different volumes of slugs (the volume of displaced water during a pneumatic-displacement-rising-head test is equal to “the slug”). The MW well can be assumed to be developed adequately and the slug test results predictive if all of the estimated hydraulic conductivity values are similar.

The appropriate analytical method for processing the field data is dependent upon aquifer conditions and on the slug test response. The Phase I and Phase II Site Investigations slug tests consistently demonstrated an overdamped response.[2] Analytical methods for overdamped responses include the method of Bouwer and Rice (1976) for unconfined aquifers; and the methods of Hvorslev (1951), Cooper, Bredehoeft, and Papadopulos (1967), and Van der Kamp (1976) for confined aquifers.

DATA ANALYSIS

The U.S. Geological Survey Open-File Report 02-197, *Documentation of Spreadsheets for the Analysis of Aquifer-Test and Slug-Test Data* (Halford and Kuniansky 2002) provides an Excel™ format for analyzing slug test data using the methods of Bouwer and Rice (1976); Cooper, Bredehoeft, and Papadopulos (1967); and Van der Kamp (1976). Although several macros in the spreadsheets are incompatible with recent versions of Excel™, approximate results can be obtained by manual, iterative replacement of formula variables and visual curve matching. The industry standard for analyzing slug test data is the use of computer programs to optimize the variable input values and slug test results. AQTESOLV™ (HydroSOLVE 2017) is a common program used for slug test and aquifer test analysis.

TEST WELLS

The Paducah Site contains 169 MWs and piezometers within and close to the site Limited Area with screens in the RGA that may be suitable for slug testing (Figure 1). Screen lengths range from 2 ft to 30 ft. The median screen length is 10 ft. Excluding the previously tested 16 MWs in the Limited Area (four of the orignial 20 tested MWs have been abandoned) and five compliance MWs that are unavailable for testing, 148 MWs and piezometers remain available for slug tests.

Slug tests results are more definitive for groundwater wells and peizometers of shorter screen length. The candidate MWs and piezometers include 15 MWs with screens of 2-ft length (all located near the northwest corner of C-400) and 46 MWs with screens of 5-ft length (Figure 2 and Table 2). These MWs offer good distribution across the site Limited Area and depth below ground surface.

The results of slug testing are significantly impacted by groundwater well conditions. Because most of the candidate MWs and peizometers are older, downhole inspection and development should be included in a slug testing program at the Paducah Site. Recent downhole video inspections of a small set of older on-site MWs with stainless steel construction revealed significant corrosion of the MWs casings. Pneumatic displacement for slug testing might further damage compromised MWs; these MWs would be excluded from testing. Furthermore, well development may provide indications of MWs that are not aequate/optimal for slug testing by revealing MWs in poor hydraulic connection with the RGA.

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[2] Overdamped responses are non-oscillatory and are common to settings of low to moderate hydraulic conductivity.

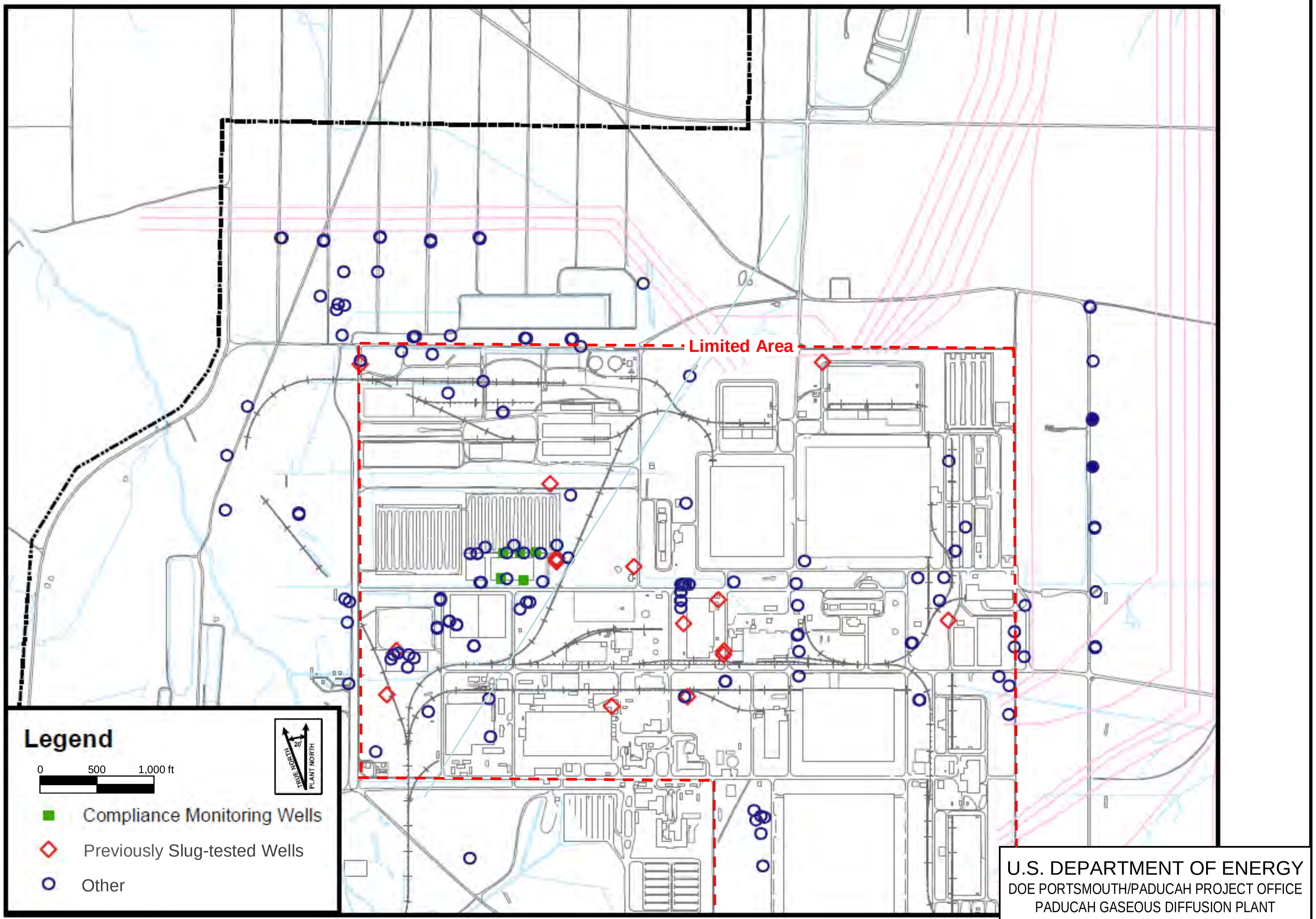

Figure 1. RGA Groundwater Monitoring Wells and Piezometers Within and Near the Limited Area

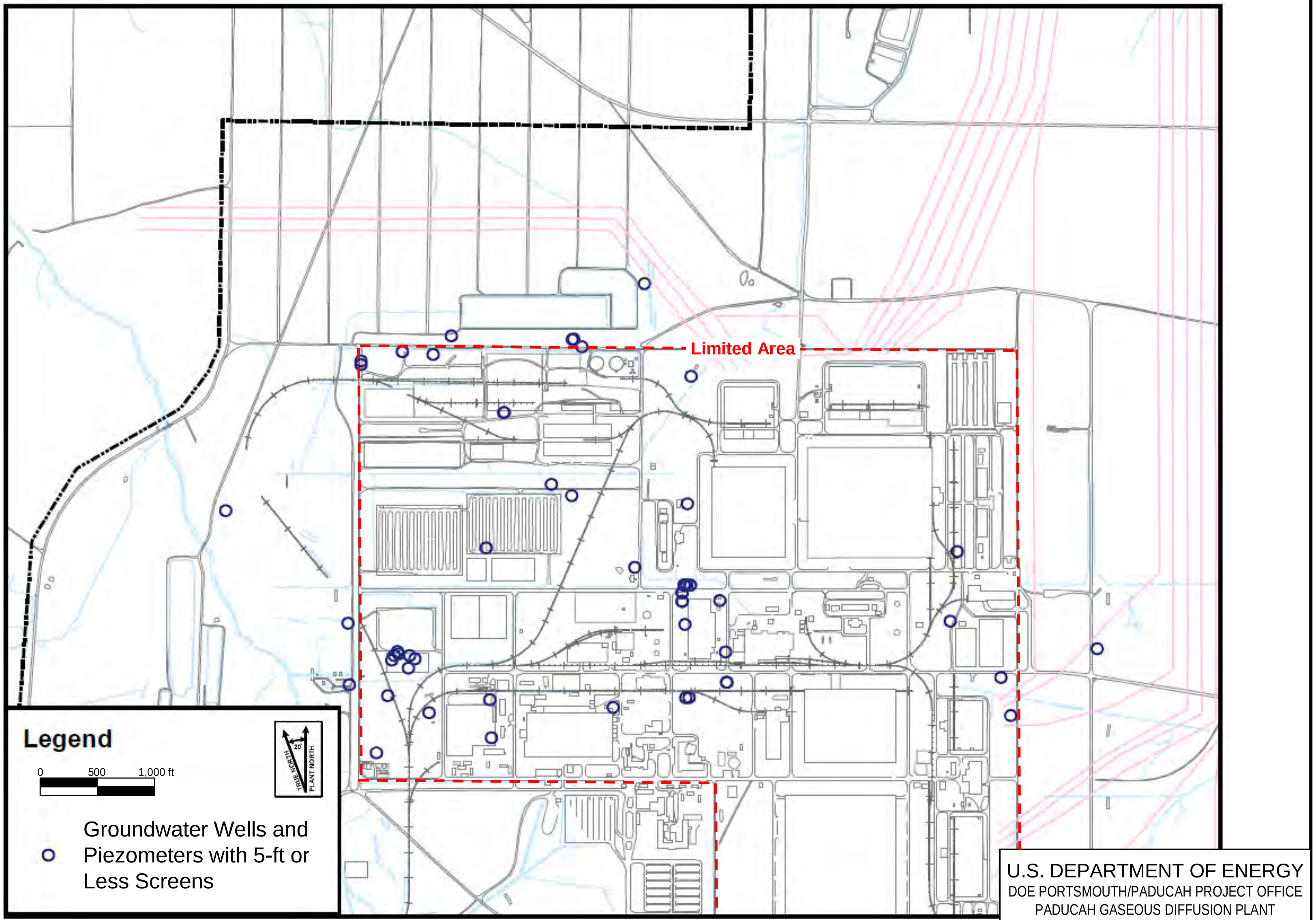

Figure 2. Candidate RGA Groundwater Monitoring Wells and Piezometers for Slug Testing Within and Near the Limited Area

Table 2. Candidate RGA Groundwater Monitoring Wells and Piezometers for Slug Testing

Well/Piezometer ID	Depth (ft) Top of Screen	Depth (ft) Base of Screen	X	Y	Screen Length (ft)	Average Scrreh Depth (ft)		Well/Piezometer ID	Depth (ft) Top of Screen	Depth (ft) Base of Screen	X	Y	Screen Length (ft)	Average Scrreh Depth (ft)
MW63	58.5	63.5	-7235.47	894.86	5.00	61.00		PZ349	48	53	-4738.76	1578.40	5.00	50.50
MW65	86.2	91.2	-7234.66	864.77	5.00	88.70		PZ351	48	53	-6439.40	1117.38	5.00	50.50
MW66	55.2	60.2	-6872.20	977.88	5.00	57.70		MW354	65	70	-8429.10	-424.58	5.00	67.50
MW67	65.3	70.3	-6133.95	-755.17	5.00	67.80		MW355	85	90	-4327.77	761.50	5.00	87.50
MW68	97.4	102.4	-4343.27	-2073.96	5.00	99.90		MW421-PRT1	71.0	73.0	-4335.15	-1082.85	2.00	72.00
MW71	67.1	72.1	-4372.95	-2073.76	5.00	69.60		MW421-PRT2	79.0	81.0	-4335.15	-1082.85	2.00	80.00
MW155	87	92	-4024.61	-1669.36	5.00	89.50		MW421-PRT3	83.0	85.0	-4335.15	-1082.85	2.00	84.00
MW161	78	83	-6916.32	-1666.84	5.00	80.50		MW422-PRT1	71.0	73.0	-4365.38	-1082.64	2.00	72.00
MW163	94	99	-2040.65	-1400.72	5.00	96.50		MW422-PRT2	79.0	81.0	-4365.38	-1082.64	2.00	80.00
MW168	63	68	-4821.93	-924.83	5.00	65.50		MW422-PRT3	83.0	85.0	-4365.38	-1082.64	2.00	84.00
MW169	65	70	-5557.36	-191.65	5.00	67.50		MW423-PRT1	70.8	72.8	-4389.12	-1082.80	2.00	71.83
MW173	53	58	-5289.60	1020.07	5.00	55.50		MW423-PRT2	78.8	80.8	-4389.12	-1082.80	2.00	79.83
MW175	75	80	-4378.81	-1428.36	5.00	77.50		MW423-PRT3	82.8	84.8	-4389.12	-1082.80	2.00	83.83
MW178	62.5	67.5	-4073.60	-1216.20	5.00	65.00		MW424-PRT1	71.0	73.0	-4404.38	-1149.40	2.00	72.00
MW185	68	73	-6601.51	952.60	5.00	70.50		MW424-PRT2	79.0	81.0	-4404.38	-1149.40	2.00	80.00
MW188	70	75	-7000.30	-2057.27	5.00	72.50		MW424-PRT3	83.0	85.0	-4404.38	-1149.40	2.00	84.00
MW203	71	76	-5014.24	-2159.19	5.00	73.50		MW425-PRT1	71.0	73.0	-4406.99	-1224.96	2.00	72.00
MW205	65	70	-4359.66	-364.19	5.00	67.50		MW425-PRT2	79.0	81.0	-4406.99	-1224.96	2.00	80.00
MW255	91	95.7	-1510.20	-2230.01	4.70	93.35		MW425-PRT3	83.0	85.0	-4406.99	-1224.96	2.00	84.00
MW256	100.2	104.9	-1596.27	-1896.29	4.70	102.55		MW503	83.6	88.6	-5360.43	1088.30	5.00	86.10
MW257	71.2	75.9	-5971.59	442.62	4.70	73.55		MW504	50.9	55.9	-5376.34	1084.73	5.00	53.40
MW258	89.2	93.9	-745.03	-1643.31	4.70	91.55		MW505	65.0	70.0	-4012.90	-1939.50	5.00	67.50
MW260	93.2	97.9	-1981.91	-785.46	4.70	95.55		MW506	77.0	82.0	-4012.90	-1939.50	5.00	79.50
MW261	90	94.7	-5978.62	442.53	4.70	92.35		MW507	90.0	95.0	-4012.90	-1939.50	5.00	92.50
MW262	90.2	94.9	-5379.82	-294.53	4.70	92.55		MW542	62.8	67.8	-6807.28	-1702.57	5.00	65.25
MW325	77.7	82.7	-6100.82	-2091.28	5.00	80.20		MW543	66.3	71.3	-6759.59	-1729.88	5.00	68.75
MW326	83	88	-6086.99	-2429.24	5.00	85.50		MW544	62.3	67.3	-6818.11	-1815.10	5.00	64.75
MW327	80.24	85.26	-7099.96	-2559.14	5.02	82.75		MW545	58.3	63.3	-6904.30	-1688.41	5.00	60.75
MW328	60	65	-7338.99	-1961.01	5.00	62.50		MW546	65.0	70.0	-6965.68	-1743.24	5.00	67.50
MW329	65	70	-7349.30	-1418.95	5.00	67.50		MW547	63.8	68.8	-6941.95	-1702.97	5.00	66.25
MW330	72	77	-6637.97	-2207.53	5.00	74.50								

ASSESSMENT OF SLUG TEST RESULTS

An optional step is to compare results of onsite slug testing against pumping test results for the same locations to assess the validity of slug test results. The Paducah Site includes two RGA pumping test locations with significantly different hydraulic conductivity that could be slug tested.

The location of the pumping test at the C-404 landfill (situated immediately east of the landfill) is an area where the RGA hydraulic conductivity is approximately 100 ft/day (3.5 x 10^{-2} cm/sec). Three MWs are candidates for slug testing (Figure 3):

- MW78, located 100 ft from the former pumping well, has a 10-ft length well screen;
- MW80 and MW81, included in previous slug testing efforts and located within 40 ft of the former pumping well, have 20-ft length well screens.

The pumping test located immediately west of the C-333 process building is an area where the RGA hydraulic conductivity is approximately 650 ft/day (2.3 x 10^{-1} cm/sec). Three piezometers are candidates for slug testing (Figure 3), each with 10-ft length piezometer screen:

- PZ109 and PZ110 are located within 60 ft of the former pumping well;
- PZ117 is located 79 ft from the former pumping well.

Comparison of results of slug testing in these two areas would indicate whether a program of slug testing has merit.

ALTERNATIVE TEST METHODS

In addition to slug testing, limited other single-well test methods are available for assessing the transmissivity and hydraulic conductivity of an aquifer and include the following technologies:

- Electromagnetic borehole flowmeter (requires the extraction of large volumes of groundwater or injection of large volumes of clean water);
- FLUTe transmissivity profile testing (offering limited resolution); and
- Straddle packer testing (requires the injection of water).

A common shortcoming of all single-well test methods is that the test only characterizes a limited depth of the aquifer and is strongly biased by the condition of the well. In cases where two MWs/piezometers are closer than 100 ft (a rare occurrence at the Paducah Site), an approach known as slug interference testing offers a hybrid method to provide characterization of the aquifer between the two MWs/piezometers. The method is outlined in *Applicability of Slug Interference Testing of Hydraulic Characterization of Contaminated Aquifer Sites* (Spane and Swanson, 1993) and involves assessing the arrival of a pressure wave in the distal groundwater MWs or piezometer for a pressure wave created by withdrawal of a slug in a groundwater MWs or piezometer. Slug interference testing benefits from the same advantages listed previously for traditional slug testing but the approach is less well documented for groundwater applications. GeoSierra, LLC, has further developed the approach, marketed as the hydraulic pulse interference test. In addition to characterizing a larger volume of the aquifer, the approach is valid for hydraulic conductivities as great as 3.3 × 10^{-1} cm/sec (935 ft/day) (Spane and Swanson 1993).

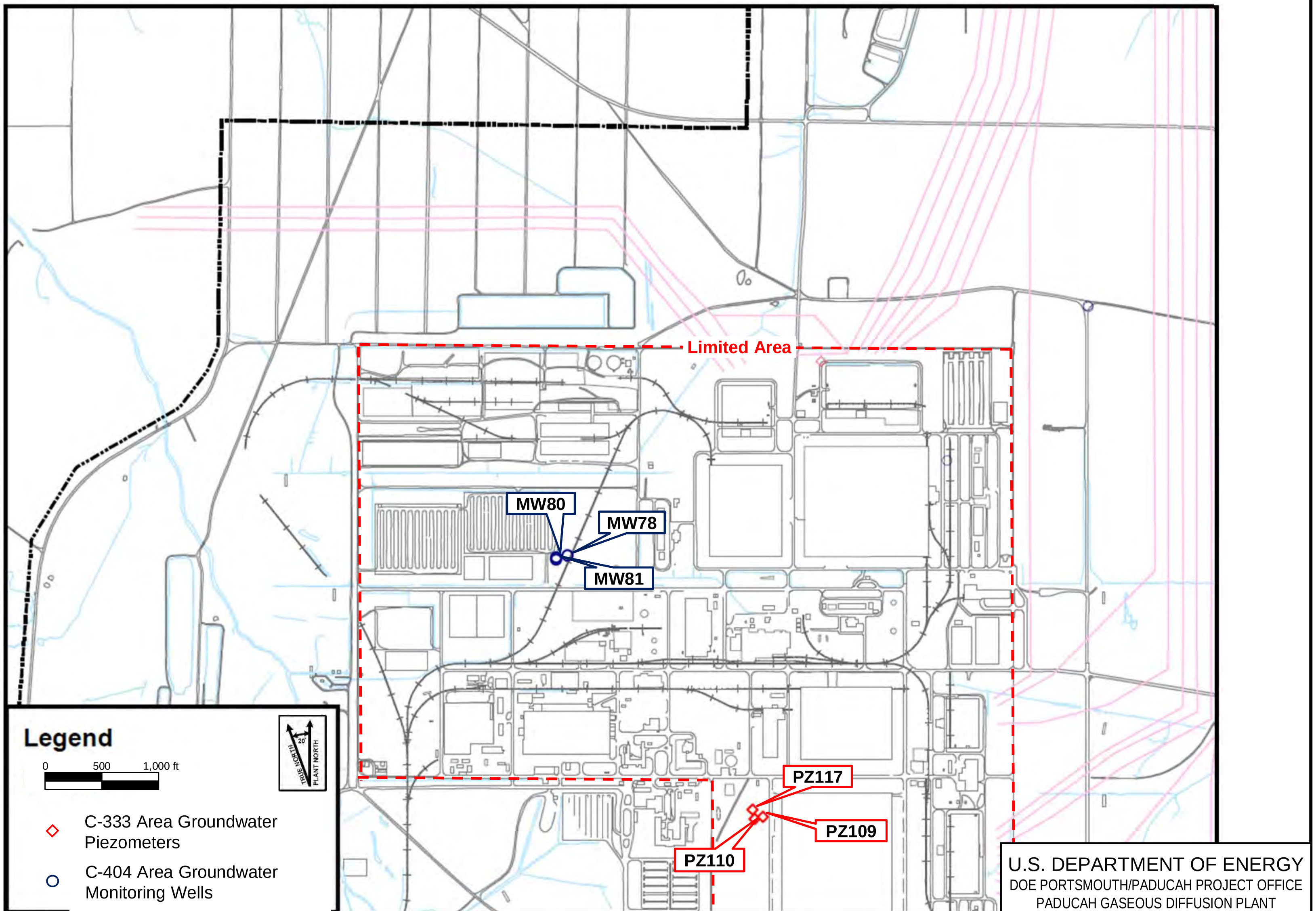

Figure 3. Location of Groundwater Monitoring Wells and Piezometers That Could be Used to Assess Slug Test Results in the RGA at the Paducah Site

Conventional slug tests can only assess hydraulic conductivities up to 8×10^{-2} cm/sec (225 ft/day) in a 30-ft thick aquifer (Ferris et al 1962; Lohman 1979).

CONCLUSION

The slug testing method is poorly matched to RGA conditions at the Paducah Site. The traditional slug test method is incapable of measuring higher hydraulic conductivities found in the RGA. Moreover, for a traditional slug test to be as representative as possible, most of the candidate groundwater MWs and piezometers would require redevelopment and an assessment of well/piezometer integrity prior to slug testing. While slug interference testing is capable of measuring higher hydraulic conductivity, it requires groundwater MW/piezometer pairs separated by less than 100-ft distance, an uncommon occurrence.

A more rigorous site assessment of the validity of slug tests in the RGA would be needed before the method could be considered for use at the Paducah Site.

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ATTACHMENT 4

Assessment of Sitewide Groundwater Flow Model Using Data from the Northeast Plume Optimization Project

DRAFT

Assessment of Sitewide Groundwater Flow Model Using Data from the Northeast Plume Optimization Project

The intent of this white paper is to summarize available and upcoming data from the Northeast Plume Optimization Project that can be used to assess the Paducah Site's current groundwater flow model documented in *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model* (DOE 2017a). The currently available data sets are the following:

- Quarterly (October 2016, January 2017, and April 2017) measurements of water level in a transect of Northeast Plume groundwater monitoring wells (MWs),
- A synoptic water level data set on July 3, 2017, for 53 groundwater MWs and piezometers of the optimized Northeast Plume interim remedial action, and
- Groundwater analyses from 32 of the same MWs.

Forthcoming data sets associated with the Northeast Plume Optimization Program that could be used for assessment of the current groundwater flow model include a hydraulic assessment of the optimized Northeast Plume groundwater extraction wells and recommended continuous monitoring of water level trends in the transect of Northeast Plume groundwater MWs (DOE 2017a).

Northeast Plume Transect Wells

A key initiative of the Northeast Plume Memorandum of Agreement (DOE 2015) was the installation and quarterly monitoring of a north-south transect of groundwater MWs located approximately 600 ft east of the C-400 Building (Figure 1). Construction and development of the transect of groundwater MWs, MW524 through MW530, was completed September 21, 2016. Quarterly sampling and water level measurements were performed in October 2016 and January, April, and July of 2017.

Figure 2 illustrates trends of the Regional Gravel Aquifer (RGA) water elevations from the quarterly water level measurements in the transect of groundwater MWs. Water elevations generally are highest and near uniform on the south half of the transect (MW527/MW528 through MW530) and consistently are lowest in the two north-most groundwater MWs (MW524 and MW525). The quarterly measurements document near-uniform water level fluctuations across the groundwater MW transect. (Continuous water level measurements in a few groundwater MWs would provide good representation of the entire transect length.)

Areal water level trends are delineated by the July 3, 2017, water level data set, when water levels were measured in 53 groundwater MWs and piezometers of the optimized Northeast Plume interim remedial action (Figures 3 and 4 and Table 1). These water level trends are consistent with those of synoptic water level measurements over the period August 22–24, 2017, taken from a sitewide set of groundwater MWs and piezometers. The RGA potentiometric contours indicate minimal groundwater flow east from C-400 and across the area of the transect of groundwater MWs.

Figure 5 summarizes trichloroethene (TCE) and technetium-99 (Tc-99) levels in water samples from the transect of monitoring wells over the four quarters. The analytical results consistently show highest TCE levels in MW525 (located east of the northeast corner of the C-400 Building). Higher Tc-99 levels are found in two areas: in MW526 (located east and south of the northeast corner of the C-400 Building) and in MW529 and MW530 (located east of the southeast corner of the C-400 Building).

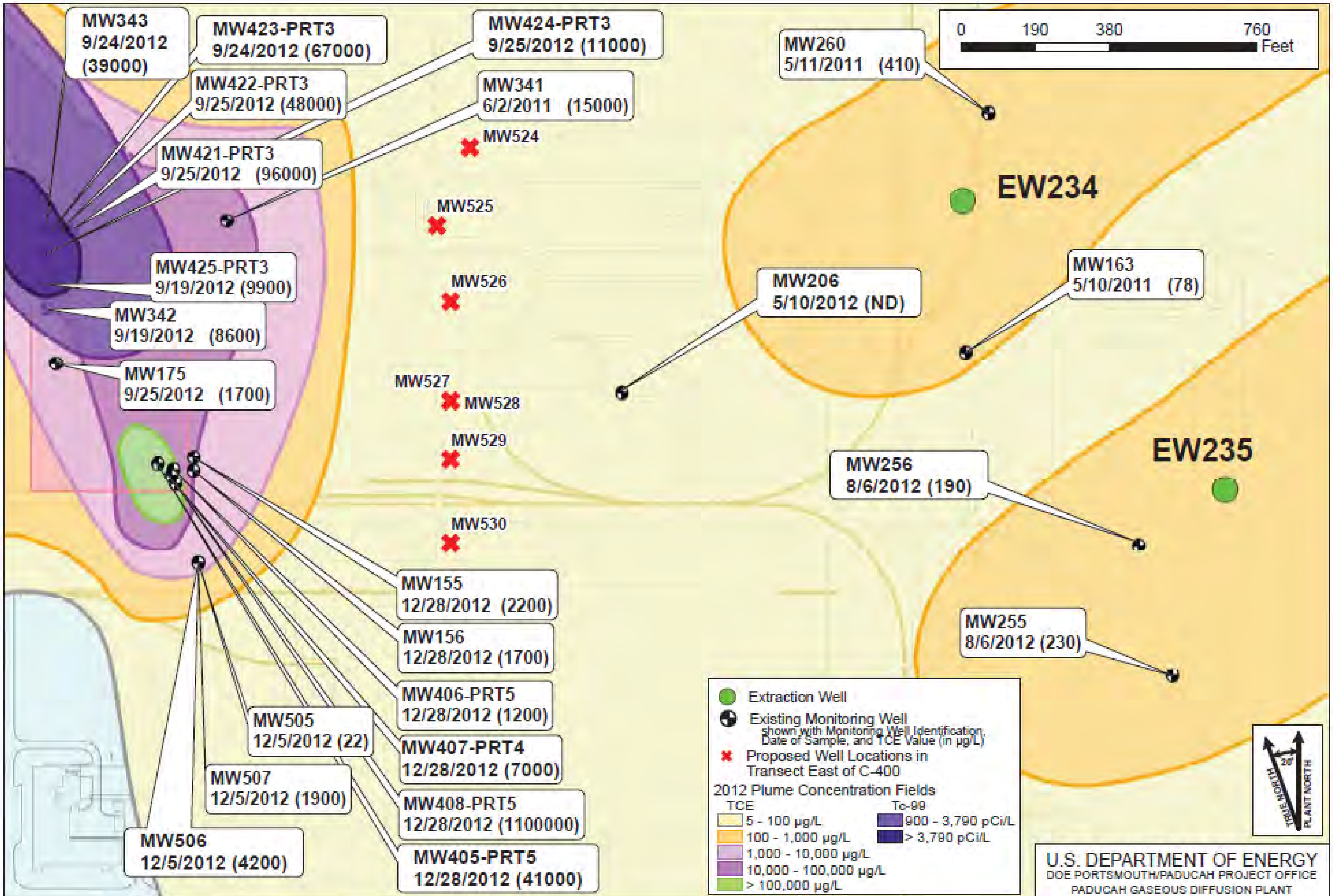

Figure 1. Transect Monitoring Well Locations East of C-400 (DOE 2016)

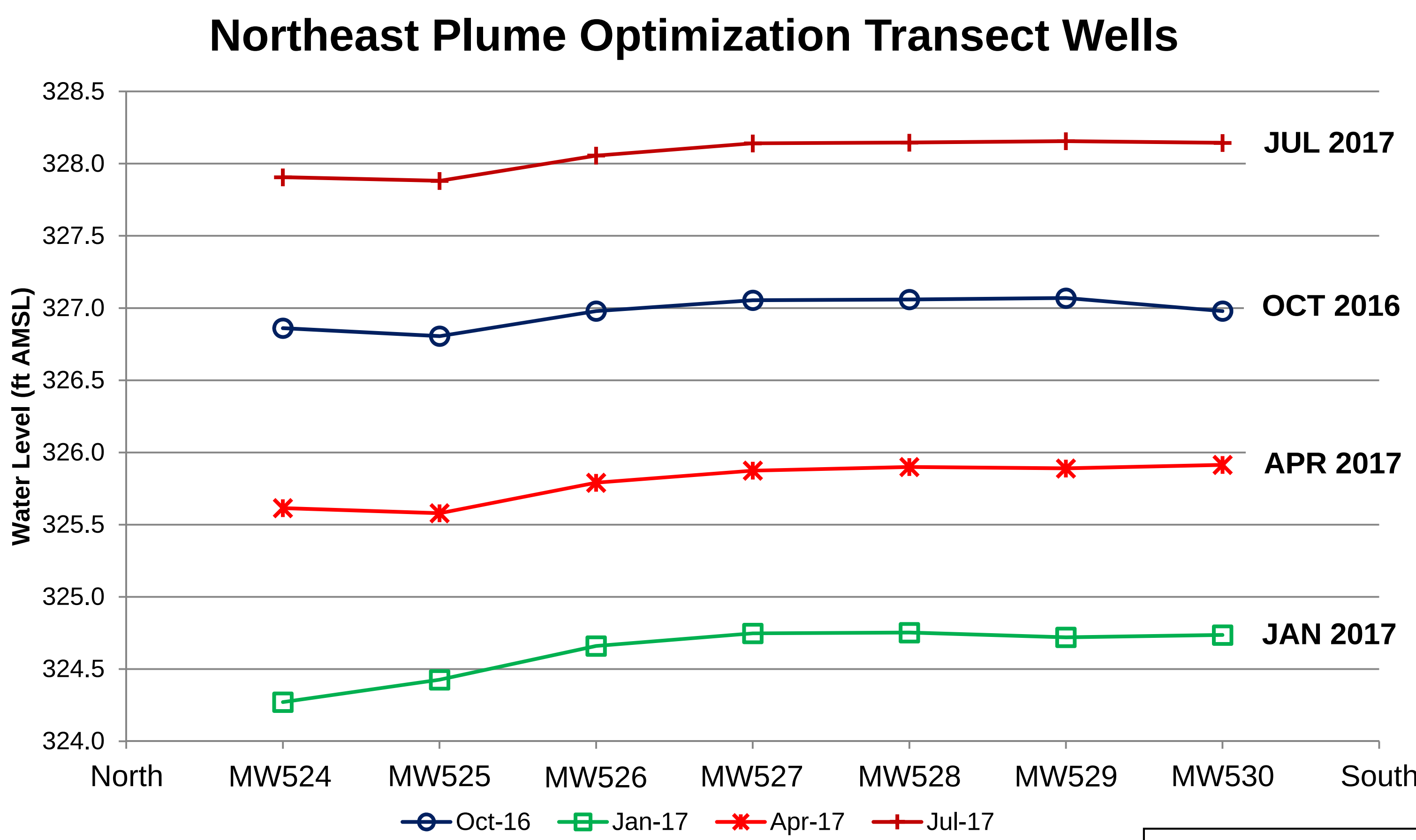

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Figure 2. RGA Water Level Trends in Northeast Plume Optimization Transect Wells

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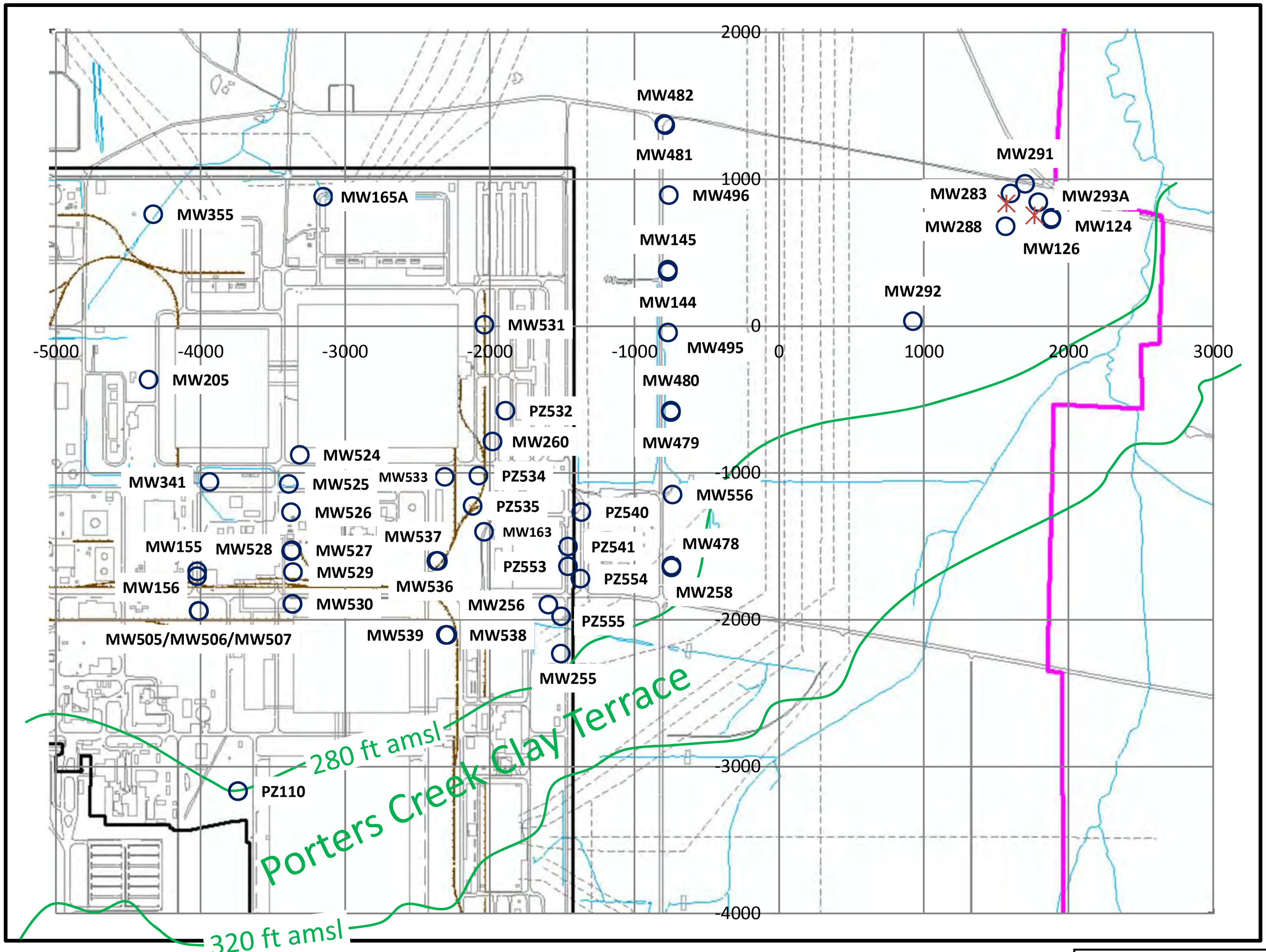

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Figure 3. Location of RGA Wells With July 3, 2017 Water Level Measurements

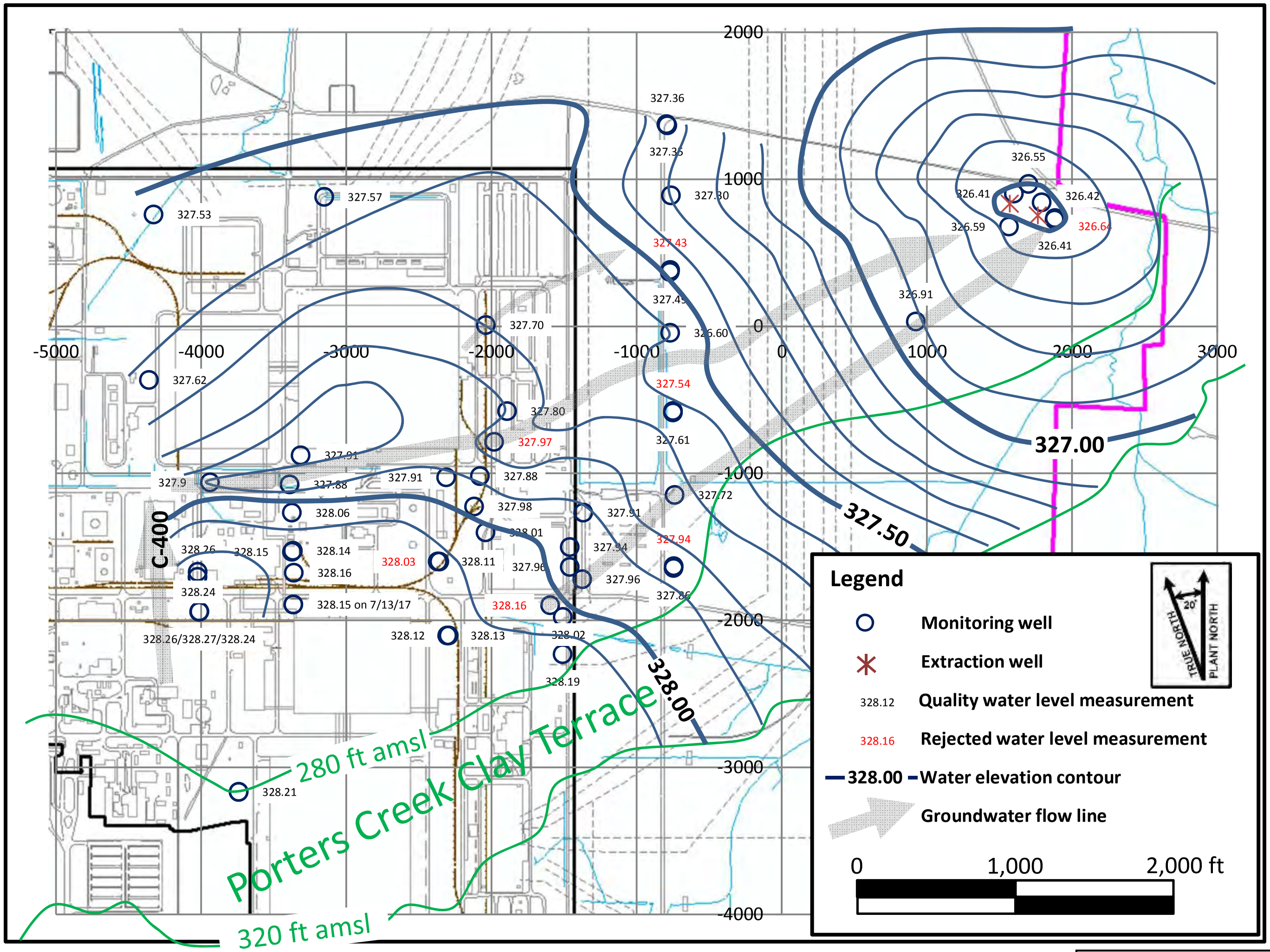

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Figure 4. July 3, 2017 RGA Potentiometric Surface

Table 1. RGA Water Level Measurements on July 3, 2017

	Well/ Piezometer	Reference Elevation (ft amsl)	Reference Point	Depth to Water (ft)	Barometric Pressure (in Hg)	Δ Barometric Pressure (ft H_2O)	Water Elevation (ft amsl)
	PZ110	385.92	Top of Inner Casing	57.71	30.06	0.00	328.21
7/13/2017	PZ110	385.92	Top of Inner Casing	57.79	30.12	-0.07	328.20
	MW124	365.40	Top of Outer Casing	38.76	30.06	0.00	~~326.64~~
	MW126	364.60	Top of Outer Casing	38.19	30.06	0.00	326.41
	MW144	380.62	Top of Outer Casing	53.13	30.06	0.00	327.49
	MW145	380.73	Top of Outer Casing	53.30	30.06	0.00	~~327.43~~
	MW155	381.57	Top of Outer Casing	53.29	30.04	0.02	328.26
	MW156	382.41	Top of Outer Casing	54.15	30.04	0.02	328.24
	MW163	386.42	Top of Outer Casing	58.39	30.04	0.02	328.01
	MW165A	380.93	Top of Outer Casing	53.34	30.04	0.02	327.57
	MW205	380.17	Top of Outer Casing	52.53	30.04	0.02	327.62
	MW255	384.35	Well Wizard Rim	56.16	30.06	0.00	328.19
	MW256	385.42	Well Wizard Rim	57.24	30.04	0.02	~~328.16~~
	MW258	383.69	Well Wizard Plate	55.83	30.06	0.00	327.86
	MW260	384.19	Well Wizard Rim	56.20	30.04	0.02	~~327.97~~
	MW283	370.08	Top of Outer Casing	43.67	30.06	0.00	326.41
	MW288	370.75	Well Wizard Plate	44.16	30.06	0.00	326.59
	MW291	370.52	Top of Outer Casing	43.97	30.06	0.00	326.55
	MW292	375.43	Well Wizard Plate	48.52	30.06	0.00	326.91
	MW293A	366.54	Top of Outer Casing	40.12	30.06	0.00	326.42
	MW341	380.52	Top of Outer Casing	52.60	30.04	0.02	327.90
	MW355	378.09	Top of Outer Casing	50.54	30.04	0.02	327.53
	MW478	384.32	Top of Outer Casing	56.38	30.06	0.00	~~327.94~~
	MW479	383.33	Top of Outer Casing	55.72	30.06	0.00	327.61
	MW480	383.38	Top of Outer Casing	55.84	30.06	0.00	~~327.54~~
	MW481	379.66	Top of Outer Casing	52.31	30.06	0.00	327.35
	MW482	379.73	Top of Outer Casing	52.37	30.06	0.00	327.36
	MW495	382.12	Top of Outer Casing	55.52	30.06	0.00	326.60
	MW496	380.41	Top of Outer Casing	53.11	30.06	0.00	327.30
	MW505	381.87	Top of Outer Casing	53.59	30.04	0.02	328.26
	MW506	381.87	Top of Outer Casing	53.58	30.04	0.02	328.27
	MW507	381.87	Top of Outer Casing	53.61	30.04	0.02	328.24
	MW524	382.02	Top of Outer Casing	54.11	30.06	0.00	327.91
	MW525	383.80	Top of Outer Casing	55.92	30.06	0.00	327.88
	MW526	384.29	Top of Outer Casing	56.23	30.06	0.00	328.06
	MW527	384.51	Top of Outer Casing	56.37	30.06	0.00	328.14
	MW528	384.57	Top of Outer Casing	56.42	30.06	0.00	328.15
	MW529	383.95	Top of Outer Casing	55.79	30.06	0.00	328.16
	MW530	384.05	Top of Outer Casing	57.88	30.06	0.00	~~326.17~~
7/13/2017	MW530	384.05	Top of Outer Casing	55.97	30.12	-0.07	328.15
	MW531	383.98	Top of Outer Casing	56.26	30.04	0.02	327.70
	PZ532	385.43	Top of Outer Casing	57.63	30.06	0.00	327.80
	MW533	384.54	Top of Outer Casing	56.61	30.04	0.02	327.91
	PZ534	384.34	Top of Outer Casing	56.44	30.04	0.02	327.88
	PZ535	385.68	Top of Outer Casing	57.68	30.04	0.02	327.98
	MW536	386.05	Top of Outer Casing	57.92	30.04	0.02	328.11
	MW537	386.32	Top of Outer Casing	58.27	30.04	0.02	~~328.03~~
	MW538	385.22	Top of Outer Casing	57.07	30.04	0.02	328.13
	MW539	385.03	Top of Outer Casing	56.89	30.04	0.02	328.12
	PZ540	387.89	Top of Outer Casing	59.96	30.04	0.02	327.91
	PZ541	384.50	Top of Outer Casing	56.54	30.04	0.02	327.94
	PZ553	385.00	Top of Outer Casing	57.02	30.04	0.02	327.96
	PZ554	386.51	Top of Outer Casing	58.55	30.06	0.00	327.96
	PZ555	386.07	Top of Outer Casing	58.05	30.06	0.00	328.02
	MW556	382.94	Top of Outer Casing	55.22	30.06	0.00	327.72

~~326.64~~ Rejected value (QC review)

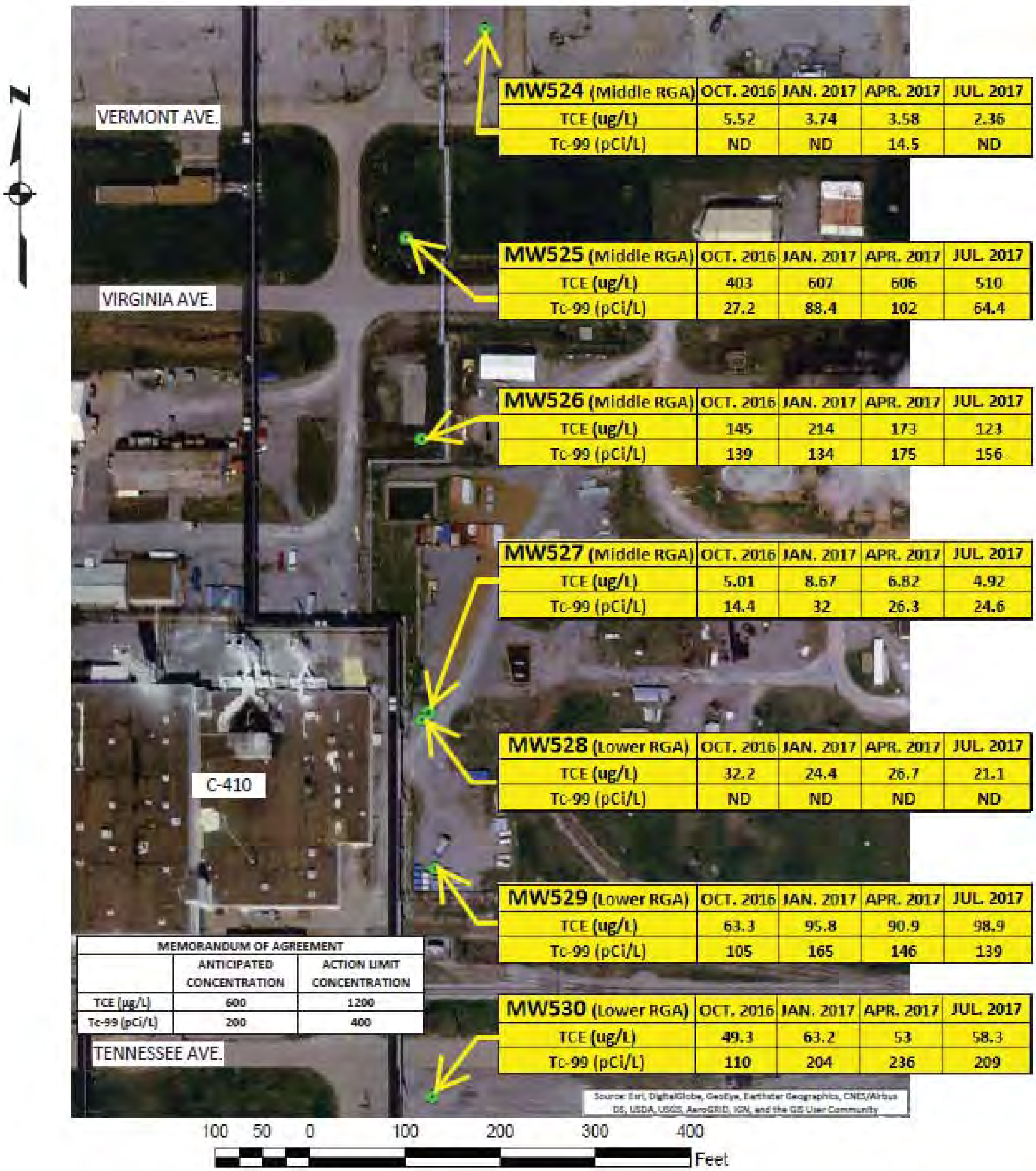

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Figure 5. Transect Wells TCE and Tc-99 Results

The July 2017 data set of analyses, representing 32 MWs of the optimized Northeast Plume interim remedial action (Table 2), define some of the areal contaminant trends. Analyses are available for 1,1-dichloroethene; TCE; and Tc-99 (Figures 6 through 8).

Hydraulic Assessment of the Optimized Northeast Plume Extraction Wells

A hydraulic assessment of the Northeast Plume Optimization Project will occur in January or February 2018 (within four months of system start-up). Plans for the hydraulic assessment, which include pumping tests of EW234 and EW235 independently, while the other groundwater extraction well is idled, and collectively, with both groundwater extraction wells operating simultaneously, require monitoring of the drawdown in the system groundwater extraction wells, MWs, and piezometers (all completed in the RGA) (DOE 2017b). The principal use of the data is to define the influence of the optimized groundwater extraction wells. The data also can be used to define transmissivity/hydraulic conductivity and storativity for the area of each groundwater extraction well, MW, and piezometer. The observed drawdown and derived hydraulic conductivity of the RGA can be compared to the current groundwater flow model, with a simulation of the optimized Northeast Plume groundwater extraction wells. Future updates of the sitewide groundwater flow model can incorporate hydraulic conductivity and storativity measurements from the hydraulic assessment.

Continuous Water Level Trends in the Northeast Plume Optimization Monitoring Network

Continuous groundwater level measurements collected with pressure transducers and data loggers will be generated as part of the hydraulic assessment of the optimized Northeast Plume extraction wells and also are recommended in the conclusions of the *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model* (DOE 2017a) for the transect of groundwater MWs in the Northeast Plume (DOE 2017a). These data sets, in conjunction with other RGA water level measurements (periodic and continuous), can be used as calibration and validation data sets for the Paducah Site groundwater flow model.

REFERENCES

DOE 2015. *Memorandum of Agreement for Resolution of Formal Dispute of the Explanation of Significant Differences to the Record of Decision for the Interim Remedial Action of the Northeast Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE/LX/07-1291&D2*), and Remedial Action Work Plan for Optimization of the Northeast Plume Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE/LX/07-1280&D2), U.S. Department of Energy, Paducah, KY, July 31.

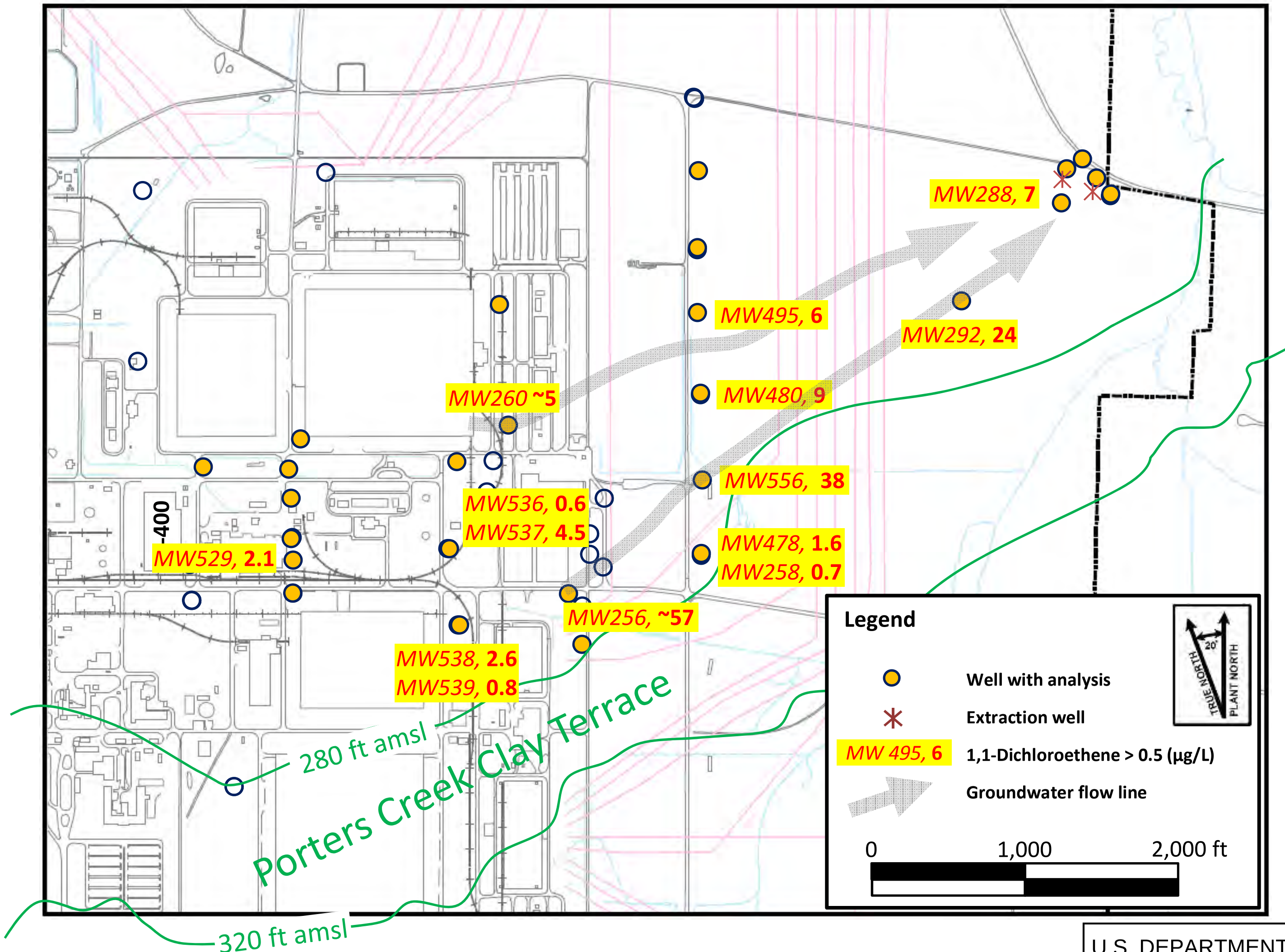
DOE 2016. *Remedial Action Work Plan for Optimization of the Northeast Plume Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1280&D2/R3, U.S. Department of Energy, Paducah, KY, April.

DOE 2017a. *2016 Update of the Paducah Gaseous Diffusion Plant Sitewide Groundwater Flow Model*, DOE/LX/07-2415&D2, U.S. Department of Energy, Paducah, KY, July.

DOE 2017b. *Operation and Maintenance Plan for the Northeast Plume Containment System Interim Remedial Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1535&D3/R6, U.S. Department of Energy, Paducah, KY, September.

Table 2. RGA Groundwater Analyses, July 10 - 13, 2017

Well	Date Collected	1,1-Dichloroethene (ug/L)	Qualifier	Technetium-99 (pCi/L)	Qualifier	Trichloroethene (ug/L)	Qualifier
MW124	10-Jul-17	1	U	1.27	U	5.65	
MW126	10-Jul-17	1	U	-2.35	U	0.38	J
MW144	11-Jul-17	0.5	J	46.9		115	
MW145	11-Jul-17	0.37	J	25		35	
MW155	11-Jul-17	100	U	90.1		7650	
MW156	11-Jul-17	500	U	-8.3	U	13800	
MW156	11-Jul-17	500	U	-2.35	U	13700	
MW258	11-Jul-17	0.72	J	1.92	U	134	
MW283	10-Jul-17	1	U	2.93	U	41.3	
MW288	10-Jul-17	7.13		30.6		139	
MW291	10-Jul-17	1	U	-1.76	U	32	
MW292	10-Jul-17	24		28.7		145	
MW293A	10-Jul-17	1	U	-6.25	U	85	
MW341	13-Jul-17	50	U	257		4280	
MW478	11-Jul-17	1.6	J	-4.46	U	152	
MW479	11-Jul-17	1	U	-7.77	U	1.34	
MW480	11-Jul-17	9.16		21.9		61.8	
MW495	11-Jul-17	6.2		36.4		373	
MW496	11-Jul-17	2	U	16		120	
MW524	13-Jul-17	1	U	9.65	U	2.36	
MW525	11-Jul-17	10	U	64.4		510	
MW526	11-Jul-17	2	U	156		123	
MW527	11-Jul-17	1	U	24.6		4.92	
MW527	11-Jul-17	1	U	20.1		4.91	
MW528	11-Jul-17	1	U	3.27	U	21.1	
MW529	11-Jul-17	2.07		139		98.9	
MW530	11-Jul-17	1	U	209		58.3	
MW531	13-Jul-17	0.49	J	90.6		91.8	
MW533	13-Jul-17	1	U	69.7		88.9	
MW536	13-Jul-17	0.56	J	33.5		173	
MW537	13-Jul-17	4.51		34		181	
MW538	13-Jul-17	2.55		2.92	U	54.6	
MW539	13-Jul-17	0.77	J	7.55	U	62	
MW556	11-Jul-17	38		42.2		195	

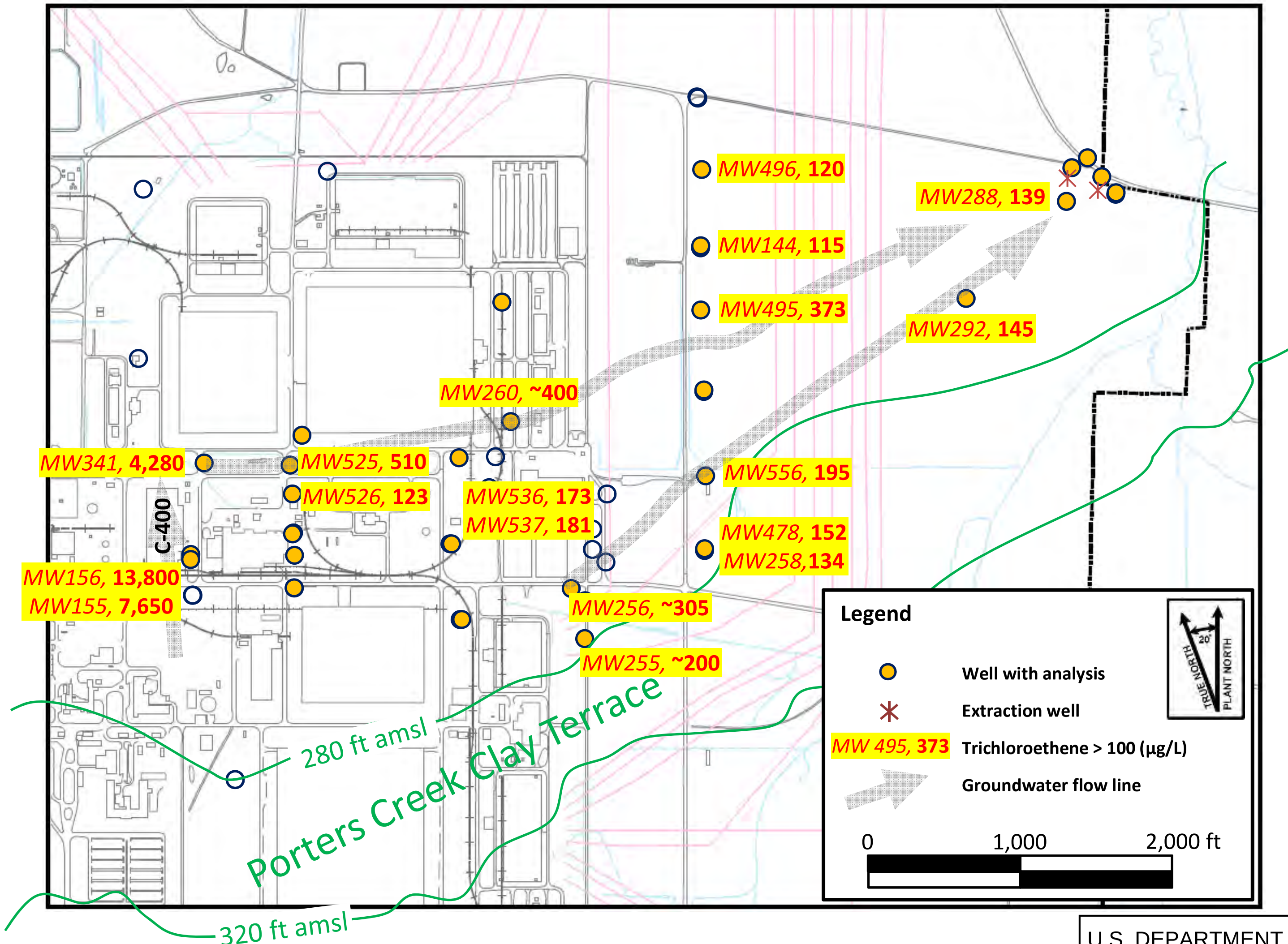


Note: approximate values (~) are based on historical analyses.
1,1-Dichloroethene = 56.9 µg/L on 2/15/17 in MW256 & 3.11 µg/L on 6/1/15 in MW260

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

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

Figure 6. July 10 - 13, 2017 1,1-Dichloroethene



Note: approximate values (~) are based on historical analyses.
Trichloroethene = 190 µg/L on 2/15/17 in MW255, 306 µg/L on 2/15/17 in MW256, & 403 µg/L on 6/1/15 in MW260

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PADUCAH GASEOUS DIFFUSION PLANT

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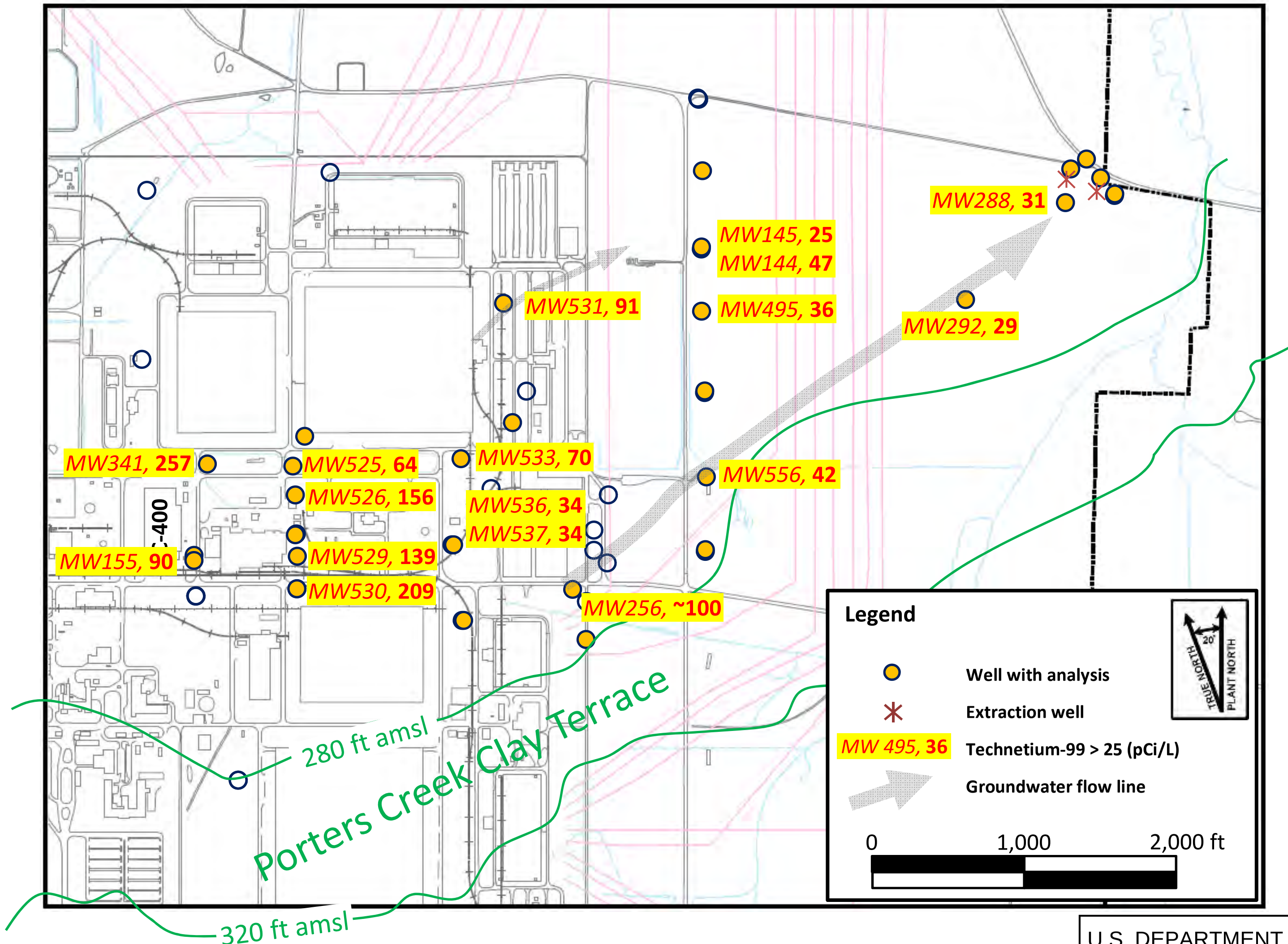
Figure 7. July 10 - 13, 2017 Trichloroethene



Note: approximate values (~) are based on historical analyses.
Technetium-99 = 99.6 pCi/L on 5/17/17 in MW256

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Figure 8. July 10 - 13, 2017 Technetium-99

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GROUNDWATER MODELING WORKING GROUP
MEETING SUMMARY—APRIL 12, 2018

Noman Ahsanuzzaman ✓
Brian Begley ✓
Ben Bentkowski ✓
Rich Bonczek ✓
Gaye Brewer ✓
Stephanie Brock ✓
Martin Clauberg ✓
Bryan Clayton
Julie Corkran
Jana Dawson
Eva Davis
Ken Davis ✓
Dave Dollins ✓
Bruce Ford
Stefanie Fountain
LeAnne Garner ✓
Nathan Garner ✓
Steve Hampson ✓
Jeri Higginbotham ✓
Chris Jung ✓
Brian Lainhart ✓
Kelly Layne
Mac McRae ✓
Bobette Nourse ✓
Todd Powers
Bruce Stearns ✓
Tracy Taylor ✓
Denise Tripp ✓

✓ indicates member was present.

1. **Call for Issues from Groundwater Modeling Working Group (MWG) Members**
None.

2. **Status of Previous Meeting Summary**
Comments received from MWG members as follows:

- Include that discussion will be held with, "DOE will investigate what option(s) is available to establish a water level gauge at the April 2018 quarterly meeting."
- Revise numbering so that there are not two Item 4s.
- Revise font in "Effective Porosity" excerpt to be black.

With these revisions, meeting summary will be considered final.

Meeting summaries should be captured so that they are available in a file. The summaries may be published as an annual compilation,.

3. **Remaining FY 2018 Schedule**

Submit recommendation for MW460 high TCE concentration	4/30/2018 (see Item 5)
Quarterly Meeting (March-April)	4/12/2018
MWG concur with DAF white paper to be included in Risk Methods Document (RMD) (Note: Entire RMD is scheduled for submission to Risk Assessment Working Group on 4/17/2018)	Pending (see Item 4)
Quarterly Meeting (June)	6/26/2018
Quarterly Meeting (September)	9/18/2018

Quarterly meetings will be Web/teleconference 8:00 a.m.–11:00 a.m. (Central), 9:00 a.m.–12:00 p.m. (Eastern)
* scheduled following the MWG meeting
Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

4. **Comments received to the DAF/SSL White Paper**

- Comment Resolution Meeting tentatively set for May 4, 2018, 9:30 Eastern (8:30 Central).

- The group needs to get the white paper complete, to be put into the Risk Methods Document.
- The group can expect a draft comment response summary on April 27, 2018, preceding the comment resolution meeting on May 4, 2018.
- A revision of our schedule for finalizing the white paper is pending.

5. Recommendation for MW460 High TCE Concentrations

- A draft white paper is expected to be sent by April 30, 2018. The paper will be discussed with the MWG at the June 2018 quarterly meeting.
- Ken presented an overview of the paper. MW460 is a lower Regional Gravel Aquifer (RGA) well, about 900 ft downgradient of the Northwest Plume extraction wells. TCE levels are rising in MW460. The paper evaluates TCE trends in this well. Kentucky's Environmental Oversight report of 2016 also has discussed these trends. The paper will discuss potential recommendations, including modeling and reconfiguring extraction well pumps/depths to optimize control of the TCE plume.
- It was suggested that the paper include discussion for consideration for an option of adding an extraction well.
- Conclusions/recommendations from the paper will be presented to DOE management. Consideration will be given to including the white paper in the Five-Year Review.

6. Option(s) to Establish a Water Level Gauge

- FRNP and DOE are investigating options to establish a water-level gauge at Metropolis Lake.
- If established, water levels at Metropolis Lake would be collected, concurrently with a synoptic water level measurement.
- Ken reported that staff gauges are available and could be affixed to a tree in the lake. The gauge would need to be surveyed. This recommendation has been made to the Environmental Monitoring group for inclusion in the Environmental Monitoring Plan (EMP).
- There is no recent water quality data from the lake. It was sampled in the early 1990s. The TCE plume does not extend to the lake. The model shows groundwater flow to that direction.
- Dr. Fryar has some studies in that location. Steve has provided additional information about those studies to the group as follows:
  - Dr. Fryar did a little work at Metropolis Lake, but not much. He submitted a short report to the Kentucky State Nature Preserves Commission in 1998 or 1999 and one of his Masters of Science students did lab experiments on TCE biodegradation in soils from Metropolis Lake.
  - From the thesis and the report to the Kentucky State Nature Preserves Commission, Dr. Fryar could find only two analyses, both for technetium-99: < 0.2 pCi/g in soil at 1.5 ft depth along the west shore and < 9 pCi/L in lake water along the south shore.

7. FY 2019 Work Plan Development

FY 2018's work plan:

Quarterly Meeting (September) (face-to-face meeting)	9/19/2017
Develop Draft FY 2018 Schedule	9/19/2017
Submit FY 2018 Schedule	10/19/2017
E-mail acknowledgement that the MWG considers the minutes to be final	11/20/2017
MWG concurs with FY 2018 Schedule	11/20/2017
MWG meeting to discuss DAF/SSL white paper	12/13/2017*
Submit proposal regarding transect of RGA water levels	1/4/2018
Submit proposal regarding which wells would be beneficial for slug testing	1/4/2018
KY report to MWG whether there is a marker to use at Metropolis Lake (Complete)	1/11/2018
Determination for synoptic water levels collected more than once per year	1/11/2018
Determination for synoptic water level at Metropolis Lake Road	1/11/2018
Submit proposal for use of NE transect wells into model	1/11/2018
Quarterly Meeting (December-January)	1/11/2018
Submit draft DAF/SSL white paper (See Item 7)	2/12/2018
Comments due for DAF/SSL white paper	3/12/2018
Submit recommendation for MW460 high TCE concentration	4/12/2018
Quarterly Meeting (March-April)	4/12/2018
MWG concur with DAF white paper to be included in Risk Methods Document (RMD) (Note: Entire RMD is scheduled for submission to Risk Assessment Working Group on 4/17/2018)	4/12/2018
Quarterly Meeting (June)	6/26/2018
Quarterly Meeting (September)	9/18/2018

LeAnne will put together proposed schedule. MWG should send suggestions to LeAnne by June 1.
Regarding funding, FRNP is looking for efficiencies. Conceptual plans have been discussed with DOE and still are under development.

Uncertainty management that has been brought up previously that could help inform the C-400 project possibly includes the high TCE south of the SE corner of C-400 (MW505, MW506, and MW507) and the higher than baseline TCE in the south NE Plume transect wells.
For these uncertainties, additional modeling may need to be considered—possibly a special run or an update to the existing model.

8. Poll MWG Members/Open Discussion

Regular meetings are necessary for understanding uncertainties.
Group discussed impacts of C-400. Ken will update plots of wells south of C-400 (i.e., MW505, MW506, and MW507).

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GROUNDWATER MODELING WORKING GROUP MEETING SUMMARY—JULY 10, 2018

Noman Ahsanuzzaman ✓	Eva Davis ✓	Brian Lainhart
Brian Begley ✓	Ken Davis ✓	Kelly Layne
Ben Bentkowski ✓	Dave Dollins ✓	Mac McRae ✓
Rich Bonczek ✓	Bruce Ford	Jacob Myers ✓
Gaye Brewer ✓	Stefanie Fountain ✓	Bobette Nourse
Stephanie Brock	LeAnne Garner ✓	Teresa Overby ✓
Martin Clauberg ✓	Nathan Garner ✓	Todd Powers ✓
Bryan Clayton ✓	Steve Hampson ✓	Bruce Stearns ✓
Julie Corkran	Jeri Higginbotham	Tracy Taylor ✓
Jana Dawson	Chris Jung	Denise Tripp ✓

✓ indicates member was present.

1. Call for Issues from Groundwater Modeling Working Group (MWG) Members

None.

2. Status of Previous Meeting Summary

The April 12, 2018, Meeting Summary was updated to reflect information provided by Steve Hampson on Dr. Fryar's work at Metropolis Lake. That information now reads as follows:

- Dr. Fryar has some studies in that location. Steve has provided additional information about those studies to the group as follows:
  - — Dr. Fryar did a little work at Metropolis Lake, but not much. He submitted a short report to the Kentucky State Nature Preserves Commission in 1998 or 1999 and one of his Masters of Science students did lab experiments on TCE biodegradation in soils from Metropolis Lake.
  - — From the thesis and the report to the Kentucky State Nature Preserves Commission, Dr. Fryar could find only two analyses, both for technetium-99: < 0.2 pCi/g in soil at 1.5 ft depth along the west shore and < 9 pCi/L in lake water along the south shore.

With these revisions, meeting summary will be considered final.

3. Remaining FY 2018 Schedule

Quarterly Meeting (March-April)	4/12/2018
MWG concur with DAF white paper to be included in Risk Methods Document (RMD) (Note: Entire RMD is scheduled for submission to Risk Assessment Working Group on 4/17/2018)	Pending (see Item 4)
Quarterly Meeting (June)	7/10/2018
Quarterly Meeting (September)	9/18/2018

Quarterly meetings will be Web/teleconference 8:00 a.m.–11:00 a.m. (Central), 9:00 a.m.–12:00 p.m. (Eastern)

Color code for schedule:

Quarterly meeting

Concurrence/acknowledgement date

4. **Comments received to the DAF/SSL White Paper**

- Comment/Response regarding DAF of 1 still outstanding
  SSLs calculated using DAFs of 1, 20, and project-specific value (if available) will be used for screening. This approach is consistent with the current RMD Modeling Matrix, which specifies that SSLs for protection of groundwater should be derived using an DAF of 1 unless site-specific information is available.
  Groundwater protection values will be determined from modeling for each project (to be reported in the RI Report), groundwater protection values will not be determined from screening values.
  DOE typically uses RESRAD for modeling radionuclides migration to groundwater from soils in the RI Reports. SESOIL also is typically used.
  Each RI Report details model inputs used for the project.

  C-400 RI/FS will be analyzing for Kds and other geotechnical parameters to inform a project-specific value.

- EPA will look back at white paper and follow up with outstanding comments.
  NOTE: Julie Corkran sent an email on July 12 stating that EPA has no further comments on the white paper and that, if KY agrees, EPA believes the white paper is acceptable for finalization and inclusion with the FY 2018 RMD.

5. **Recommendation for MW460 High TCE Concentrations**

- Draft white paper was sent April 30, 2018 as discussed in the previous meeting. MW460 is a lower Regional Gravel Aquifer (RGA) well, about 900 ft downgradient of the Northwest Plume extraction wells. TCE levels are rising in MW460. The paper evaluates TCE trends in this well. Kentucky's Environmental Oversight report of 2016 also has discussed these trends. The paper discusses potential recommendations, including modeling and reconfiguring extraction well pumps/depths to optimize control of the TCE plume.

- It was questioned if the extraction well lithologies indicated a more transmissive zone in the lower RGA. The lower RGA does not appear to be more transmissive, but it appears to be where the majority of the contamination is.

- It was suggested that lowering the pump may not help significantly with the issue.

- A comment was made to add as a recommendation to rehab the extraction wells more frequently. Discussion was held regarding when biofouling was last noticed and that we do not know if the condition exists with the new wells.

- It was recommended that the white paper consider as an option whether the old extraction wells could be added to the extraction well field. (FRNP should verify the treatment capacity for the system.)

- A formal optimization plan should be developed to determine which combination of recommendations would work best.

- An update to this white paper with the above additions will be sent back to the group (with a 30-day review period).

- The recommendation that this issue should be studied will be presented in the Five Year Review.

6. Option(s) to Establish a Water Level Gauge

- Update regarding options to establish a water level gauge at Metropolis Lake.
- FRNP is moving ahead with putting this in place (e.g., work documentation).
- Growth of the tree will need to be considered. Placing the gauge on a tree with public access could be subject to vandalism (or other damages). A second gauge could be added as a back-up.
- Permission needs to be confirmed with Kentucky State Nature Preserve Commission. Ken Davis and Brian Begley to follow up.

7. Update on TVA Landfill

An e-mail was sent May 9, 2018 from Brian Begley regarding TVA's Environmental Impact Statement, "Management of Coal Combustion Residuals from the Shawnee Fossil Plant."

Additionally, MW152 and MW153 will be affected by TVA's proposed process water basin. Proposed location for relocated MW152A is as shown in Attachment 1. (NOTE: the location of TVA's proposed process water basin is preliminary and may be revised)

DOE plans to share TVA well data.

8. FY 2019 Work Plan Development

Proposed Schedule:

Develop Draft FY 2019 Schedule	9/12/2018
Quarterly Meeting (October)*	10/3/2018
Submit FY 2019 Schedule	10/10/2018
MWG concurs with FY 2019 Schedule	11/9/2018
Quarterly Meeting (January)	1/9/2019
Submit Compilation of Meeting Notes and White Papers completed	2/12/2019
Comments due for Meeting Notes and White Papers compilation	3/12/2019
Quarterly Meeting (April)	4/10/2019
Quarterly Meeting (July)	7/17/2019
Quarterly Meeting (October)*	10/2/2019

Quarterly meetings will be Web/teleconference 8:00 a.m.–11:00 a.m. (Central), 9:00 a.m.–12:00 p.m. (Eastern)
*Meeting is tentatively planned to be held at the EIC, for those available to travel.
Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

Additional projects proposed include the following:

- Look at west side of site associated with SW Plume (TCE extents, to address anomaly in plume maps).
- Similar look at downgradient NE Plume (TCE extents).

- Synoptic water levels in transect back to Ohio River (combination of physical measurement and data loggers).

- Continuous water levels near the Ohio River to document aquifer properties prior to completion of the Olmsted Dam project.

- Look at water level divide (NE Plume hydraulic study).

DOE management has been briefed on these proposed projects. At the Fall 2018 meeting, additional details will be presented regarding how these project will be accomplished.

The following recommendations attached to the modeling paper may address data gaps and should be considered in the Fall 2018 meeting.

- Stream gauging in relation to the synoptic water levels should be considered.

- White paper in FY 2020 to address "Installation of piezometers equipped with continuous water level monitors associated with several of the large process buildings [or evaluation of sumps] would define the thickness of the sub-slab gravel base and the temporal water level fluctuations beneath several of the large buildings better."

- White paper in FY 2019 to address "Flow rate in the McNairy Formation is negligible compared to the RGA because the hydraulic conductivity is 2 to 3 orders of magnitude lower than in the RGA; however, the McNairy Formation may be significant for DNAPL source accumulation and contaminant transport. Future transport models based on the 2016 flow model will need to consider potential mass flux from the McNairy to the RGA resulting from back diffusion." During this discussion, it was noted that RGA and McNairy information from the C-400 RI/FS would be needed to complete this White Paper.

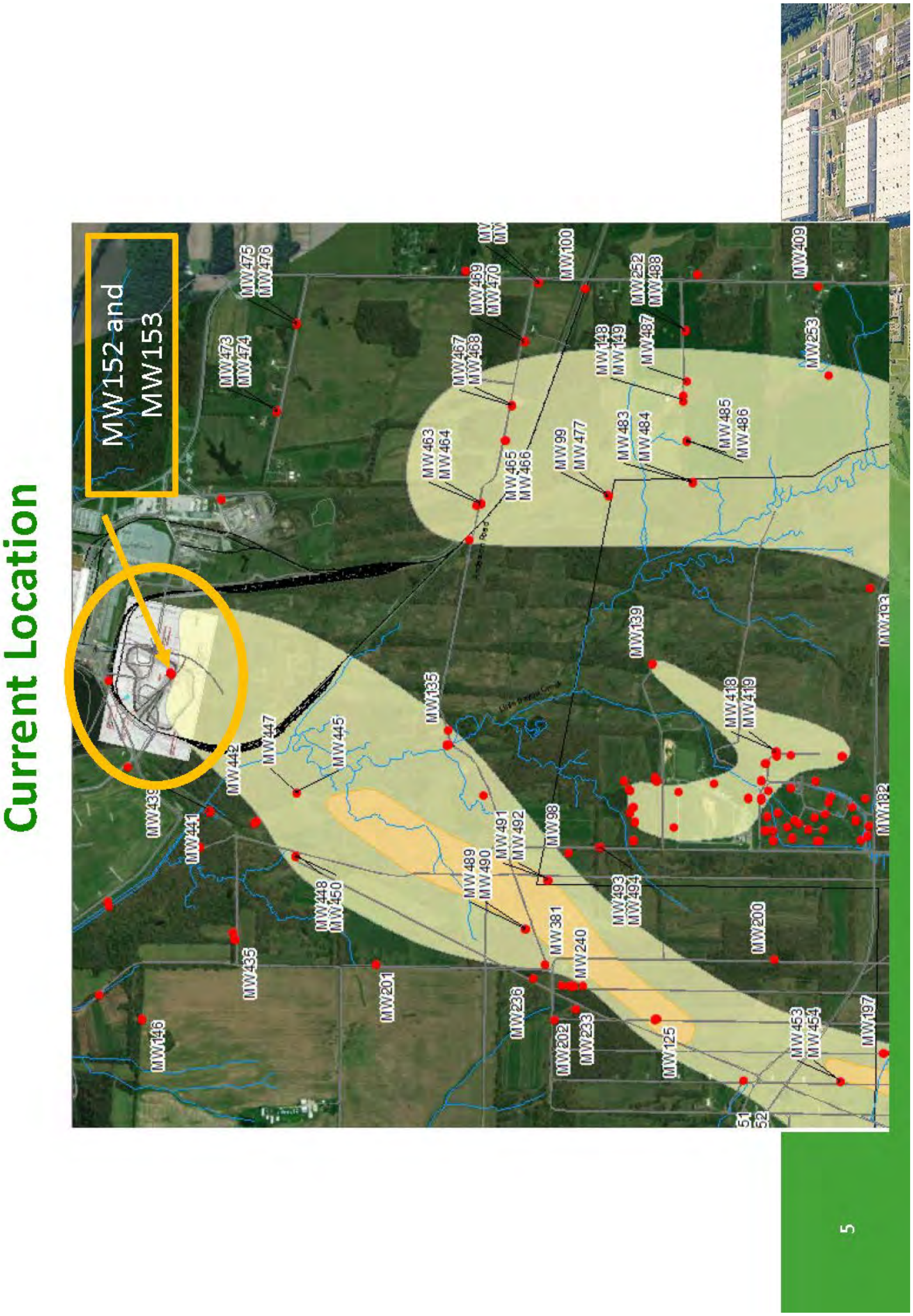
- Corridors where overhead transmission lines have been removed have been considered for monitoring well placement, especially with respect to the west side of the NE Plume. Previously overhead transmission lines prevented installation of wells to the west in the northern-most transect of wells. Installation of additional wells in this transect can be considered for efficiency during installation of new MW152A.

9. Poll MWG Members/Open Discussion

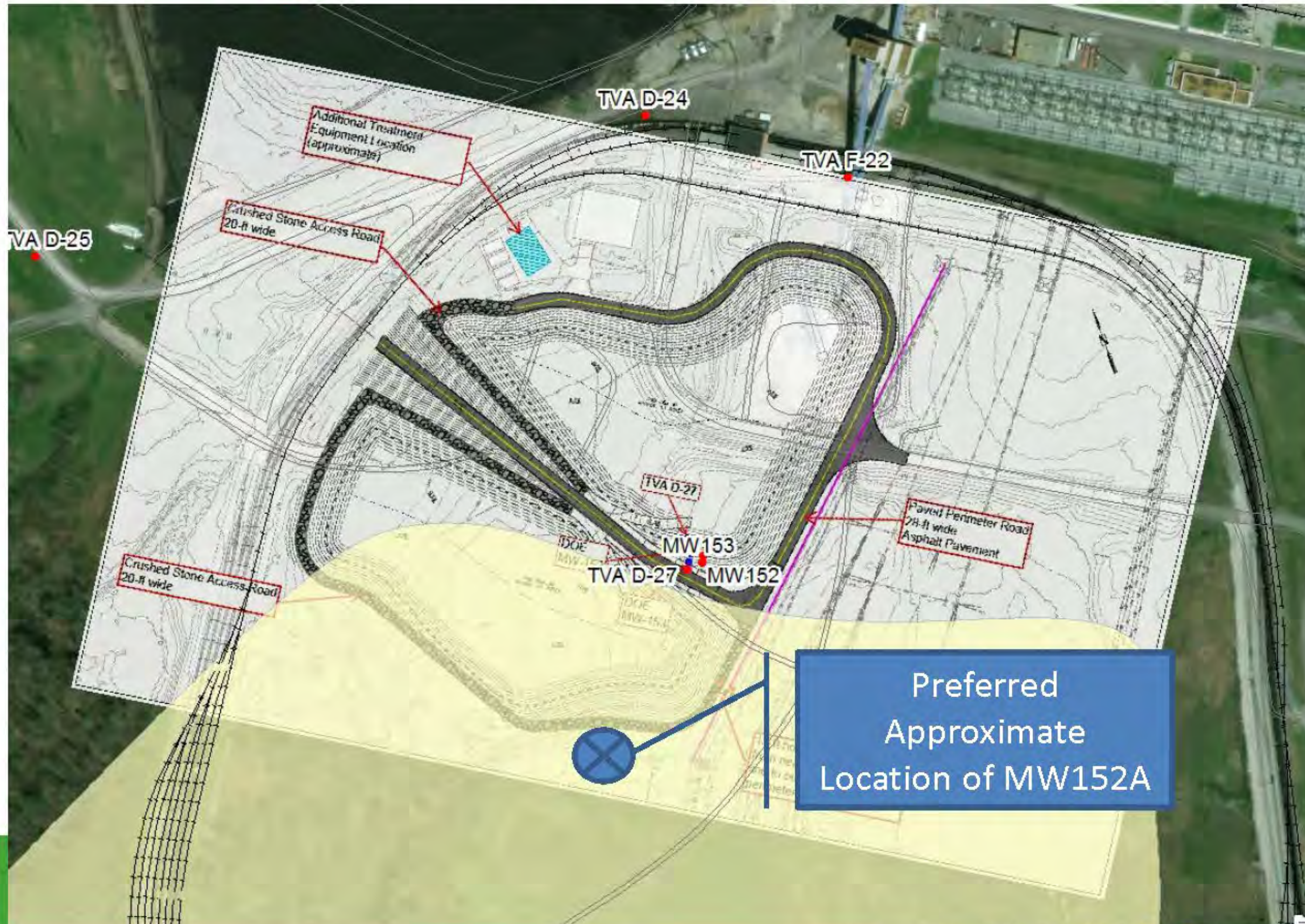
Implementation of RESRAD will be discussed at a later date. DOE Headquarters' RESRAD memo is provided in Attachment 2.

Any other topics should be sent to LeAnne by September 15, 2018, in preparation for the Fall 2018 Quarterly Meeting.

ATTACHMENT 1
LOCATION OF MW152 AND MW153 AND
TVA's PRELIMINARILY PROPOSED PROCESS WATER BASIN



Close-up Location with Current Existing Wells and Proposed Location of Replacement Well



6

ATTACHMENT 2

Department of Energy
Washington, DC 20585

May 7, 2018

MEMORANDUM FOR DISTRIBUTION

FROM: MARK GILBERTSON
ASSOCIATE PRINCIPAL DEPUTY ASSISTANT
SECRETARY FOR REGULATORY AND POLICY AFFAIRS

SUBJECT: Application of RESidual RADioactivity and the Preliminary Remediation Goal Calculator for Conducting Radiological Risk Evaluations at Comprehensive Environmental Response, Compensation, and Liability Act Sites

The purpose of this memorandum is to: 1) provide expectations to the Office of Environmental Management (EM) Field Managers on the appropriate application of the RESidual RADioactivity (RESRAD) family of codes to radiological risk assessments and evaluations conducted by the Department of Energy (DOE) in support of its cleanup decisions under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and 2) provide clarification on the application of the Environmental Protection Agency's (EPA) Preliminary Remediation Goal (PRG) and Dose Compliance Consecration (DCC) Calculators (here in referred to as the PRG Calculator) as a screening tool at those DOE's sites on EPA's CERCLA National Priority List (NPL).

The RESRAD is a family of computer codes that was developed to assist in evaluating the condition of radioactive contamination in environmental media (e.g., soils) and buildings/structures, and to demonstrate compliance with DOE's established dose limits (as outlined in the DOE Orders 458.1, *Radiation Protection of the Public and the Environment* and 435.1, *Radioactive Waste Management*) for the protection of human health and the environment. RESRAD has been extensively applied in the DOE complex for: 1) determining final cleanup levels in support of deactivation and decommissioning (D&D) projects, including the free-release of previously contaminated materials and real property; 2) supporting risk and dose assessments for regulatory decision making; 3) evaluations to support response decisions and excess real property transfers; and 4) conducting performance assessments (PAs) for disposal facilities in accordance with DOE Order 435.1. These codes have been peer reviewed and widely used by federal and state agencies, including EPA, within the United States and internationally.

In June 2014, the EPA published Radiation Risk Assessment at CERCLA Sites: Q&A, EPA 540-R-012-13, which provides updated guidance for radiation risk assessment (see https://semspub.epa.gov/work/HQ/176329.pdf). Central to EPA's guidance is the PRG Calculator, which is a tool that allows users to calculate initial cleanup levels for radiation in soil, water, and air at CERCLA sites, based on standardized assumptions and default input values. The EPA uses the PRG calculator to derive risk-based, screening values that can be compared to the concentrations of site contaminants. Comparison to these default values can be used during project scoping to identify areas of a site where radionuclides of potential concern may warrant further evaluation. Areas of the site where the concentrations of radionuclides of potential concern fall below the default, risk-based screening values do not need further investigation or action. Areas where radionuclide concentrations are above the PRG screening values are further assessed using a more detailed model (e.g., RESRAD) with site-specific data to support response action decisions.

Following EPA's release of the June 2014 guidance, questions have arisen regarding the use of the RESRAD family of codes and the PRG calculator for supporting CERCLA response decisions at the DOE's NPL sites. As the lead CERCLA agency for the DOE sites, the DOE issues this memorandum to clarify that EPA 540-R-012-13 does allow for the use of alternate models other than PRG or other EPA calculators at CERCLA sites. In addition, this memorandum, establishes direction for the DOE site offices that RESRAD models are approved for use in cleanup decisions at the DOE sites.

IMPLEMENTATION:

Generic Screening Evaluations

The EPA considers the PRGs obtained from the PRG calculator using default scenarios and inputs to be protective for generic screening during project scoping at any location. More specifically, the PRG calculator includes a full suite of generic inputs and default exposure scenarios that purposefully calculate screening values. By definition, screening values are conservative thresholds based on an established risk or dose level. Values below the screening level have no potential for exceeding the threshold, and values above the screening level may exceed the threshold, but warrant further evaluation based on site-specific or site-relevant conditions. Thus, if the RESRAD or another tool is to be used in a similar manner for generic screening purposes only, site personnel will need to ensure their EPA regulators agree to the use of these inputs and default scenarios in order to remain consistent with similar generic screening within their region.

Site-Specific Screening Evaluations

When further analysis is needed, the DOE recommends that available site-specific data be used in place of generic inputs to provide for a more accurate portrayal of potential site risks. These site-specific input values or alternative exposure and land use scenarios) used in the PRG Calculator, RESRAD or other appropriate tools, need to be documented and justified. Regardless of which approach is followed, site personnel need to work with their EPA regulator to ensure the site-specific screening analysis remains consistent with CERCLA requirements, giving due consideration to the site-specific factors.

Risk Assessment & Remedial Alternative Risk Evaluations

Once a site has conducted screening and determined there is need for additional site-specific analysis, any such analysis should be completed consistent with EPA's Risk Assessment Guidance for Superfund, which requires the consideration of site-specific conditions and incorporates the concept of reasonable maximum exposure. This guidance also allows for the calculation of site-specific risk values over a wide-range of current and potential future uses and the use of modeled concentrations, such as those representative of impacts from sources to groundwater, when applicable to the decision. Therefore, sites may choose to use the EPA's PRG calculator for screening purposes only, but the DOE's policy is to use RESRAD (or other models meeting the DOE quality assurance requirements) for site-specific and site-relevant risk assessments and determining appropriate cleanup levels.

If you have any further questions, please contact Mr. Robert W. Seifert, Director, Office of Regulatory Compliance, at (301) 903-9638 or Robert.seifert@em.doe.gov.

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Barton Barnhart, EM-4.1
Mark Senderling, EM-4.2
Elizabeth Connell, EM-4.3
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Steve Golian, EM-4.31
Ming Zhu, EM-4.31

GROUNDWATER MODELING WORKING GROUP
MEETING SUMMARY—SEPTEMBER 18, 2018

Noman Ahsanuzzaman ✓
Brian Begley ✓
Ben Bentkowski ✓
Rich Bonczek ✓
Gaye Brewer ✓
Stephanie Brock
Martin Clauberg ✓
Bryan Clayton ✓
Julie Corkran✓
Jana Dawson
Eva Davis
Ken Davis ✓
Dave Dollins ✓
Bruce Ford ✓
Stefanie Fountain ✓
LeAnne Garner ✓
Nathan Garner
Steve Hampson ✓
Jeri Higginbotham
Chris Jung ✓
Brian Lainhart ✓
Kelly Layne
Mac McRae ✓
Teresa Overby
Todd Powers ✓
Bruce Stearns ✓
Tracy Taylor ✓
Denise Tripp ✓

✓ indicates member was present.

1. **Call for Issues from Groundwater Modeling Working Group (MWG) Members**

AIP collected RGA wells during August synoptic well level event for TVA wells to provide a more robust set, and tied the measurements in with Ohio River. TVA has an Ohio River water level monitoring station. Brian Begley provided TVA contact information; Ken Davis will get in touch with TVA for additional information.

2. **Status of Previous Meeting Summary**

The July 10, 2018, Meeting Summary was updated to reflect the redlined changes shown in the agenda. The July 10, 2018, Meeting Summary is considered final with these changes.

3. **Remaining FY 2018 Schedule**

Quarterly Meeting (September)	9/18/2018

Quarterly meetings will be Web/teleconference 8:00 a.m.–11:00 a.m. (Central), 9:00 a.m.–12:00 p.m. (Eastern)

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

4. **Proposed FY 2019 Work Plan/Schedule**

Develop Draft FY 2019 Schedule	9/12/2018
Quarterly Meeting (October)	10/3/2018
Submit FY 2019 Schedule	10/10/2018
MW460 White Paper Revision	10/30/2018
MWG concurs with FY 2019 Schedule	11/9/2018
MW460 White Paper Comments Due	11/30/2018
Quarterly Meeting (January)	1/9/2019
Submit Compilation of Meeting Notes and White Papers completed	2/12/2019
Comments due for Meeting Notes and White Papers compilation	3/12/2019
Quarterly Meeting (April)	4/10/2019
Quarterly Meeting (July)	7/17/2019
Quarterly Meeting (October)	10/2/2019

Quarterly meetings will be Web/teleconference 8:00 a.m.–11:00 a.m. (Central), 9:00 a.m.–12:00 p.m. (Eastern)*
If topics warrant, a face-to-face meeting will be considered. Currently, a face-to-face meeting is not scheduled.

Color code for schedule:

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Note that the first FY 2019 meeting follows this meeting very closely. LeAnne explained that the intent was to space the MWG meetings with the Risk Assessment Working Group meetings more evenly.

Additional projects proposed include those listed below.

- Look at west side of site associated with SW Plume (TCE extents, to address anomaly in plume maps).[7]

- Similar look at downgradient NE Plume (TCE extents).*

- Synoptic water levels in transect back to Ohio River (combination of physical measurement and data loggers). (Include AIP's measurements—Coordinates in OREIS for a couple of the TVA wells did not plot in correct location. Information will be transmitted formally; raw data also available.)*

- Continuous water levels near the Ohio River to document aquifer properties prior to completion of the Olmsted Dam project.*

- Look at water level divide (NE Plume hydraulic study).*

- Stream gauging in relation to the synoptic water levels should be considered.

- White paper in FY 2020 to address "Installation of piezometers equipped with continuous water level monitors associated with several of the large process buildings [or evaluation of sumps] would define the thickness of the sub-slab gravel base and the temporal water level fluctuations beneath several of the large buildings better."

- White paper in FY 2020 to address "Flow rate in the McNairy Formation is negligible compared to the RGA because the hydraulic conductivity is 2 to 3 orders of magnitude lower than in the RGA; however, the McNairy Formation may be significant for DNAPL source accumulation and contaminant transport. Future transport models based on the 2016 flow model will need to consider potential mass flux from the McNairy to the RGA resulting from back diffusion." RGA and McNairy information from the C-400 RI/FS will be needed to complete this White Paper.

  Adding McNairy Formation will be considered for future models. Addition of McNairy wells can be considered as part of C-400 RI/FS. The Work Plan is expected in November for comments. Some upper McNairy Formation wells are available on-site currently.

- Corridors where overhead transmission lines have been removed have been considered for monitoring well placement, especially with respect to the west side of the NE Plume. Previously, overhead transmission lines prevented installation of wells to the west in the northern-most transect of wells. Installation of additional wells in this transect can be considered for efficiency during installation of new MW152A.

[7] At the **<u>October 2018</u>** meeting, additional details will be presented regarding how these projects may be accomplished.

5. Olmstead Locks and Dam Update

Ribbon cutting was held August 30, 2018. Current schedule is for the dam to be operational in October 2018 and to complete the project, including removal of Dams 52 & 53, in December 2020 (https://www.lrl.usace.army.mil/Portals/64/docs/Olmsted%20MEDIA%20KIT%20July%2020%202018.pdf?ver=2018-07-20-145628-757).
USGS Ohio River elevations are available for Olmstead. A water level graph is attached. The group discussed whether the increasing water levels could be the result of discharging water upstream (TVA's preparation for hurricanes) or the result of Olmstead Locks and Dam starting to hold water. Ken will check with TVA to see if they can provide any information.

6. Option(s) to Establish a Water Level Gauge

- An update regarding options to establish a water level gauge at Metropolis Lake was given.
  Ken and Brian Lainhart checked for locations that might work for a water level gauge. We have been unable to find an appropriate location; we are unable to survey at this time.
  The group discussed considering establishing a water level gauge to collect data, and survey the location at another time. Other options are being considered (e.g., drone, Bluetooth, pressure transducer). Brian Begley is checking with contacts to determine possibilities.

7. Recommendation for MW460 High TCE Concentrations

- An update to this white paper with the above additions is under development and will be sent back to the group (with a 30-day review period).
  MW135 and MW454 with increasing TCE trends in the NW Plume were discussed.

- The recommendation, "Extraction well pump placement and pumping rates should be evaluated to optimize capture of the Northwest Plume," has been presented in the Five-Year Review.

8. Update on TVA Process Water Basin

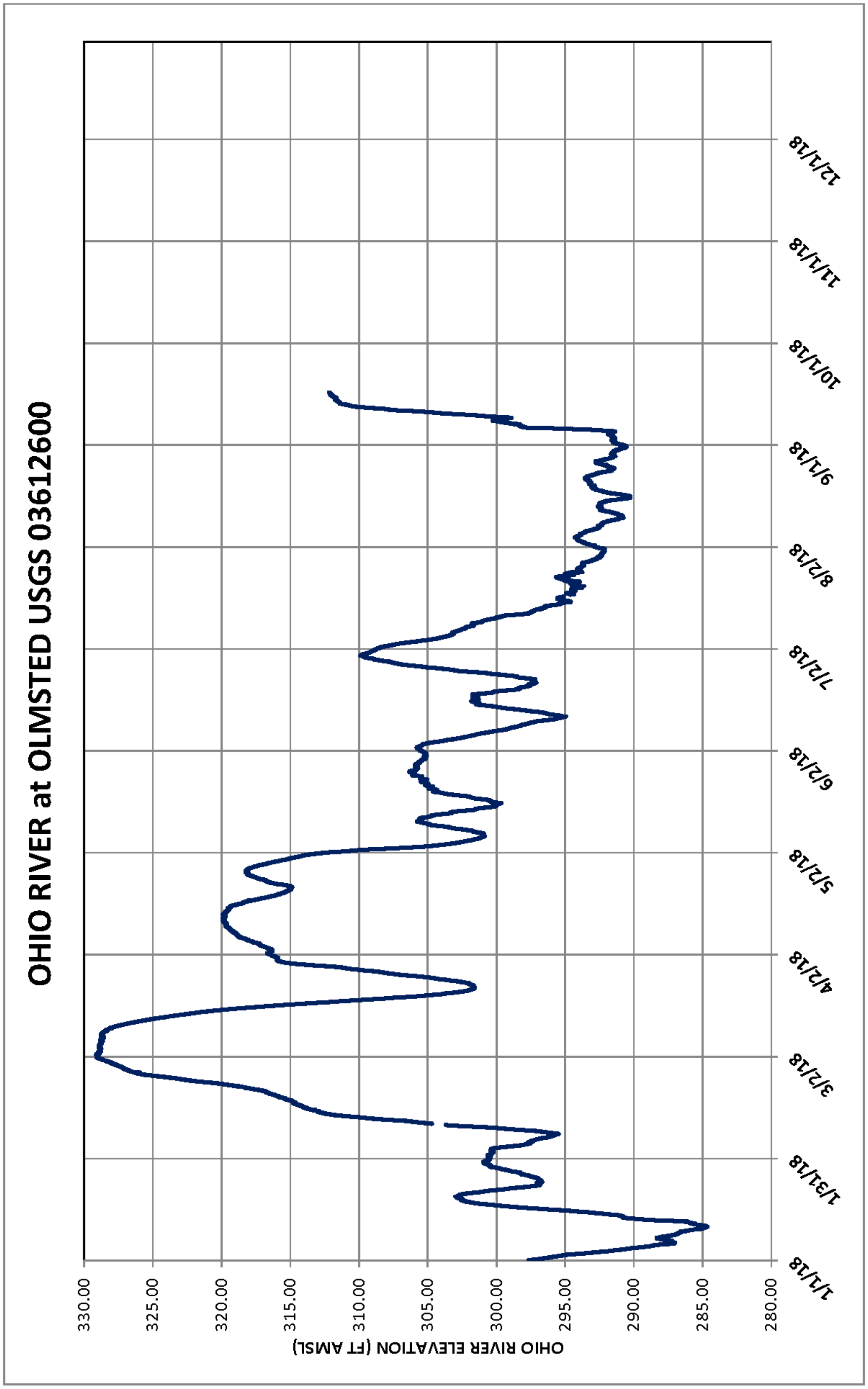
- MW152 and MW153 currently are being abandoned. New well (MW152A) is being installed.
- DOE plans to share new TVA well data, once it is available to share.

9. Poll MWG Members/Open Discussion

MW464 (NE Plume) is being abandoned and replaced because casing had failed.
MW253 (NE Plume) is being abandoned and replaced because casing failure is suspected. (Monitoring well number was corrected following the meeting.)

The intent is to install replacement wells next to previous locations. Work is ongoing now.

ATTACHMENT



OHIO RIVER at OLMSTED USGS 03612600
OHIO RIVER ELEVATION (FT AMSL)
330.00
325.00
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305.00
300.00
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1/31/18
3/2/18
4/2/18
5/2/18
6/2/18
7/2/18
8/2/18
9/1/18
10/1/18
11/1/18
12/1/18

GROUNDWATER MODELING WORKING GROUP
MEETING SUMMARY—OCTOBER 3, 2018

Noman Ahsanuzzaman ✓
Brian Begley ✓
Ben Bentkowski
Rich Bonczek ✓
Gaye Brewer ✓
Stephanie Brock
Martin Clauberg ✓
Bryan Clayton
Julie Corkran ✓
Jana Dawson
Eva Davis ✓
Ken Davis ✓
Dave Dollins ✓
Bruce Ford ✓
Stefanie Fountain
LeAnne Garner ✓
Nathan Garner ✓
Steve Hampson ✓
Jeri Higginbotham ✓
Chris Jung ✓
Brian Lainhart ✓
Kelly Layne ✓
Mac McRae ✓
Teresa Overby
Todd Powers ✓
Bruce Stearns ✓
Tracy Taylor ✓
Denise Tripp ✓

✓ indicates member was present.

1. Call for Issues from Groundwater Modeling Working Group (MWG) Members

Ken Davis has a river evaluation hydrograph provided by the Tennessee Valley Authority (TVA) (Attachment 1). The far right side of the graph shows Olmsted dam operating (approximately 308 ft baseline). Ken also discussed the discrepancies between river levels at various gauge stations.

2. Status of Previous Meeting Summary

September Meeting Summary was sent October 1. A revised summary will be sent after comments are received.

3. Proposed FY 2019 Work Plan/Schedule

Develop Draft FY 2019 Schedule	9/12/2018
Quarterly Meeting (October)	10/3/2018
Submit FY 2019 Schedule	10/10/2018
DOE Issue Revised MW460 White Paper to MWG for Review and Comment	10/30/2018
MWG concurs with FY 2019 Schedule	11/9/2018
MW460 White Paper Comments from MWG Due to LeAnne/Ken	11/30/2018
Quarterly Meeting (January)	1/9/2019
LeAnne will Submit Compilation of Meeting Notes and White Papers Completed	2/12/2019
Comments from MWG Due for Meeting Notes and White Papers Compilation to LeAnne	3/12/2019
Quarterly Meeting (April)	4/10/2019
Quarterly Meeting (July)	7/17/2019
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Quarterly meetings will be Web/teleconference 8:00 a.m.–11:00 a.m. (Central), 9:00 a.m.–12:00 p.m. (Eastern)
If topics warrant, a face-to-face meeting will be considered. Currently, a face-to-face meeting is not scheduled.

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

Additional details for projects proposed at the September 2018 meeting are the following.

- **Look at west side of site associated with the Southwest (SW) Plume [Trichloroethene (TCE) extents, to address anomaly in plume maps].** A Regional Gravel Aquifer (RGA) water level study is planned, including use of colloidal borescope and pressure transducers. Data collection is expected to last about one year. 24 manual water level measurements are planned to be collected in 20 wells (i.e., approximately 2 per month for each well). Additionally, measurements from 3 colloidal borescopes and 4 pressure transducers over 12 mobilizations are planned be collected.

Ken Davis explained that colloidal borescopes show the direction of flow by measuring the movement of visible colloids within the well. The intent is to measure flow in the highest velocity interval of the well screen. The midpoint of the well screen is planned to be the default setting where a depth of higher flow velocity is not evident. A project plan is being developed and will be shared, once it is ready.

Reference information regarding the colloidal borescope can be found at the website of the primary colloidal borescope vendor, Geotech Environmental Equipment, Inc.: http://www.geotechenv.com/geotech_colloidal_borescope.html. The website contains links to several papers describing use of the colloidal borescope.

Additionally, a study was completed at Paducah, the Phase 1 Waste Area Group 6 Industrial Hydrogeologic Study. This study can be found at the following link: https://eic.pad.pppo.gov/Search.aspx?accession=I-00809-0061.

- **Similar look at downgradient Northeast (NE) Plume (TCE extents).** Similar steps as described above for SW Plume. Manual water level measurements are planned to be collected in about 40 wells. Additionally, measurements from 3 colloidal borescopes and 4 pressure transducers over 12 mobilizations are planned to be collected. Data collection is planned to be completed over east and west sides of NE Plume, for about one year. The two studies (NE and SW Plumes) are planned to be run concurrently, to the extent practical.

- **Synoptic water levels in transect back to Ohio River (combination of physical measurement and data loggers).** (Include AIP's measurements—Coordinates in OREIS for a couple of the TVA wells did not plot in correct location. Information will be transmitted formally; raw data also available.) Synoptic water levels also have been completed previously, but now are planned to be completed more frequently during the year-long test. (See also next bullet.)

- **Continuous water levels near the Ohio River to document aquifer properties prior to completion of the Olmsted Dam project.** The dam was completed prior to recording continuous water levels, but we do have a baseline from synoptic water event in August 2018 (additionally, including the TVA data will achieve a more robust baseline dataset). Manual water level measurements are planned to be collected for up to four quarterly events for 1 year in approximately 248 wells (i.e., all of the RGA wells). At least one of the quarterly synoptic efforts is planned to include water level measurements in the Upper Continental Recharge System and other wells that are part of the Paducah Site monitoring network. The MWG requested this project consider also including McNairy wells.

- **Look at water level divide (NE Plume hydraulic study).** Hydraulic study will be included in FFA Semiannual Report. A separate report will be developed to include colloidal borescope information from upcoming study.

  This project is planned to include 3 colloidal borescopes and manual water level measurements across 46 wells, lasting approximately 3-4 months.

4. Olmstead Locks and Dam Update

Locks and dam have started operating.

5. Update on Option(s) to Establish a Water Level Gauge at Metropolis Lake

Brian Begley has sent new contact information with the Kentucky Nature Preserves (Josh Lillpop) and a research permit application. Brian and Chris Jung met with Josh, and he expressed his concerns regarding collection of water levels (e.g., creation of new trails). FRNP/DOE will need to complete application. Permits typically are for one year, but Josh will allow this activity to be for two years. The application will need to be renewed, as appropriate. Ken will let Brian know when the application has been sent, so that Brian can follow up.

6. Update on TVA Process Water Basin

- MW152 and MW153 currently are being abandoned. New well (MW152A) is planned to be installed in the spring. Follow up information regarding installation of the replacement well, MW152A is dependent on final design and building of the road for access. The location of MW152A was placed using the best information available at the time (i.e., TVA's design of process water basin).

- DOE plans to share new TVA well data, once it is available to share.

7. Update on Paducah Site Monitoring Well Abandonment/Replacement

MW464 (NE Plume) is being abandoned and replaced because casing had failed.
MW253 (NE Plume) is being abandoned and replaced because casing failure is suspected.
The intent is to install replacement wells next to previous locations.
Teresa Overby reported, as a follow up to the meeting, these wells are scheduled to be abandoned/replaced following completion of the MW152/MW153 abandonment.

8. Projects on the "Watch Topics" List

- **Stream gauging in relation to the synoptic water levels should be considered.** Steam gauging has been discussed as part of out-year activities. Stream gauging could be as simple as a measurement of the water depth at control points, more complete measurements of total-stream flow rate at control points, or a stream-length survey of total-stream flow to define gaining and loosing reaches. The group needs a defined scope of what is needed, and why it is needed.

  USGS previously had stream gauges, but they no longer are operating. Flow rates would be useful to determine whether the stream is losing or gaining. These rates would be collected over different times and possibly in transects. This information could be included with the SW Plume Information (Bayou Creek) (See Item 3, Bullet 1).

  Watershed Monitoring Reports (from Oak Ridge National Laboratory) contain historical information on gaining/losing streams, collected from approximately 1989-2000. The most recent of these reports is linked here: https://eic.pad.pppo.gov/Search.aspx?accession=H-00101-0001.

  Elevation of creek is an important parameter for the boundary of the model. Base of creek is available from previous Corps of Engineer study and the Surface Water Operable Unit Scoping Document. The following is reference information for these documents.

COE (U.S. Army Corps of Engineers) 1994. *Environmental Investigations at the Paducah Gaseous Diffusion Plant, and Surrounding Area, McCracken County, Kentucky*, Volume V, *Floodplain Investigation, Part A, Results of Field Survey*, U.S. Army Corps of Engineers, Nashville, TN, May. Accessible at https://eic.pad.pppo.gov/Search.aspx?accession=I-04502-0004.

DOE (U.S. Department of Energy) 1999. *Scoping Document for the Surface Water Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Paducah, Kentucky, DOE/OR/07-1798&D1, U.S. Department of Energy, Paducah, KY, March. Accessible at https://eic.pad.pppo.gov/Search.aspx?accession=I-04810-0001.
See especially, Figures 3-4 and 3-5 (pages 44 and 45 of the pdf), Figures 3-7 and 3-8 (pages 51 and 52 of the pdf).

Additionally, a total maximum daily load study was performed by KY as part of a warm water aquatic habitat/impaired waters study (additional information here: http://water.ky.gov/waterquality/Pages/303dList.aspx). No flow or elevation information is provided in the report.

For the groundwater model, the northern portion of the creek would be relevant. Assumptions were made elsewhere. See Figure 5.4 of the Sitewide Groundwater Flow Model (page 83 of the pdf). Where creeks cross the plume, determining the accuracy of the assumptions is important. This information is especially important for understanding the SW Plume.

- White paper in FY 2020 to address "Installation of piezometers equipped with continuous water level monitors associated with several of the large process buildings [or evaluation of sumps] would define the thickness of the sub-slab gravel base and the temporal water level fluctuations beneath several of the large buildings better."

- White paper in FY 2020 to address "Flow rate in the McNairy Formation is negligible compared to the RGA because the hydraulic conductivity is 2 to 3 orders of magnitude lower than in the RGA; however, the McNairy Formation may be significant for DNAPL source accumulation and contaminant transport. Future transport models based on the 2016 flow model will need to consider potential mass flux from the McNairy to the RGA resulting from back diffusion." RGA and McNairy information from the C-400 RI/FS will be needed to complete this White Paper.

  Adding McNairy Formation will be considered for future models. Addition of McNairy wells can be considered as part of C-400 RI/FS. The D1 C-400 RI/FS Work Plan is due to EPA and KDEP in November 2018 for review and comment. Some upper McNairy Formation wells are available on-site currently.

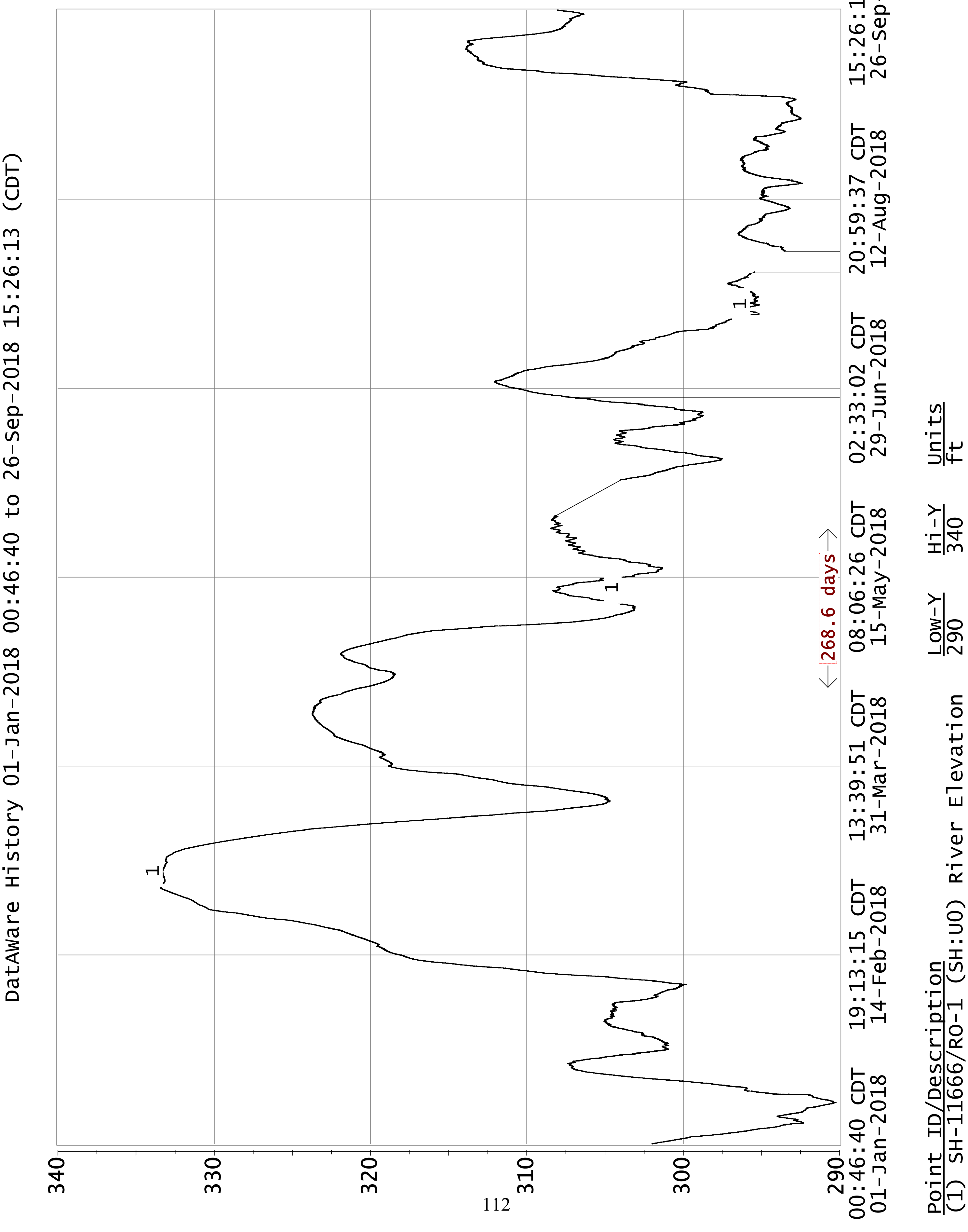
- Corridors where overhead transmission lines have been removed have been considered for monitoring well placement, especially with respect to the west side of the NE Plume. Previously, overhead transmission lines prevented installation of wells to the west in the northern-most transect of wells. Installation of additional wells in this transect can be considered for efficiency during installation of new MW152A. See also Item 6.

9. Poll MWG Members/Open Discussion

Raw water lines: Currently the Paducah Site is using only one raw water line; the other is out of service. Kelly Layne checked to see if leaking water is evident. She followed up after the meeting with an e-mail stating she had checked with the utilities manager and all known water leaks with the raw water line in use have been addressed.

Pygmy meters: Pygmy meters were suggested to be considered for measuring streamflow velocities. (See Item 8, Bullet 1.)

ATTACHMENT 1



REVISED

EVALUATION OF TCE TRENDS IN MW460

INTRODUCTION

As a step in optimization of the Northwest Plume Groundwater System, pumping shifted from former extraction wells, EW228, EW229, EW230, and EW231, to new extraction wells, EW232 and EW233, in October 2010. A transect of monitoring wells was installed downgradient of EW232 and EW233 to assess the capture efficiency of the new extraction wells. Analyses of groundwater samples from the downgradient transect monitoring wells (Figures 1 and 2) have continued to detect higher trichloroethene (TCE) levels in lower Regional Gravel Aquifer (RGA) monitoring well MW458 (up to 540 µg/L, with the peak in December 2011) and in lower RGA monitoring well MW460 (up to 445 µg/L in September 2016). These TCE levels might indicate either lingering TCE levels in the Northwest Plume to the north of the extraction wells, as groundwater is pulled back (southward) to the extraction wells, or Northwest Plume bypass of the extraction wells within the lower RGA. The overall potentiometric surface of the RGA for August 2016 (Figure 3) shows the extent of the cone of depression induced by the new extraction wells. Vertical gradients within the RGA are slight; available monitoring data do not define the vertical extent of the zone of capture.

INTERPRETATION OF TCE MONITORING RESULTS

Figure 1 provides a plan view of Northwest Plume extraction wells at the northwest corner of the Paducah Gaseous Diffusion Plant (PGDP) limited access area, including currently operating extraction wells EW232 and EW233, and the associated downgradient monitoring well network. The figure identifies the downgradient monitoring well clusters (screened in the upper and lower RGA) that make up the transect of monitoring wells, along with two areas of interest, Area A, and a far downgradient monitoring well cluster, Area B. Three lines denote the interpreted location of the centroid of TCE concentration in the Northwest Plume downgradient of the extraction wells during December 2011, October 2012, and January 2017.

Figure 4 presents TCE trends in the lower RGA monitoring wells with higher TCE levels, MW458 and MW460, of the monitoring well transect, and MW454 of the far downgradient monitoring well cluster, and summarizes the interpretation of the location of the centroid of the downgradient TCE plume relative to the monitoring wells. The centroid of TCE contamination within the Northwest Plume appears to be migrating eastward with little decrease of TCE levels over time. An alternative interpretation is that TCE levels have declined in the centroid of the plume in Area B since May 2013 (and are expected to decline in MW460 in the future).

It is noted that a recent review of seismic information indicates that some contaminant plume migration at PGDP might be fault-controlled. More recently, a review of results from seismic (shear wave) and electrical resistivity (dipole-dipole) experiments implies that the groundwater TCE plumes at PGDP are aligned with the general orientation of an underlying Paleozoic fault system (Almayahi and Wollery 2018). This implication is consistent with alignment of the Northwest Plume with a series of imaged grabens identified by Blits, Woolery, Macpherson, and Hampson in 2008. As such, the increasing TCE levels in downgradient MW460 may be an indication of plume migration along structurally controlled preferential pathway(s) due to faulting. Currently, uncertainty exists regarding the influence of fault-control plume migration both within the PGDP security-fenced area and outside this area. Detailed correlations between lithologic units across the site should be developed so an accurate characterization of site faulting can be performed.

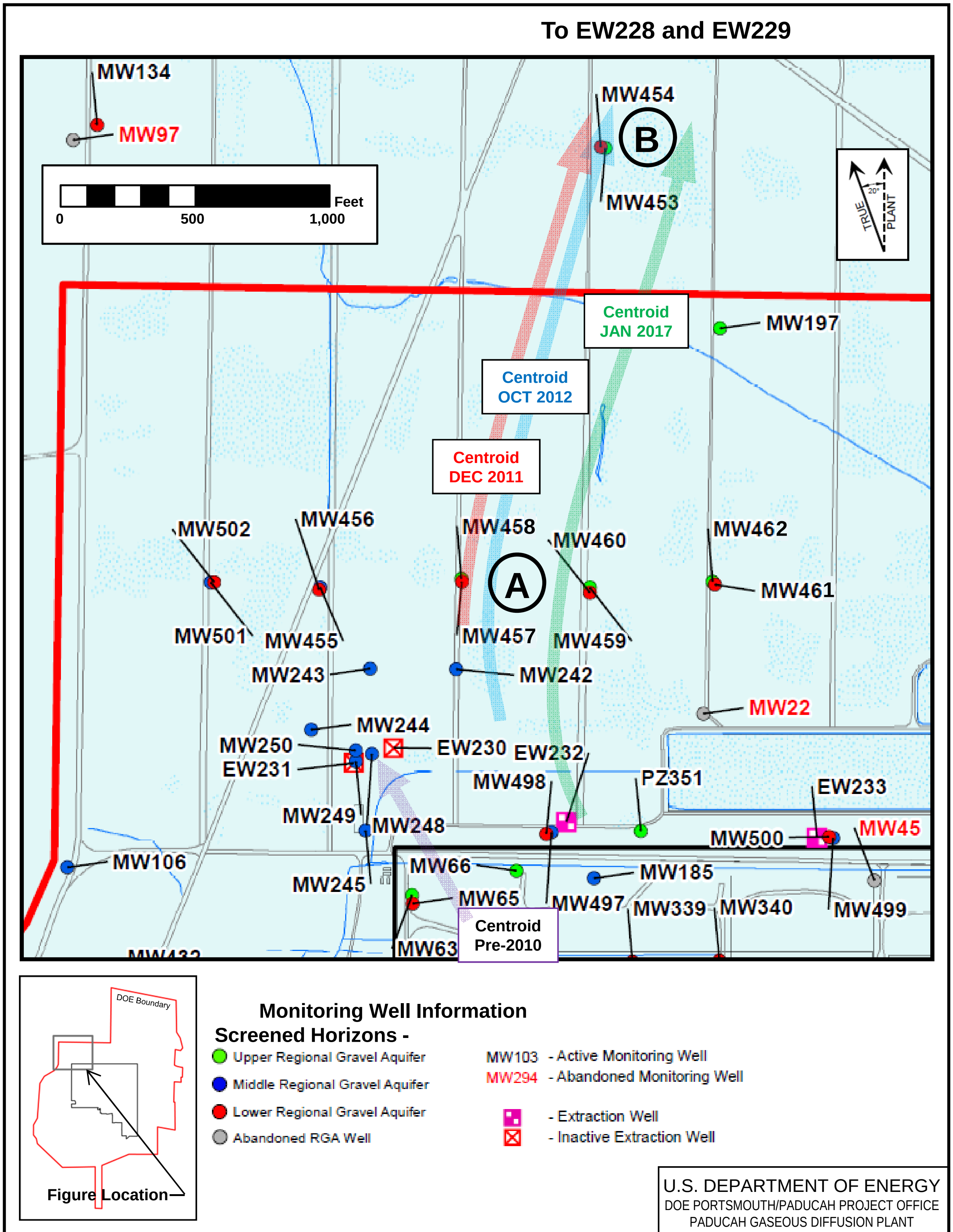


Figure 1. Plan View in the Area of the Northwest Plume Extraction Wells

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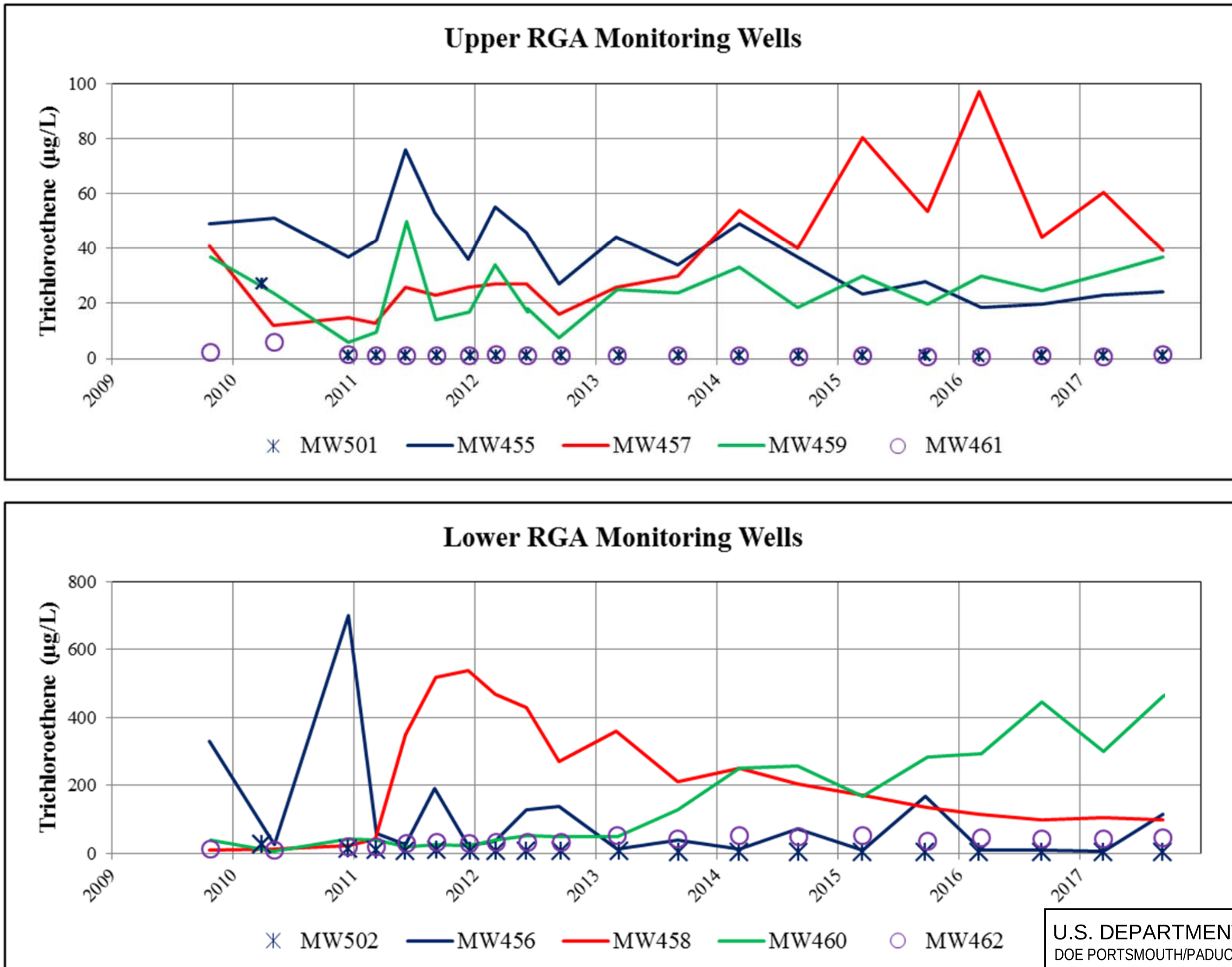
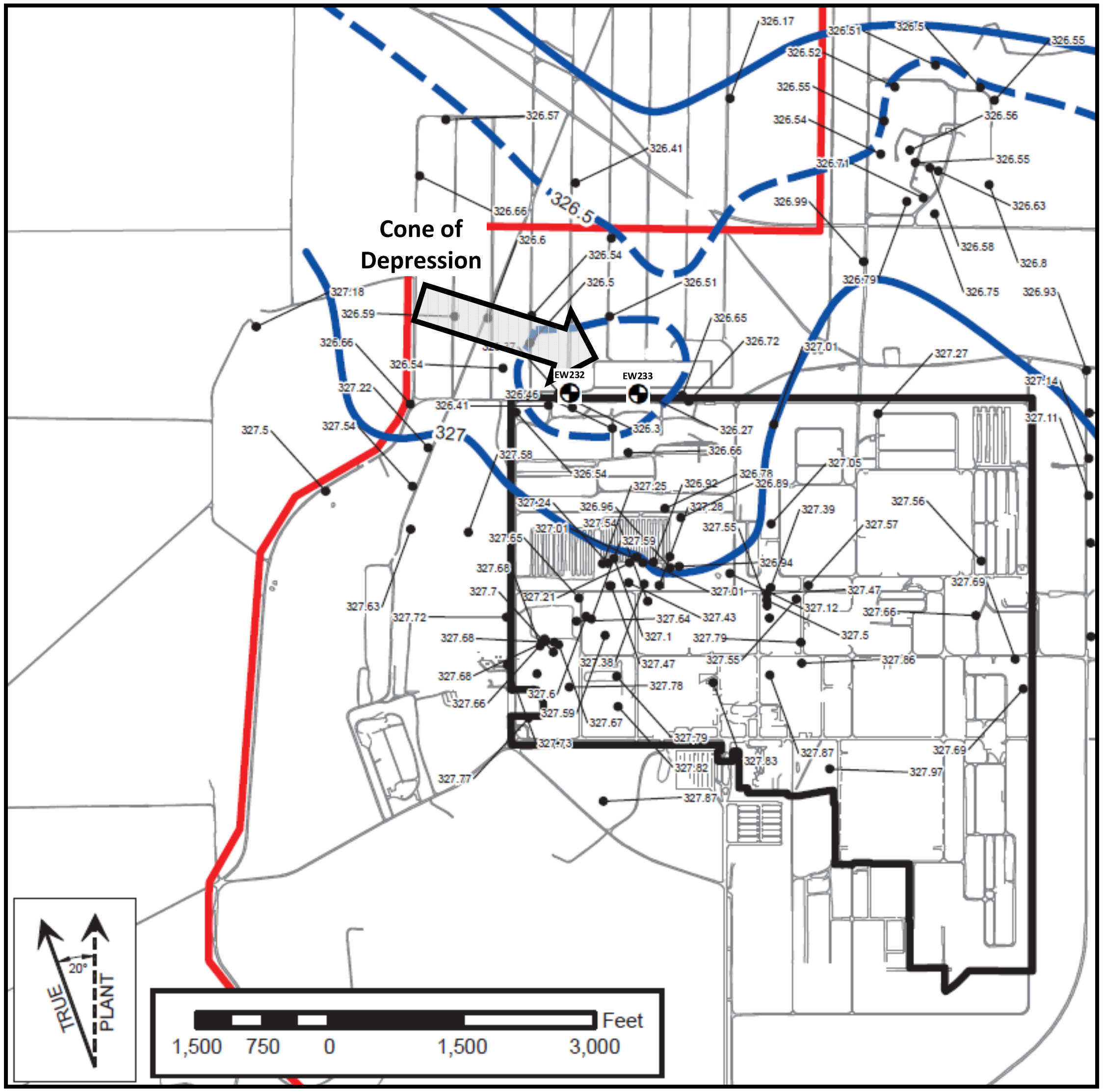


U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

Figure 2. Trichloroethene Trends in Monitoring Wells of Downgradient Transect



LEGEND

Monitoring Well or Piezometer Location with Water Level Measurement (ft amsl)

Extraction Well

Potentiometric Contour (ft amsl)

PGDP Boundary

DOE Property Boundary

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DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

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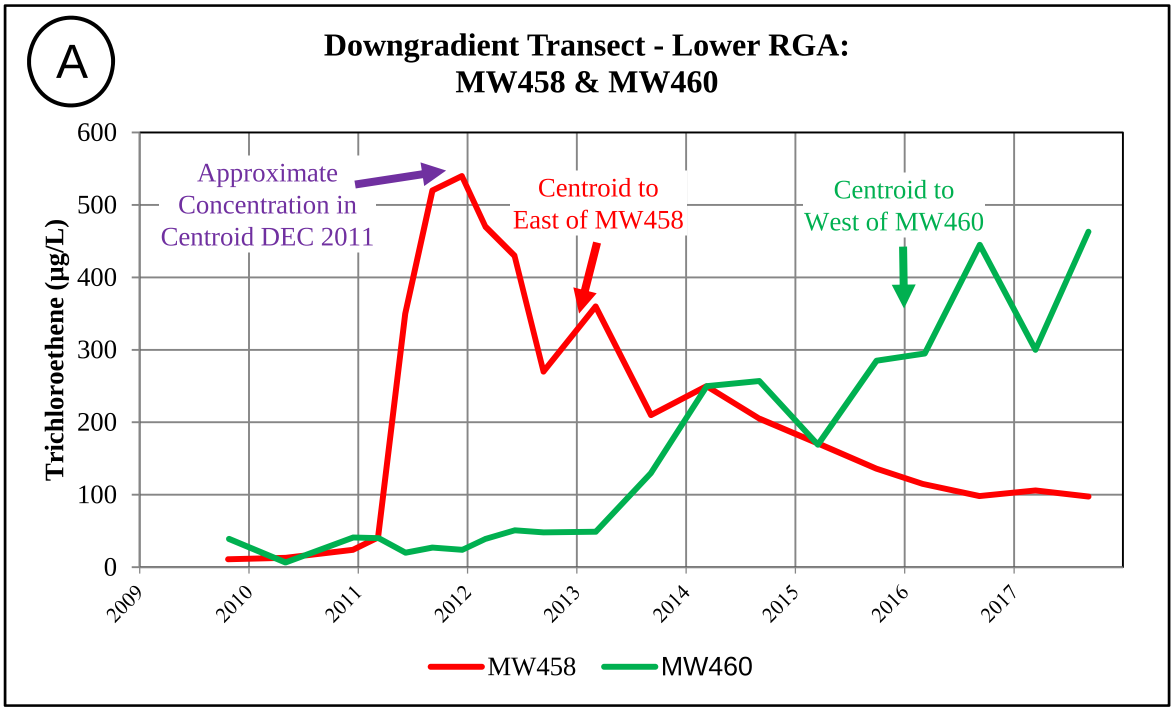
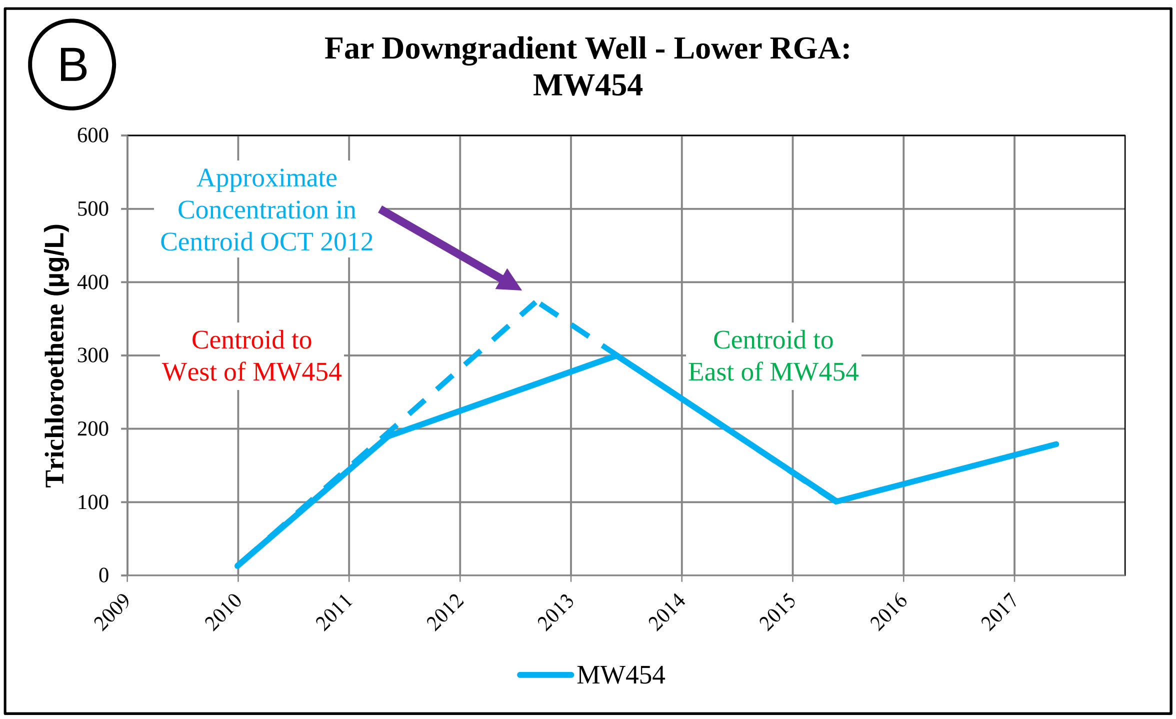
Figure 3. Regional Gravel Aquifer Potentiometric Map (August 2016)
from *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2016 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE 2017)*





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DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 4. Trichloroethene Trends in Select Monitoring Wells Located Downgradient of the Northwest Plume Extraction Wells

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ASSESSMENT OF VERTICAL ANISOTROPY

Vertical anisotropy of hydraulic conductivity generally is not apparent in soil cores of the RGA and was not apparent in the soil cores of monitoring wells located adjacent to EW232 and EW233. The lithologic logs for MW498 (located adjacent to EW232) and MW500 (located adjacent to EW233) report sands and gravels throughout the RGA interval. Grain size analyses are available for several depth intervals in these soil cores (10 each representing EW232 and EW233) with a minimally greater percentage of fine sand and silt at depths of 73.5 to 76.5 ft in EW232 and 86.5 to 92.5 ft in EW233.

A steam injection treatability study in the RGA at Building C-400, located approximately 3,000 ft southeast of EW232 and EW233, revealed the presence of distinctive lower and upper RGA facies, which was not visually evident. Steam front advancement determined the anisotropy of horizontal to vertical hydraulic conductivity to be 10:1 in the upper RGA and 30:1 in the lower RGA. It is likely that similar vertical anisotropy is present in the area of EW232 and EW233 and that horizontal flow dominates in the RGA in response to pumping in the extraction wells.

Groundwater samples collected in 1994 (before the Northwest Plume pump-and-treat system became operational), using a drive-point sampling system to vertically characterize TCE levels in the Northwest Plume, documented the centroid of TCE contamination occurred in the lower RGA at the northwest corner of the limited area [*Final Report on Drive-Point Profiling of the Northwest Plume and Analysis of Related Data* (DOE 1995)]. This is consistent with TCE occurrence in transects sampled further downgradient and is a key characteristic of the Northwest Plume conceptual site model. The centroid of the Northwest Plume in 1994 was located approximately 500 ft west of EW232 and 1,450 ft west of EW233 (both EWs were installed in 2010). Although the plume has migrated eastward, in part in response to pumping in EW232 and EW233 (since 2010), monitoring well analyses indicate the centroid of the Northwest Plume remains within the lower RGA (Figure 5).

Table 1 summarizes depths of EW232 and EW233 and the top and bottom of the RGA in the vicinity of the wells. In EW232, the pump intake is set 14.3 ft above the base of the RGA; in EW233, the pump intake is set 12.0 ft above the base of the RGA.

Table 1. Depths of EW232 and EW233 and Top and Bottom of RGA

Depth (feet below ground surface)	EW232	EW233
Top of HU5 Gravel Member of RGA	58.5	62.8
Top of Well Screen	66.5	73.5
Depth of Pump Intake	74.5	81.5
Base of Well Screen	86.8	93.5
Base of "Clean" HU5 Gravel Member of RGA	88.8	95.7

Figure 6 illustrates the screen and pump depths of EW232 and EW233 (installed in 2010) relative to vertical trends of TCE levels, as documented in 1994. The EW screen placement in EW233 appears optimal to intercept the TCE plume centroid.

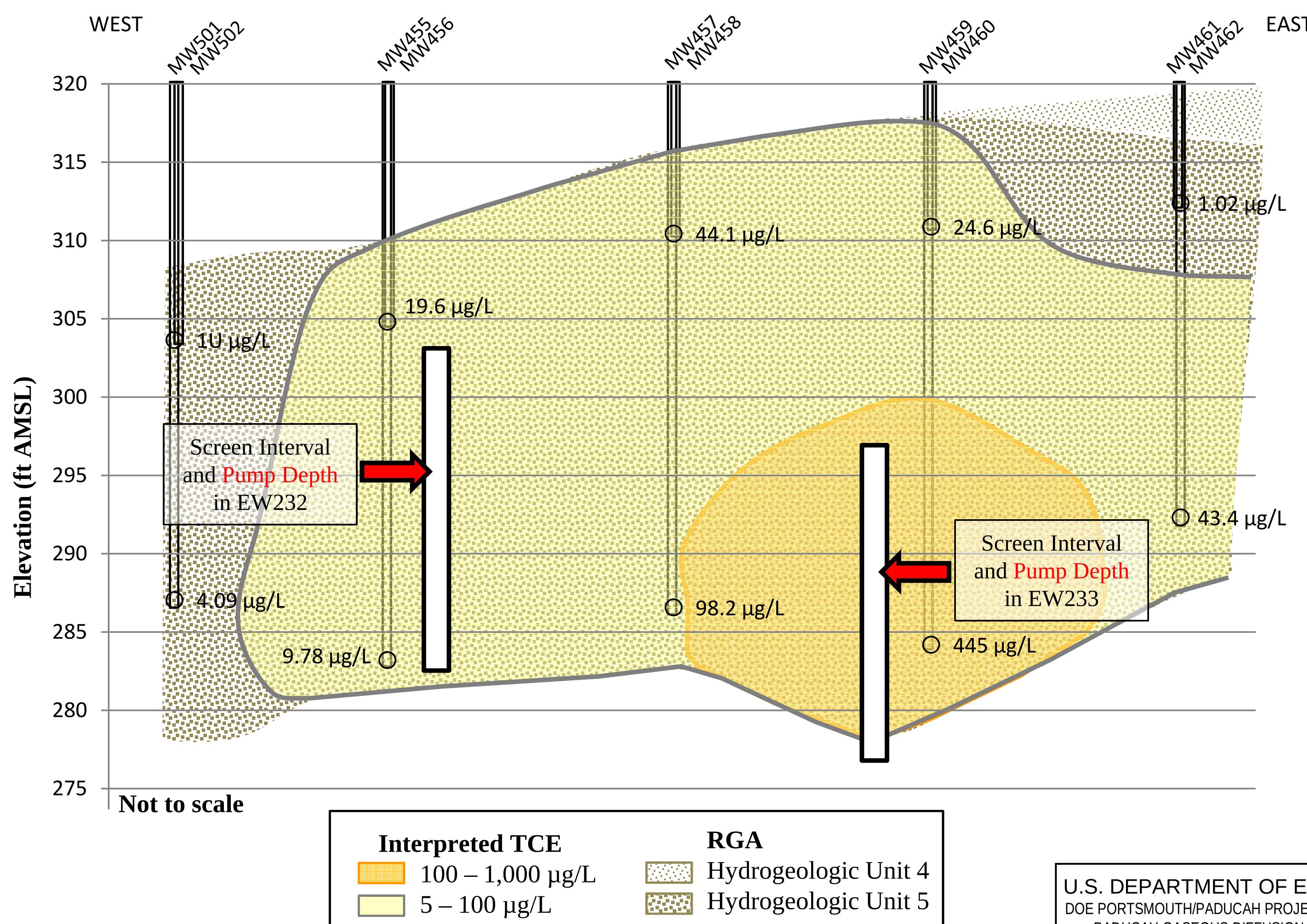

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Figure 5. 2016 TCE Plume Regional Gravel Aquifer Cross-Section, adapted from *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2016 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2017)

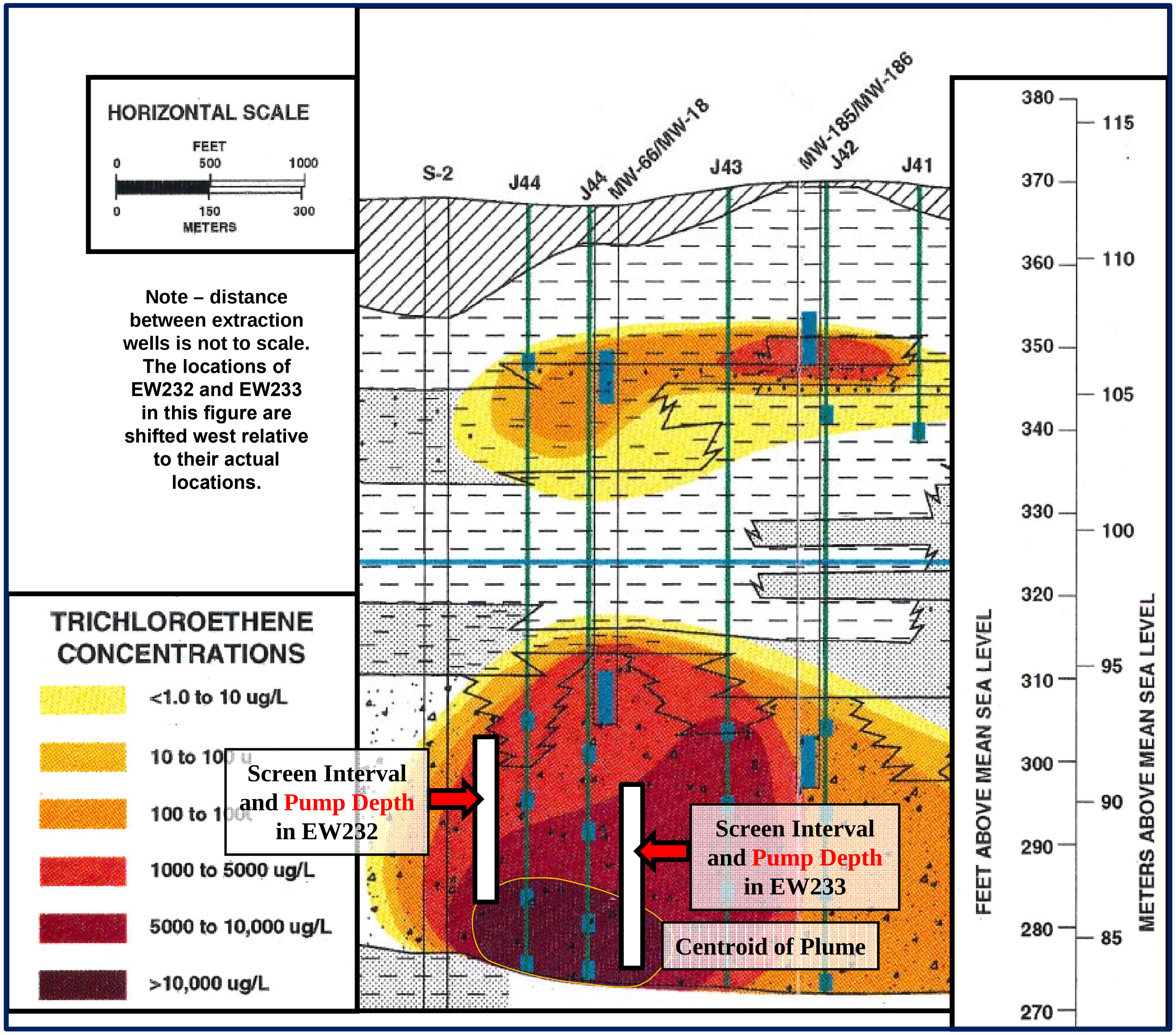

Figure 6. Model of Northwest Plume Extraction Well Depths in Relation to Trichloroethene Profile adapted from *Final Report on Drive-Point Profiling of the Northwest Plume and Analysis of Related Data* (DOE 1995)

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CONCLUSION

This assessment indicates that the likely condition is that the Northwest Plume is bypassing the EW232/EW233 well field within the lower RGA.[1] Soil texture indicates the horizontal hydraulic conductivity in the HU5 interval of the RGA in the area of the extraction wells is uniform throughout the depth of HU5. Nevertheless, a significantly greater mass of dissolved TCE occurs in the lower HU5 interval. Detailed correlations between lithologic units across the site should be developed so that the uncertainty in the presence of site faulting and its potential impact on contaminant movement and groundwater flow can be addressed. Three readily available options to optimize capture of the TCE plume centroid are (1) adjust the pumping rates between the two wells[2] (both wells are pumping at approximately 100 gal/minute: the combined pumping rate of the two wells is near the capacity of the treatment facility)[3]; (2) lower the pump intake in one or both wells; and (3) assess the need for rehabilitation of the extraction wells.[4] Should biofouling (or other blockage) be evident, then initiate a program of rehabilitation for the extraction wells. Either or both options may reduce or eliminate the potential for plume bypass. A third option is to incorporate pumping in one or both of the extraction wells of the original south wellfield for the Northwest Plume (EW230 and EW231) to increase the width and dynamics of the capture zone. Because the C-612 Pilot Pump-and-Treat facility is operating at near capacity, the resumption of pumping in the original extraction wells, EW230 or EW231, would require reduced pumping rates in the current extraction wells, EW232 and EW233.

The latest update of the groundwater flow model provides a basis to predict the benefits of different pumping scenarios by using a subset of the model created with the telescopic mesh refinement technique and centered on the optimized EWs. Appropriate boundary conditions would be defined by the sitewide model. A groundwater model assessment of the proposed actions for the EWs would require additional revisions to the subset model, including the following:

- Creation of additional RGA sublayers in the model to assess vertical capture better;
- Assignment of depth-discrete vertical anisotropy within the RGA, similar to that observed at C-400; and
- Improved resolution of the screen interval of the EWs. (The EWs currently are modeled as fully penetrating wells.)

The PGDP Sitewide Groundwater Modeling Working Group recommends development of an optimization plan to evaluate which combination of recommendations would work best.

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[1] A similar, independent assessment was noted in *Commonwealth of Kentucky Environmental Oversight Report 2016, Paducah Gaseous Diffusion Plant*, by Kentucky Division of Waste Management. Note, the lingering TCE levels in monitoring wells north of the EWs yet may be the result of pulling back downgradient contamination.

[2] Increasing the pumping rate in EW233 while decreasing the pumping rate in EW232 may optimize plume capture because of the current proximity of the centroid of TCE contamination to EW233 and because the RGA at EW233 has a lower hydraulic conductivity (as compared to EW232), resulting in a more extensive cone of depression.

[3] The maximum flow rate of several pieces of equipment in the C-612 Pilot Pump-and-Treat facility is 230 gal/minute or less, notably the equalization tank pump, the sand filter vessels, the air stripper pump, and the Kentucky Pollution Discharge Elimination System discharge header. The most limiting piece of equipment is the ion exchange system with a maximum flow rate of 200 gal/minute.

[4] The current EWs have not required rehabilitation previously. No downhole video inspections of the EWs have been made.

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