APPENDIX E

TECHNICAL INFORMATION

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E.1. DATA AND DOCUMENTS USED TO ESTABLISH BACKGROUND CONCENTRATIONS

As early as the late 1950s, the U.S. Department of Energy (DOE) and its predecessor organization determined the importance of identifying background concentrations for metals and radionuclides in the environment. Routine monitoring programs were established for air and grass. In 1971, the monitoring program was expanded to include surface soil samples taken at four locations at the plant perimeter, with the only analyte being total uranium.

In 1973, the locations of sampling were changed from the perimeter locations mentioned herein to four locations five miles from the plant perimeter. The only analyte was total uranium. From 1975 until 1985, the environmental monitoring program for soils continued as described.

The environmental report for 1986 states that the analyte list for soil samples was expanded from only uranium to thorium-230, neptunium-237, plutonium-239, and isotopic uranium. Starting in 1988, the radionuclide analyte list for soil samples taken as part of the environmental monitoring programs was expanded to include total uranium, uranium-238, cesium-237, potassium-40, neptunium-237, plutonium-239, thorium-230, and technetium-99. Also, beginning in 1988, analyses were performed for 36 metals. Metals included in the analyte list were aluminum, antimony, arsenic, barium, beryllium, bismuth, calcium, cadmium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, niobium, phosphorus, potassium, ruthenium, silver, sodium, silicon, strontium, tantalum, thallium, thorium, tin, titanium, tungsten, vanadium, zinc, and zirconium.

PHASE I AND II SITE INVESTIGATIONS REFERENCE SAMPLING

In 1988, DOE and the U.S. Environmental Protection Agency (EPA) entered into a Consent Order that defined the mutual objectives of the EPA and DOE to study groundwater contamination and the threat of releases from the Paducah Gaseous Diffusion Plant (PGDP). A copy of that Consent Order can be found at the following link: https://eic.pad.pppo.gov/Search.aspx?accession=I-02004-0002.

As part of the effort to address the Consent Order, a Site Investigation was performed in two phases. The *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, (ER/KY-4) was completed in 1991; and *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/SUB/13B-97777C P-03/1991/1, was completed in 1992. During the completion of Phase I and II Site Investigations, the need for background or reference concentrations for inorganic analytes and reference activities radionuclides was recognized. To meet this need, the Site Investigations included the collection of soil samples from areas outside known plant influence. To establish reference activities for radionuclides, 33 surface soil samples (from 0 to 12 inches in depth) were collected from areas at least 5 miles east and southeast of PGDP in May and June of 1990. The analytes for this sampling effort included gross alpha and gross beta, neptunium-237, technetium-99, plutonium-239, thorium-230, uranium-238, uranium-234, and uranium-235.

To establish reference concentrations for inorganic and metals, five surface samples (from 0 to 6 inches in depth) were taken during the Phase II Site Investigation in areas near the PGDP, but outside areas suspected to be influenced by the plant operations. The metals included aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, cyanide, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, vanadium and zinc. A report entitled *Inorganic Soil and Groundwater Chemistry Near Paducah Gaseous Diffusion Plant; Paducah, Kentucky*, ORNL/TM-12897, was prepared and sent to the regulatory agencies for information purposes. While this report was not prepared to establish background groundwater and soil concentrations, it did discuss potential background concentrations for soil and groundwater at PGDP.

In response to comments on *Soil and Groundwater Chemistry Near Paducah Gaseous Diffusion Plant; Paducah, Kentucky,* ORNL/TM-12897 (1996), DOE prepared another internal report with a more extensive evaluation of existing data (primarily data from the Phase I and II Site Investigations, entitled *Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant*, KY/EM-77&D1. The report contained data for 146 surface sampling locations and 597 samples for subsurface soils for metals analysis. The metals included all of those analyzed in the Phase II report with the exception of cyanide in surface and subsurface soils and thallium in subsurface soils. A consensuses of reviewers believed that the data evaluation in this report was not sufficient to establish background of metals in soil and requested that the document be revised.

In response, a revised report, *Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1417&D2, was prepared (DOE 1996). EPA conditionally approved this revised document. The conditions included the reanalysis of four metals including antimony, beryllium, cadmium, and thallium. Also in 1996, the Commonwealth of Kentucky accepted the revised report. The Commonwealth also called for additional sampling to verify the background concentrations of antimony, beryllium, cadmium, and thallium.

DOE issued the final revision of a work plan entitled *Project Plan for the Background Soils Project for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1414&D2 (DOE 1996). As described in this work plan, DOE was to verify with additional sampling the background concentrations for the four metals listed in the conditional approval letters for DOE/OR/07-1417&D2 and to determine the background concentrations of selected radionuclides.

DOE issued the final revision of the report for the background soils project entitled, *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1586&D2. In this report, the values selected by DOE as background concentrations for soil in the DOE/OR/07-1417 report were combined with the background concentrations analyzed for antimony, beryllium, cadmium, thallium, and selected radionuclides, and final background concentration data sets were established. This report included 15 surface soil and 41 subsurface soil sampling locations for the four metals listed above. In addition the significant radionuclides included cesium-137, neptunium-237, plutonium-239, plutonium-238, potassium-40, radium-226, strontium-90, technetium-99, thorium-228, thorium-230, thorium-232, uranium-238, uranium-234, and uranium-235. A variety of statistical methods as described in *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1586&D2, were used to evaluate the data and ultimately these data were used with data from previous investigations to establish the background values for soils at PGDP. The background values are presented in Appendix A.

APR 1 1996

JAMES E. BICKFORD
SECRETARY

PAUL E. PATTON
GOVERNOR

received
4/3/96 bsg

COMMOMWEALTH OF KENTUCKY
NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION CABINET
DEPARTMENT FOR ENVIRONMENTAL PROTECTION
FRANKFORT OFFICE PARK
14 REILLY RD
FRANKFORT KY 40601

March 21, 1996

Mr. Jimmie Hodges, Site Manager
U.S. Department of Energy
Paducah Site Office
P.O. Box 1410
Paducah, Kentucky 42001

Mr. Jimmy Massey, Plant Manager
Lockheed Marietta Energy Systems
761 Veterans Avenue
Kevil, Kentucky 42053

RE: Comments to Comment Summary Response for the Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky. Document Number DOE/OR/07-1417&D1 (formerly known as KY/EM-77).
EPA Number KY8-890-008-982

Gentlemen:

This letter is intended to serve as the response to DOE's Comment Response Summary dated February 5, 1996, for the above mentioned document. In addition, the following comments have been generated in response to our phone conversations of January 16 and 17, 1996 with Tony Able of EPA Region IV, Carlos Alvarado of DOE, and their contractors.

Background concentrations must be determined at this facility under condition IV.D.3.b. of DOE's Kentucky Hazardous Waste Permit (#KY8-890-008-982). To satisfy this condition for inorganics in soil, DOE submitted *Inorganic Soil and Groundwater Chemistry Near Paducah Gaseous Diffusion Plant* (Moore Report, released as Lockheed Martin document # ORNL/TM-12897) and the *Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (released as Lockheed Martin document # KY/EM-77) in April 1995. The Division of Waste Management (Division), after review of these two documents, rejected the Moore Report and asked DOE to resubmit the EM-77 report. The EM-77 Report was resubmitted in September 1995 under DOE Document # DOE/OR/07-1417 with the same title.

After further review of the EM-77 Report, the Division's accepts the background values based on the fact they are comparable to background values established by H. T. Shacklette, 1981. Additionally, the selected background values for PGDP are comparable to the Western Kentucky Region. The selected background values, which are summarized below, are found in Tables 2.14 and 2.15 of DOE's current background soils document.

	SURFACE SOILS (mg/kg)	SUBSURFACE SOILS (mg/kg)
Aluminum	15,700	17,300
Arsenic	12.0	18.7
Barium	198	341
Calcium	293,000	236,000
Chromium	16.0	112
Cobalt	14.0	16.0
Copper	19.0	61.5
Iron	27.700	47,400
Lead	38.0	119
Magnesium	8,250	3,250
Manganese	2,700	1,920
Mercury	0.33	0.42
Nickel	21.0	84.7
Potassium	1,870	1,640
Selenium	0.98	0.87
Silver	2.3	3.8
Sodium	344	404
Vanadium	38	68.9
Zinc	65	190

The remaining four analytes, which are antimony, beryllium, cadmium, and thallium, will be addressed in the *Project Plan for the Background Soils Project for Paducah (BSPP) Gaseous Diffusion Plant, Paducah, Kentucky* (DOE/OR/07-1414&D2). The Division understands that the BSPP is scheduled to start field work late this summer.

Additionally, the Division understands that these numbers are maximum background values where variability of the soil has been taken into consideration. Therefore, any value exceeding these numbers will be considered contamination.

If you have any comments or questions, please call Tuss Taylor at (502) 564-4797.

Sincerely,

Robert H. Daniell, Director
Kentucky Division of Waste Management

RHD/tt/ke

cc: Tony Able, EPA Region IV
Robert Sleeman, DOE
John Morgan, LMES
Carlos Alvarado, DOE
Ken Yates, KDWM-Paducah
Pending File # 95-0019

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

MAR 22 1996

4WD-FFB

Mr. Jimmie C. Hodges, Facility Manager
U.S. Department of Energy
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Paducah, Kentucky 42001

Mr. Jimmy C. Massey, Plant Manger
Martin Marietta Energy Systems, Inc.
P.O. Box 1410
Paducah, Kentucky 42001

Mr. Robert C. Sleeman, Manager
Enrichment Restoration Programs
U.S. Department Of Energy
Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831-8541

SUBJ: Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant (DOE/OR/07-1417&D1)

Dear Gentlemen:

The Environmental Protection Agency (EPA) has completed review of the subject document dated September 1995. EPA is hereby conditionally approving the subject document. The basis of approval will be the reanalysis of the four (4) analytes including Antimony, Beryllium, Cadmium, and Thallium. Per discussions between our staffs, reanalysis of these metals will be completed during the Background Soils Project to be initiated later this fiscal year. Of the four analytes, Beryllium and Cadmium will require surface sampling. Antimony and Cadmium will require subsurface sampling.

The development of the Background Soils Concentrations will be useful in future investigations. Specifically, it will save time and investigation costs by eliminating the need for background sampling for each new investigation.

If you have questions regarding this matter, please contact me at 404-347-3555, extension 6429.

Sincerely Yours,

Tony Able

Tony Able
Remedial Project Manager
Waste Management Division

cc: Tuss Taylor, KDEP
Arnold Guevara, DOE-HQ
✓ John W. Morgan, MMES
Pat Haight, KDEP

3233

DWM# 830-6

CABINET FOR HEALTH SERVICES
COMMONWEALTH OF KENTUCKY
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DEPARTMENT FOR PUBLIC HEALTH

MAY 15 1997

May 15, 1997

Myrna Redfield
U.S. Department of Energy
Paducah Site Office
P.O. Box 1410
Paducah, Kentucky 42001.

Tuss Taylor
UKFFOU
14 Reilly Road
Frankfort, Kentucky 40601

Re: Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, PGDP, Paducah Kentucky (DOE/OR/07-1586&D1).

Dear Ms. Redfield and Mr. Taylor:

The Radiation Control Program (RCP) has completed its' review of the subject document. The RCP's concerns and questions were addressed during the scoping, data analysis, and data assessment processes. The RCP has no comments at this time.

The RCP commends the Department of Energy for conducting a scientifically sound project that has provided reference data for the assessment of radionuclide contamination and risk at the Paducah Gaseous Diffusion Plant. Because of the sound scientific approach utilized during this project, I have sent the document to the Multi-Agency Radiation Laboratory Analytical Procedure Committee for consideration as a model to be used by all federal and state agencies for project planning and execution.

If you have questions regarding the RCP's position on the subject document, feel free to contact Dr. John A. Volpe (502) 564-3700 or Steve Hampson (502) 564-8390.

Sincerely,

John A. Volpe, Ph.D., Supervisor
Radiation and Toxic Agents Control Section

c: Steve Hampson

RECEIVED 6/11/97 dne

RECEIVED 8/9/99 CH

(1)

RECORD COPY

JAMES E. BICKFORD
SECRETARY

PAUL E. PATTON
GOVERNOR

COMMONWEALTH OF KENTUCKY
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FRANKFORT KY 40601

Morgan
S.N.
D.L.

May 28, 1997

I-04202-0001

Mr. Jimmie Hodges, Site Manager
United States Department of Energy
Paducah Site Office
P. O. Box 1410
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Mr. Jimmy C. Massey, Plant Manager
Lockheed Martin Energy Systems, Inc.
761 Veterans Avenue
Kevil, Kentucky 42053

Re: Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, KY (DOE/OR/07-1586&D1)
Permit # KY8-890-008-982
McCracken County

Gentlemen:

The Division of Waste Management has reviewed the background values presented in the above document. The values presented for the radionuclides, beryllium, thallium, antimony, and cadmium are approved. The investigation has provided valuable data for background at this site. We commend DOE for working closely with personnel from the Agreement in Principle and the Cabinet for Health Services Radiation Control Branch to develop a scientifically sound background investigation. It is our hope that DOE will continue this trend when developing future workplans for investigating contamination at the Paducah Gaseous Diffusion Plant.

The Division approves the following values for beryllium, thallium, antimony, and cadmium in soil as presented in the *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, KY (DOE/OR/07-1586&D1)*:

REVIEWED FOR CLASSIFICATION
Ccw 2-15-14
Initials Date
UNCLASSIFIED

REVIEWED FOR CLASSIFICATION
G. Lamb 5/9/22
Name Date

UNCLASSIFIED

UNCLASSIFIED

Analyte	surface (0-1 ft) (mg/Kg)	subsurface (below 1 ft) (mg/Kg)
beryllium	0.673	0.686
thallium	0.209	0.336
antimony	0.21	0.21
cadmium	0.21	0.21

If you have any question or need additional information, please call Tuss Taylor at (502) 564-4797.

Sincerely,

Robert H. Daniell, Director
Division of Waste Management

RHD/tt/ke

cc: Carl R. Froede, Jr., USEPA Region 4
Robert Sleeman, DOE
Carlos Alvarado, DOE
Margie Williams, DWM-Paducah Regional Office
John Morgan, LMES
John Volpe, CHS
DWM file #830

Received 7/15/97

RECEIVED 8/11/97 CH

JUL 14 1997

①

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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Morgan.
S.N.
J.L.
copy to DMM
[illegible]

JUL 08 1997

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

4WD-FFB

Mr. Jimmie Hodges, Site Manager
U.S. Department of Energy
Paducah Site Office
P.O. Box 1410
Paducah, Kentucky 42001

Mr. Jimmy C. Massey, Plant Manager
Lockheed Martin Energy Systems, Inc.
761 Veterans Avenue
Kevil, Kentucky 42053

SUBJ: D2 - Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant (DOE/OR/07-1586&D2)

Gentlemen:

The Environmental Protection Agency (EPA) has completed our review of the revised D2 version of the Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant. This revised document adequately addresses all of our previous comments. This document is approved in this version.

Any and all concerns raised by the Kentucky Department of Environmental Protection must be addressed within this document as required under their authority.

Any questions concerning these matters should be directed to me, at (404) 562-8550.

I-04202-0002

Sincerely,

Carl R. Froede Jr.

Carl R. Froede Jr., P.G.
DOE Remedial Section
Federal Facilities Branch
Waste Management Division

REVIEWED FOR CLASSIFICATION
G. Lamb 5/9/22
Name Date
UNCLASSIFIED

cc: T. Taylor, KDEP/Frankfort
R. Thomas, KDEP/Frankfort
J. Stickney, KDEP/Frankfort

REVIEWED FOR CLASSIFICATION
AWW 2-15-13
Initials Date
UNCLASSIFIED

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E.2. SITE-SPECIFIC EXPOSURE INFORMATION

This section of the appendix contains copies or excerpts of reports, memoranda, articles, and links to reports that are useful in developing exposure assessments for PGDP and justifying various assumptions made when completing risk assessments and analyses. These include the following:

- Site Investigation surface water and groundwater users survey to determine groundwater use near PGDP (CH2M HILL 1991);
- Summary of agricultural practices in Ballard County, Kentucky;
- Summary agricultural practices in McCracken County, Kentucky;
- Area of crop land in Ballard and McCracken Counties, Kentucky;
- Recreational use of Bayou and Little Bayou Creeks near PGDP;
- Annual harvests of geese, ducks, turkeys, and deer in McCracken and Ballard Counties, Kentucky; and
- Reports entitled, "Planning Issues for Superfund Site Remediation," and "Quantitative Decision Making in Superfund: A Data Quality Objectives Case Study," from *Hazardous Materials Control* regarding use of exposure units in risk calculations and remedial decisions.

E.2.1 PHASE I SITE INVESTIGATION RESULTS OF SURFACE WATER AND GROUNDWATER USERS SURVEY TO DETERMINE GROUNDWATER USE NEAR PGDP

A surface water and groundwater user's survey was conducted as part of the Site Investigation Phase I, and is included in the document's Appendix 2B-15 (CH2M HILL 1991). The appendix in its entirety can be found at the following link: https://eic.pad.pppo.gov/Search.aspx?accession=I-02300-0001 (part f). Appendix 2B-15 begins on page 276 of the pdf.

> Because the Site Investigation Phase I is large, it is broken into several parts. Part "f" contains Appendix 2B-15. Click "View" at the left of the screen of the above link to see the document.

E.2.2 SUMMARY OF AGRICULTURAL PRACTICES IN BALLARD COUNTY, KENTUCKY

This section summarizes information obtained from a 2017 search of various public records to identify the parameters of agricultural practices in Ballard County, Kentucky.

Population. Population information for Ballard County is taken from http://www.city-data.com/county/Ballard_County-KY.html, accessed October 2017.

- 8,240 population (as of 2014)
- Size of family households: 1,179 2-persons; 552 3-persons; 405 4-persons; 157 5-persons; 52 6-persons; 27 7-or-more-persons

- Size of nonfamily households: 881 1-person; 131 2-persons; 5 3-persons; 6 4-persons; 1 5-persons; 1 6-persons

Agriculture in Ballard County. Agriculture information for Ballard County is taken from http://www.city-data.com/county/Ballard_County-KY.html, accessed October 2017.

- Average size of farms: 233 acres
- Average value of agricultural products sold per farm: $70,647
- Average value of crops sold per acre for harvested cropland: $213.68
- The value of nursery, greenhouse, floriculture, and sod as a percentage of the total market value of agricultural products sold: 0.18%
- The value of livestock, poultry, and their products as a percentage of the total market value of agricultural products sold: 55.27%
- Average total farm production expenses per farm: $60,366
- Harvested cropland as a percentage of land in farms: 63.59%
- Irrigated harvested cropland as a percentage of land in farms: 0.29%
- Average market value of all machinery and equipment per farm: $50,268
- The percentage of farms operated by a family or individual: 91.56%
- Average age of principal farm operators: 55 years
- Average number of cattle and calves per 100 acres of all land in farms: 8.31
- Milk cows as a percentage of all cattle and calves: 5.09%
- Corn for grain: 22,422 harvested acres
- All wheat for grain: 10,372 harvested acres
- Soybeans for beans: 39,814 harvested acres
- Vegetables: 15 harvested acres
- Land in orchards: 5 acres

Gardening. Gardening information was updated from a 1994 interview with the Agricultural Extension Agent of Ballard County. The current Ballard County Agricultural Extension Agent confirmed in December 2013 that most of the information is feasible; however, the percentage of the population with a garden has dropped considerably.

(1) Approximately 25–30% of the population have a garden
(2) Commonly grown garden vegetables are squash, corn, tomatoes, green beans, and peas
(3) The average garden site is one-fourth acre
(4) Approximately 0.1 to 0.2 pounds of garden grown vegetables are consumed per individual per day

(5) Approximately 80% of gardeners can their produce
(6) Growing season is April 5 to October 12: 4,560 hours

E.2.3 SUMMARY OF AGRICULTURAL PRACTICES IN MCCRACKEN COUNTY, KENTUCKY

This section summarizes information obtained from a 2017 search of various public records to identify the parameters of agricultural practices in McCracken County, Kentucky.

Population. Population information for McCracken County is taken from http://www.city-data.com/county/McCracken_County-KY.html, accessed October 2017.

- 65,316 population (as of 2014)
- Size of family households: 8,862 2-persons; 4,185 3-persons; 3,035 4-persons; 1,200 5-persons; 411 6-persons; 198 7-or-more-persons
- Size of nonfamily households: 8,993 1-person; 1,153 2-persons; 119 3-persons; 50 4-persons; 11 5-persons; 5 6-persons; 5 7-or-more-persons

Agriculture in McCracken County: Agriculture information for McCracken County is taken from http://www.city-data.com/county/McCracken_County-KY.html, accessed October 2017.

- Average size of farms: 161 acres
- Average value of agricultural products sold per farm: $29,777
- Average value of crops sold per acre for harvested cropland: $215.65
- The value of nursery, greenhouse, floriculture, and sod as a percentage of the total market value of agricultural products sold: 11.92%
- The value of livestock, poultry, and their products as a percentage of the total market value of agricultural products sold: 26.35%
- Average total farm production expenses per farm: $22,605
- Harvested cropland as a percentage of land in farms: 63.19%
- Irrigated harvested cropland as a percentage of land in farms: 0.21%
- Average market value of all machinery and equipment per farm: $34,300
- The percentage of farms operated by a family or individual: 96.80%
- Average age of principal farm operators: 55 years
- Average number of cattle and calves per 100 acres of all land in farms: 3.63
- Corn for grain: 9,160 harvested acres
- All wheat for grain: 3,899 harvested acres

- Soybeans for beans: 37,579 harvested acres
- Vegetables: 85 harvested acres
- Land in orchards: 122 acres

Gardening. Gardening information was updated from a 1994 interview with the Agricultural Extension Agent of McCracken County. The current McCracken County Agricultural Extension Agent confirmed in January 2014, that most of the information still is feasible; however, the percentage of the population with a garden has dropped considerably, as has the average garden size.

(1) Approximately 10% of the population have a garden.

(2) Common grown garden vegetables are squash, com, tomatoes, green beans, and lettuce.

(3) The average garden size is one-eighth acre.

(4) During harvest season (three months), approximately 2 pounds of garden grown vegetables are consumed per individual per day.

(5) Approximately all gardeners can their produce.

E.2.4 AREA OF CROP LAND IN BALLARD AND MCCRACKEN COUNTY, KENTUCKY

The following information is taken from USDA's National Agricultural Statistics Service in cooperation with the Kentucky Department of Agriculture. The information is available at the following web site, accessed October 2017:

http://www.nass.usda.gov/Statistics_by_State/Kentucky/Publications/State_Census_Summaries/Historical_Ag_Statistics/

	Harvested Acres	
Year	**Ballard**	**McCracken**
1982	80,133	45,870
1987	62,583	40,444
1992	69,662	36,450
1997	74,158	46,291
2002	71,870	54,003
2007	70,700	43,272
2012	78,427	41,832

E.2.5 RECREATIONAL USE OF BAYOU AND LITTLE BAYOU CREEKS NEAR PGDP

The usage information originally was provided by Charlie Logsdon, West Kentucky Wildlife Management Area (WKWMA) Supervisor, in November 1995, in response to a questionnaire sent to him by Fuller, Mossbarger, Scott, and May Engineers, Inc., of Lexington, Kentucky (see Attachment E1). The information was used by the United States Army Corps of Engineers to support a preliminary risk calculation for Bayou and Little Bayou Creeks that was completed in 1997. In response to a recommendation from the Paducah Risk Assessment Working Group (RAWG) in October 2013, the information was provided to Tim Kreher, the current WKWMA Manager, for review and update. Mr. Kreher returned the updated information to the RAWG on January 21, 2014. Mr. Kreher's e-mail to LeAnne Garner, chair of the Risk Assessment Working

Group, is included in Attachment E2.The information below provides a summary of the updated information.

E.2.5.1. Bayou Creek

1. What is the average number of visitors per year to Bayou Creek?

The number of visits by people using Bayou Creek specifically is estimated to be 225 visits. This is for a specific activity involving Bayou Creek, such as fishing. More people may be in the vicinity while using the WKWMA, but their use of Bayou Creek maybe for only an instant (i.e., using a log to cross Bayou Creek to hunt on the other side of the creek).

2. Of this number, how many are adults and how many are children?

Of the 225 visits of people using Bayou Creek, 150 are adults and 75 are children. This is an estimate based on our observations of people using the area.

3. Are most of your visitors repeat or one-time visitors on a yearly basis?

Most of these people would be one-time users; however, 10% of the total number of users could be classified as repeat users. The highest number of visits by one person specifically using Bayou Creek would probably be < 15.

4. What is the average time (hours) spent in Bayou Creek? Is there a difference in average time spent between adult and child usage?

The average time spent in Bayou Creek by users is unknown; however, the amount of time spent/trip would be similar to other activities. An estimate of the average number of hours spent/trip for activities were as follows: Quail hunting ~ 5, rabbit hunting ~ 5, bowhunting for deer ~ 5, duck hunting ~ 4, and raccoon hunting ~ 4. Raccoon hunting and duck hunting would be the activities most likely associated with Bayou Creek. There would be little, if any, difference between adult and child usage of the area.

Actual time spent in the creek may be cases where hunters cross one or both creeks by wading through shallow spots; in most cases, these people are wearing rubber boots or waders. When hunters do wade through the creeks, again it is a brief exposure of less than 30 seconds each time.

5. What are the common recreational usages in the area? What is the percentage breakdown of usages by the visitors (i.e., what percentage of visitors fish, hunt, hike, swim. etc.)?

WKWMA is used heavily by a wide variety of users. Annually, the estimated number of visits for the following activities are the following: fishing ~ 7,500 visits/year; hunting and dog training ~ 6,000-9,000; field trials ~ 2,250; hiking ~ 150; berry and nut picking ~ 300; driving through for a variety of reasons ~ 75,000.

There are brief exposures to both Bayou and Little Bayou Creeks by dog trainers riding horses where they cross the creek via the method of the horse and dog wading through the creek while the rider is mounted (i.e., the riders does not have contact with the water for the most part). Such crossings are brief, less than 10 seconds at a time. For activities involving Bayou Creek alone: fishing—225 (see Question 1).

6. What is the number of repeat visits per year by anyone individual or group of individuals? What is the average time spent (hours) in the area by the higher frequency visitors?

Refer to Questions 3 and 4.

7. For individuals who are fishing in the area, are they mostly bank fishing or wade fishing? Can you estimate the percentage breakdown between the two? What is the average time spent in the area by a fisherman?

Most, if not all, would be bank fishermen. Most of the fishing would occur at three points: (1) where the iron bridge in Tract 4 crosses Bayou Creek, (2) where the collapsed bridge in Tract 4 crosses Bayou Creek (by weir constructed by PGDP), and (3) where the concrete crossing bridges Bayou Creek in Tract 6. While it may occur, no wade fishing has been observed. No actual data are available, but should be similar to the length of visits noted in Question 4.

8. Is there a harvestable fish population in Bayou Creek? If there is, is there enough to support subsistence fishing (i.e., 0.284 kg of meat flesh/meal) for one person to eat 128 meals a year? If not, how much fish, and how often could a person best expect to harvest a meal for consumption?

There is a harvestable fish population in Bayou Creek. A person potentially could expect to catch 0.284 kg of fish on a regular basis; however, this is assuming that the person is not culling (throwing back extremely small fish). The frequency of being able to catch 0.248 kg of fish would increase as one approaches the mouth of Bayou Creek. Also, the only way the creek could support 128 meals a year is if there were a major influx of fish from the Ohio River. This does occur when there is a backwater. During the backwater periods, catches of 50 to several hundred pounds of catfish can be taken (this has been observed) on trotlines. This would not be indicative of risks associated with the plant.

Fishing activity in the creeks rarely is observed outside of the portion that crosses through TVA-owned property near where the creeks join and meet the Ohio River (referred to as Tract 6 of the WKWMA).

E.2.5.2. Little Bayou Creek

1. What is the average number of visitors per year to Little Bayou Creek?

The number of people visiting Little Bayou Creek essentially is zero, with the exception of PGDP personnel and a few fishermen (maybe 30 visits annually) who fish a large beaver pond above the outfalls of the plant. A few people (bowhunters and dog trainers) may cross the creek occasionally, but these visits would be brief (the majority would be measured in seconds or minutes). Field trial galleries do cross the creek (over a large dirt-covered culvert) north of McCaw Road; however, they do not enter the creek, and the whole process takes seconds.

2. Of this number, how many are adults and how many are children?

The visitors would be adults.

3. Are most of your visitors repeat or one-time visitors on a yearly basis?

Refer to Bayou Creek Question 3 (Section E.2.5.1). Visitors to Little Bayou Creek would be repeat users, probably less than 15 visits per year, and most of them fall into the brief encounter scenario described in Question 1.

4. What is the average time (hours) spent in Little Bayou? Is there a difference in average time spent between adult and child usage?

Most encounters with Little Bayou Creek would be measured in seconds. Fishermen who use the beaver pond above the outfalls may fish on average 3 hours.

5. What are the common recreational usages in the area? What is the percentage breakdown of usages by the visitors (i.e. what percentage of visitors fish, hunt, hike, swim, etc.)?

See Bayou Creek Question 5 (Section E.2.5.1).

6. What is the number of repeat visits per year by anyone individual or group of individuals? What is the average time spent (hours) in the area by the higher frequency visitors?

Field trials that cross the creek may occur 12–15 weekends of the year. Most of the participants would be repeat users. The sum of all the encounters with Little Bayou Creek would be measured in minutes for the most frequent user, and most would cross the creek only on the culvert and dirt crossings.

7. For individuals who are fishing in the area, are they mostly bank fishing or wade fishing? Can you estimate the percentage breakdown between the two? What is the average time spent in the area by a fisherman?

All fishermen in the beaver pond would be bank fishermen because the pond is too deep to wade.

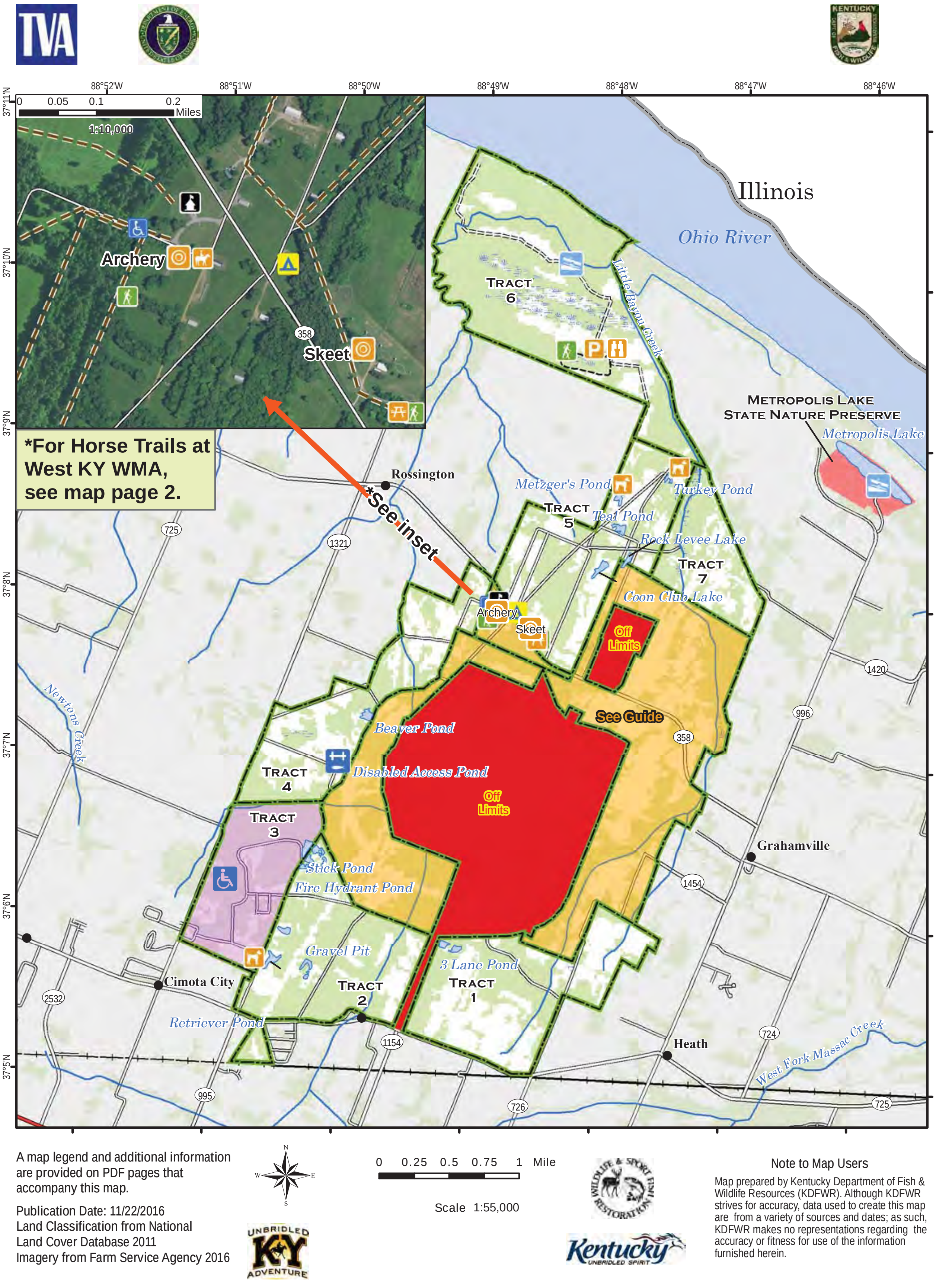
8. Is there a harvestable fish population in Little Bayou? If there is, is there enough to support subsistence fishing (i.e., 0.284 kilograms of meat flesh/meal) for one person to eat 128 meals a year? If not, how much fish, and how often could a person best expect to harvest a meal for consumption?

Other than the beaver pond above the outfalls, it would be nearly impossible to catch 0.284 kg of fish from Little Bayou Creek. There is a fish population, but most would fall in the minnow category and are not desirable by fishermen. In the beaver pond, it would be possible to catch this amount, but it would not support subsistence fishing (128 meals/year).

E.2.6 ANNUAL HARVESTS OF TURKEYS AND DEER IN MCCRACKEN AND BALLARD COUNTIES, KENTUCKY, AND WATERFOWL IN BALLARD COUNTY, KENTUCKY

PGDP is surrounded by the WKWMA (Figures E.1 and E.2). Additionally, several solid waste management units (SWMUs) (currently listed as no further action) are located in the Ballard Wildlife Management Area (WMA) (Figure E.3). Figure E.4 provides a legend for features in the WMAs. Both of these areas are home to hunting and fishing. Huntable populations of turkey, deer, dove, squirrel, rabbits, and quail exist in the area. Migratory geese and ducks also are abundant in the area. Table E.1 and Figure E.5 and Table E.2 and Figure E.6 show the hunting statistics for turkey and deer in western Kentucky.

The figures and tables within this subsection include additional information regarding wildlife harvests of turkey and deer recorded by Kentucky’s telecheck program. Additionally, the reported inventories of ducks and geese found in the Ballard WMA during the 2015/2016 and 2016/2017 hunting seasons are presented in Table E.3. Maps and information regarding game were taken from the Kentucky Department of Fish and Wildlife Resources web site, http://fw.ky.gov accessed in October 2017.



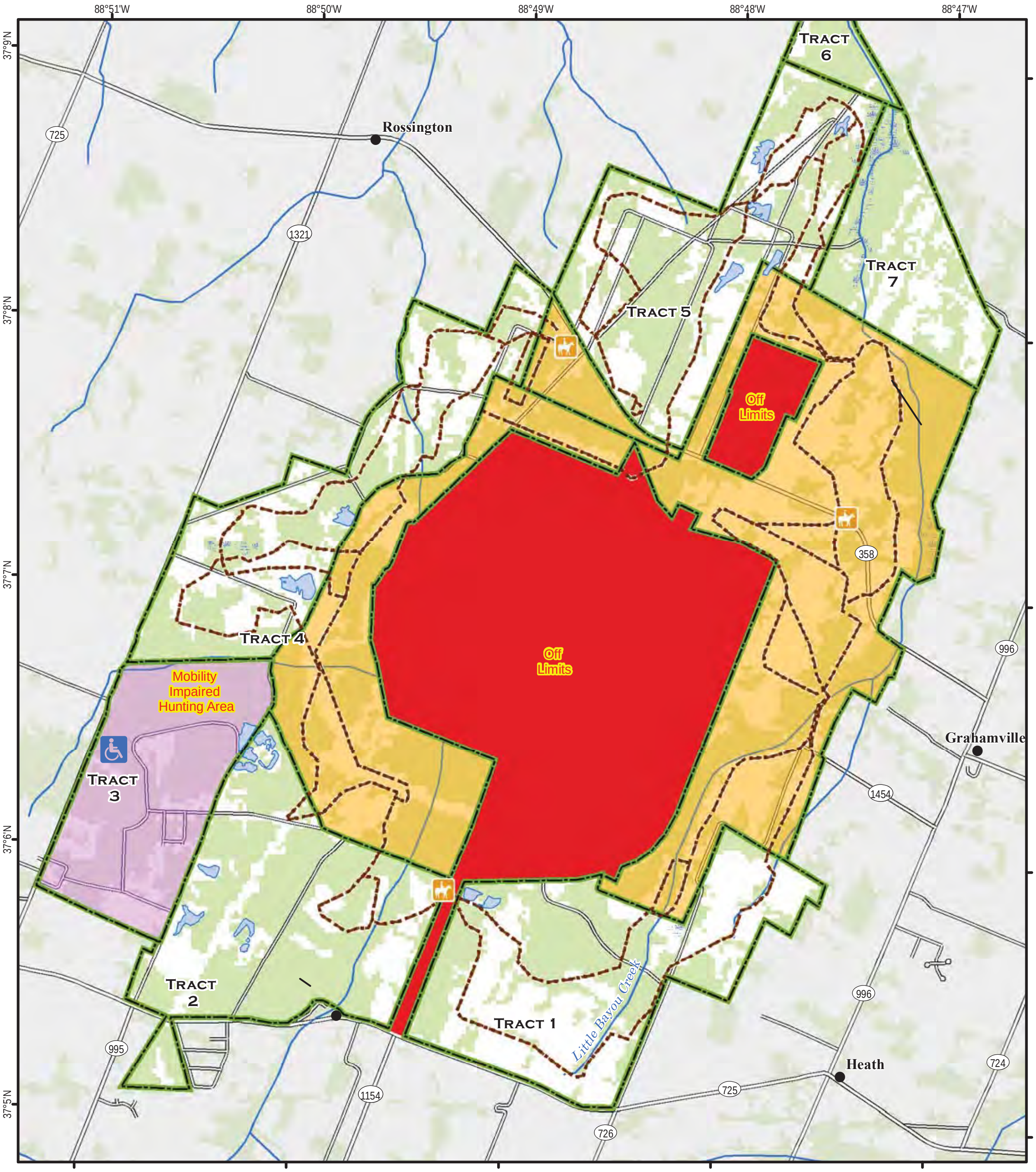
A map legend and additional information are provided on PDF pages that accompany this map.

Publication Date: 11/22/2016
Land Classification from National Land Cover Database 2011
Imagery from Farm Service Agency 2016

Note to Map Users

Map prepared by Kentucky Department of Fish & Wildlife Resources (KDFWR). Although KDFWR strives for accuracy, data used to create this map are from a variety of sources and dates; as such, KDFWR makes no representations regarding the accuracy or fitness for use of the information furnished herein.

Figure E.1. Map of West Kentucky Wildlife Management Area



A map legend and additional information are provided on PDF pages that accompany this map.

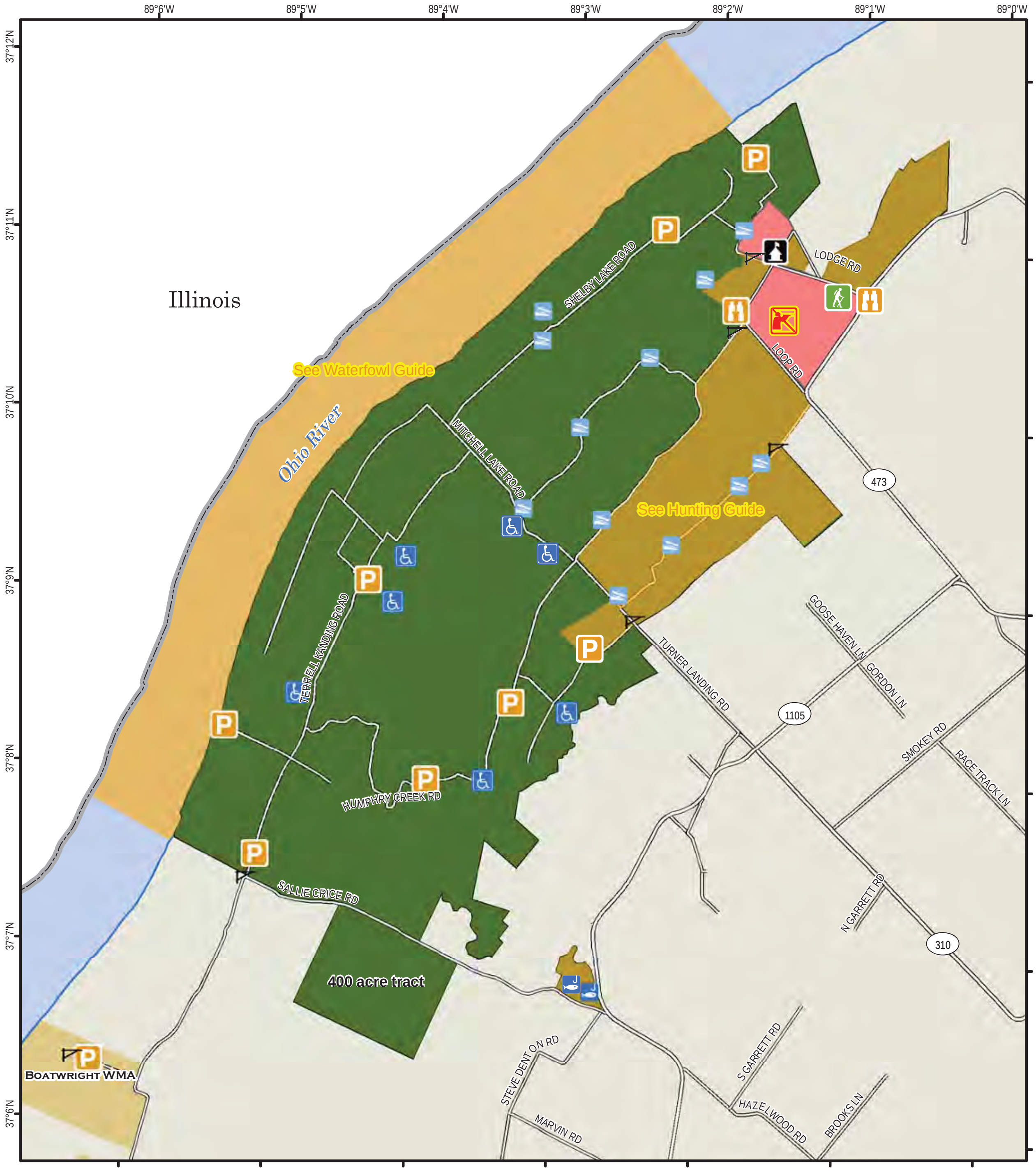
Publication Date: 11/19/2016
Land Classification from National Land Cover Database 2011

Scale 1:37,000

Note to Map Users

Map prepared by Kentucky Department of Fish & Wildlife Resources (KDFWR). Although KDFWR strives for accuracy, data used to create this map are from a variety of sources and dates; as such, KDFWR makes no representations regarding the accuracy or fitness for use of the information furnished herein.

Figure E.2. Map of West Kentucky Wildlife Management Area Horse Trails



A map legend and additional information are provided on PDF pages that accompany this map.

Publication Date: 11/16/2016

0 0.25 0.5 0.75 1 Mile

Scale 1:55,000

Note to Map Users

Map prepared by Kentucky Department of Fish & Wildlife Resources (KDFWR). Although KDFWR strives for accuracy, data used to create this map are from a variety of sources and dates; as such, KDFWR makes no representations regarding the accuracy or fitness for use of the information furnished herein.

Figure E.3. Map of Ballard Wildlife Management Area

Wildlife Management Area Map Notes & Legend

NOTE TO MAP USERS:

For most WMA maps the landscape is depicted using a combination of elevation contours, hillshading and a green tint indicating woodland areas that is derived from satellite imagery. On WMAs that are relatively small or have a history of surface mining aerial photography is used.

WMA Map Legend

- WMA Office
- ? Information Kiosk
- ✓ Check station
- ♿ Mobility-impaired Hunting Site
- Trailhead
- Horseback Trailhead
- P Parking Lot
- Picnic Area
- Restrooms
- Wildlife Viewing Site
- Interpretive Site
- Retriever Training Site
- Gate
- Campground
- Cemetery
- Corps of Engineers Office
- Waterfowl Blind
- ◎ Shooting Range
- Established Bank Access
- Fishing Pier
- Carrydown Launch
- Small Boat Ramp
- Large Boat Ramp
- State Park Office

- ▭ WMA Boundary
- Aerial photograph
- Other Public Hunting Areas
- Off Limits Area Off Limits
- No Hunting
- See Guide Seasonally Restricted Access
- ♿ Mobility Impaired Hunting Area
- Primitive Hunting Only
- Foot Traffic Only
- Open Water
- Wetland
- 🟩 Woodland

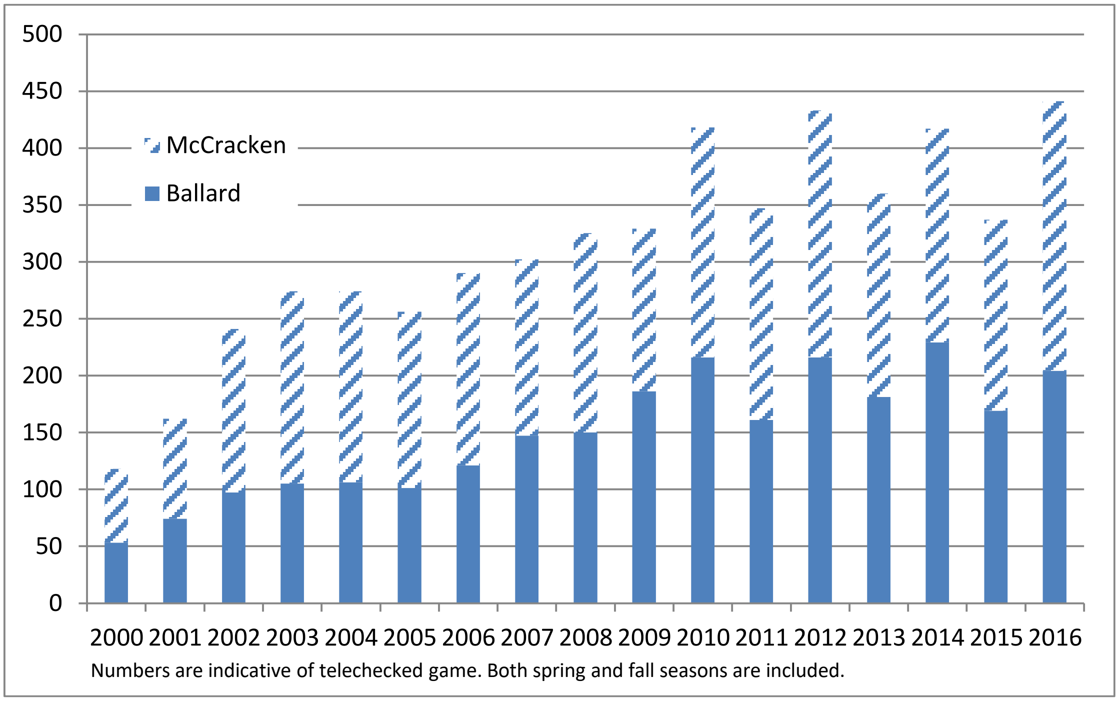
- ● Populated Place
- Kentucky Boundary
- 75 Interstate Highway
- Kentucky Parkway
- 60 U.S. Highway
- 169 State Highway
- Named Road Local Road
- 4596 Forest Service Road
- Active Railroad
- Abandoned Railroad
- Federal Recreation Trail
- ====== WMA Road
- ------ WMA Foot Trail
- – – – WMA Horse Trail
- Gas Pipeline
- Powerline
- Rivers and Streams
- Dam
- Trout Waters
- Elevation Contour

Figure E.4. Wildlife Management Area Map Legend

Table E.1. Turkey Harvested on Public Land in Western Kentucky in 2016[a]

Public Land	Male	Female	Total	Archery	Firearm	Muzzle loader	Crossbow
Ballard WMA	23	1	24	0	24	0	0
Beechy Creek WMA	2	0	2	0	2	0	0
Boatwright WMA	7	0	7	0	7	0	0
Clarks River National Wildlife Refuge	19	3	22	0	21	1	0
Coil Estate WMA	1	0	1	0	1	0	0
Doug Travis WMA	14	4	18	1	17	0	0
Jones-Keeney WMA	1	0	1	0	1	0	0
Kaler Bottoms WMA	6	0	6	00	6	0	0
Kentucky Lake WMA	3	0	3	0	3	0	0
Lake Barkley WMA	11	0	11	0	11	0	0
Land Between the Lakes National Recreational Area	54	0	54	0	54	0	0
Livingston County WMA and State Natural Area	9	2	11	1	10	0	0
Obion Creek WMA	4	0	4	0	4	0	0
Ohio River Islands WMA	0	0	0	0	0	0	0
Pennyrile State Forest	21	0	21	0	21	0	0
Reelfoot National Wildlife Refuge	0	0	0	0	0	0	0
Tradewater WMA	1	0	1	0	1	0	0
West Kentucky WMA	32	2	34	1	33	0	0
Winford WMA	0	0	0	0	0	0	0
Totals	208	12	220	3	216	1	0

[a] Numbers are indicative of telechecked game (http://app.fw.ky.gov/harvestweb/TurkeyPublicLandRegion.aspx, accessed 10/6/2017). Both spring and fall hunting seasons are included.



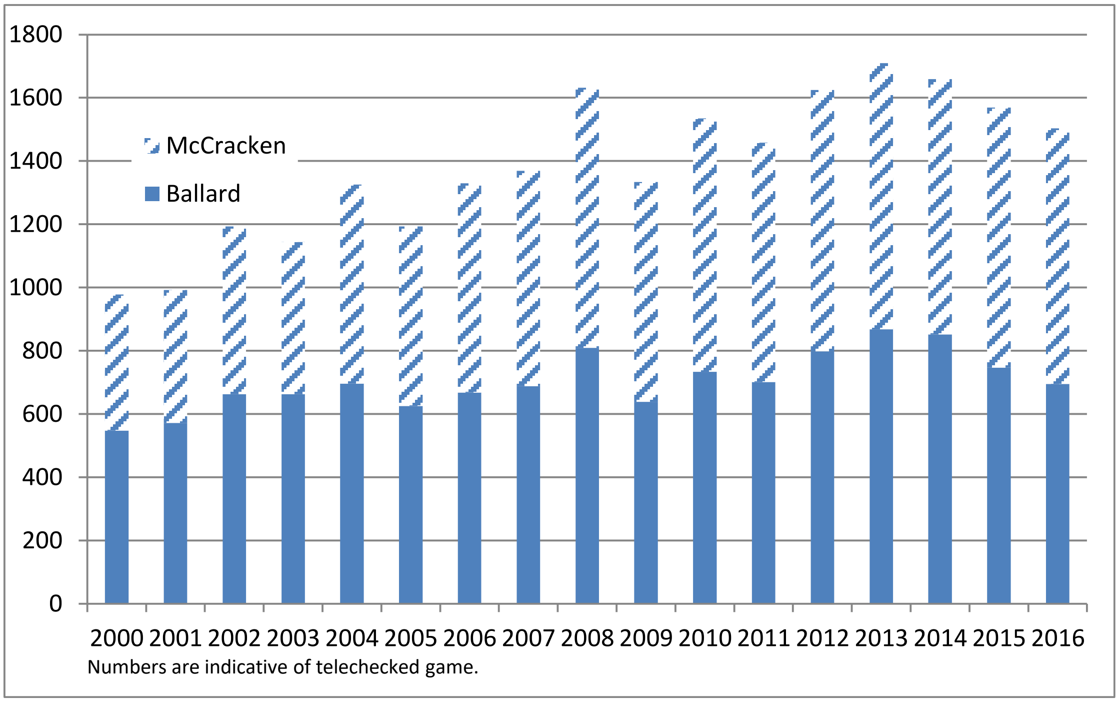
Numbers are indicative of telechecked game. Both spring and fall seasons are included.

Figure E.5. Total Turkey Harvest in Ballard and McCracken Counties 2000–2016

Table E.2. Deer Harvested on Public Land in Western Kentucky in 2016[a]

Public Land	Male	Female	Total	Archery	Firearm	Muzzle loader	Crossbow
Ballard WMA	24	26	50	17	33	0	0
Beechy Creek WMA	12	9	21	3	18	0	0
Boatwright WMA	25	15	40	2	36	1	1
Clarks River National Wildlife Refuge	79	94	173	20	139	13	1
Coil Estate WMA	0	0	0	0	0	0	0
Doug Travis WMA	17	14	31	3	26	2	0
Jones-Keeney WMA	6	3	9	1	7	1	0
Kaler Bottoms WMA	11	18	29	3	25	1	0
Kentucky Lake WMA	37	28	65	6	55	3	1
Lake Barkley WMA	45	47	92	8	65	17	2
Land Between the Lakes National Recreational Area	168	61	229	57	155	15	2
Livingston County WMA and State Natural Area	34	32	66	11	5	49	1
Obion Creek WMA	19	23	42	4	37	1	0
Ohio River Islands WMA	1	1	2	0	2	0	0
Pennyrile State Forest	22	18	40	37	1	1	1
Reelfoot National Wildlife Refuge	0	0	0	0	0	0	0
Tradewater WMA	1	4	5	4	1	0	0
West Kentucky WMA	15	27	42	40	0	0	2
Winford WMA	3	0	3	0	3	0	0
Totals	**519**	**420**	**939**	**216**	**608**	**104**	**11**

[a]Numbers are indicative of telechecked game (http://app.fw.ky.gov/harvestweb/deerpubliclandregion.aspx, accessed 10/6/2017).



Numbers are indicative of telechecked game.

Figure E.6. Total Deer Harvest in Ballard and McCracken Counties 2000–2016

Table E.3. Waterfowl Counts in Ballard Wildlife Management Area

Date	Population Count		Harvest		
	Ducks	Geese	Ducks	Canada Geese	Other Geese
12/16/2015	43,000	2,600	19	0	1
12/17/2015	43,000	2,600	16	0	0
12/18/2015	43,000	2,600	24	0	0
12/19/2015	41,500	500	26	0	0
12/20/2015	41,500	500	28	0	0
12/30/2015	No counts on waterfowl due to flood waters		WMA closed		
12/31/2015					
1/1/2016					
1/2/2016					
1/3/2016					
1/6/2016					
1/7/2016					
1/8/2016					
1/9/2016					
1/10/2016					
1/13/2016					
1/14/2016					
1/15/2016					
1/16/2016					
1/17/2016					
1/27/2016			93	1	0
1/28/2016			104	1	4
1/29/2016			86	2	4
1/30/2016			114	0	0
1/31/2016			110	0	2

Date	Population Count		Harvest		
	Ducks	Geese	Ducks	Canada Geese	Other Geese
12/7/2016	35,900	65	85	2	1
12/8/2016	35,900	65	72	3	0
12/9/2016	35,900	65	27	0	0
12/10/2016	35,900	65	17	0	1
12/11/2016	35,900	65	70	0	0
12/14/2016	60,672	120	45	0	0
12/15/2016	60,672	120	6	0	0
12/16/2016	60,672	120	19	2	0
12/17/2016	60,672	120	88	2	0
12/18/2016	60,672	120	78	0	0
12/21/2016	64,122	564	55	0	0
12/22/2016	64,122	564	62	0	0
12/23/2016	64,122	564	56	0	0
12/28/2016	54,000	350	73	2	2
12/29/2016	54,000	350	50	2	0
12/30/2016	54,000	350	41	0	0
12/31/2016	54,000	350	80	2	0
1/4/2017	22,500	350	49	0	0
1/5/2017	22,500	350	40	0	0
1/6/2017	22,500	350	0	0	1
1/7/2017	22,500	350	5	0	0
1/8/2017	22,500	350	2	0	0
1/11/2017	55,000	600	61	1	6
1/12/2017	55,000	600	62	0	3
1/13/2017	55,000	600	88	0	6
1/14/2017	55,000	600	31	0	0
1/15/2017	55,000	600	57	1	2
1/18/2017	41,500	150	53	0	0
1/19/2017	41,500	150	20	0	0
1/20/2017	41,500	150	21	0	0
1/21/2017	41,500	150	57	0	0
1/22/2017	41,500	150	44	0	2
1/25/2017	39,000	480	22	0	1
1/26/2017	39,000	480	20	0	1
1/27/2017	39,000	480	51	0	2
1/28/2017	39,000	480	40	6	0
1/29/2017	39,000	480	71	0	0
2/4/2017	30,010	415	62	0	3
2/5/2017	30,900	415	50	0	1

E.2.7 USE OF EXPOSURE UNITS IN RISK CALCULATIONS AND REMEDIAL DECISIONS

According to two reports (“Planning Issues for Superfund Site Remediation” and “Quantitative Decision Making in Superfund: A Data Quality Objectives Case Study,” from *Hazardous Materials Control*) received by the risk analysis section, industrial workers range 0.5 acres per day. This area is where the worker may be exposed to contamination. This area is called an exposure unit. For risk assessment purposes, it is reasoned that an exposure unit of 0.5 acres is consistent with the activities at PGDP. Exposure was weighted based on the size of the SWMU and the 0.5-acre exposure units. If the size of the SWMU was smaller than the 0.5-acre exposure unit, then the fraction was introduced into the chronic daily intake equation. The fraction, however, cannot exceed 1. Copies of the two reports are provided as references.

PLANNING ISSUES FOR SUPERFUND SITE REMEDIATION

Randall T. Ryti
Dean Neptune

Abandoned drums located behind the "burn shed" at the site

One function of the Superfund program is to assess the risk posed by hazardous waste sites. Sites that merit inclusion on the National Priorities List (NPL) are analyzed intensively through the Remedial Investigation/Feasibility Studies (RI/FS) process, which provides estimates of the risk posed by the site and the cost of cleanup. In this article we will review the planning issues for RI/FS through a case study of a specific Superfund site—a former transformer storage and rehabilitation facility in North Carolina.

The planning process used for this example is the Data Quality Objectives (DQO) process, which consists of the following steps: define the problem, define the question, define the data needs (the domain and decision rule), and define the data performance for the main question (*1,2*).

The planning approach is flexible; we have successfully applied the DQO process to two other Superfund sites. This site differed in the complexity of the problem, as well as the time frame within the Superfund assessment and cleanup process. We have observed that using the DQO process has not increased the resources expended (either time or money). Indeed, the process has resulted in substantial savings at a dioxin site in Missouri (*3,4*).

Another advantage of the planning process is that data collection can be focused. If one or a few contaminants are of interest, then more specific tests can be used. The planning process also sets goals for data collection, so that a criterion for the adequacy of data collection can be specified. The question of "how much is enough" develops naturally during the planning process.

Site history

The site is a former transformer storage and rehabilitation facility located on 4.8 acres of swampy terrain. The site lies within the 100 year floodplain of the Cape Fear River. Rebuilding of transformers was discontinued in 1982, but storage of transformers continued until 1986 when the site was abandoned. The initial sampling in 1978 found chlorobenzene in the well water on the site. Adjacent residences were placed on city water at that time. In 1979, PCBs were found in both the soil and well water, but no other action was taken. An Emergency Removal Action (ERA) was conducted in 1984 to remove contaminated soil. Sampling after the ERA detected PCBs at up to 140 ppm in the sub-surface soil.

The United States Environmental Protection Agency (EPA) Region 4 is administering the assessment and cleanup activities at the site. Discussions with the Region indicated that there were two phases to these activities. In Phase 1, the short list of contaminants of concern (COCs) and the general location of these COCs are determined. In Phase 2, the locations of the COCs are determined more precisely and the costs of various remedial alternatives are estimated. Through the steps of the DQO process, these general statements were refined and quantitative error tolerances were specified.

Phase 1

Discussion with EPA Region 4 indicated that Phase 1 of the assessment should answer two questions: What is the list of COCs at the Carolina Transformer site, and what is the x, y and z location of these contaminants?

Determining the list of COCs and the spatial scale of the contamination are essentially interrelated. For example, a "hot spot" of dioxin at a concentration of 10 ppb, but only in a few grams of soil at one location is not a threat to human health. Thus a contaminant causes concern if it exists above a specific concentration over an area where exposure is possible.

What logic can be used to define the area and concentration that makes a particular contaminant a concern? One approach is to compute the concentration and exposure area from a risk perspective. A second approach is to consider the way that the contaminant came to be distributed on the site.

EPA policy puts an acceptable risk level between 1 in 10,000 and 1 in 10,000,000 additional cancers (*5*). In this case, Region 4 decided that an acceptable risk is an additional 1 in 1,000,000 cancer incidence.

For PCBs in soil, the likely exposure route is through ingestion of contaminated soil. Exposure scenarios were investigated for adult workers on the site or children trespassers.

A risk scenario is based on assumptions about the absorption rate of the contaminant, the soil ingestion rate, and the length of the exposure. For example, a 70 kg adult is assumed to absorb 30% of the PCBs ingested. Adults are assumed to ingest a total of 100 mg of soil per day. These PCBs accumulate over 30 years, where the worker is present at the site 5 days a week for 50 weeks a year. Based on laboratory models and these exposure assumptions, an additional one in one million risk is equivalent to a PCB concentration of 1 ppm in the soil. For children trespassers, the end concentration is roughly the same, although the assumptions are different.

Over what area is this exposure accumulated? Some construction workers work over (and thus integrate exposure) an area of 1/2 acre. Children playing on a baseball field would also cover about 1/2 acre. We define an exposure unit (EU) as 1/2 acre. Since exposure is integrated over a large area (1/2 acre), small "hot spots" are only important if the overall average in a 1/2 acre area is greater than 1 ppm.

The preceding scenario was based on ingestion of surface soil. Based on CFR guidelines (an ARAR for PCBs), subsurface soil can be backfilled with clean soil if the concentration of PCBs are less than 10 ppm at a depth of 10 inches; thus <1 ppm PCBs is acceptable for soil in the 0–10 in. layer, and <10 ppm PCBs is acceptable below 10 in.

The likely source of the contamination was from leaking transformers. Thus a "hot spot" could result from a single leaking transformer. The Region decided that a leaking transformer would likely result in a 10 ft by 10 ft footprint. This implies that the smallest area that should need remediation is also a 10-ft square. The spatial scale is now bounded between 100 ft^2 and 22,500 ft^2. (1/2 acre). What concentration of PCBs in 100 ft^2 would result in an average of 1 ppm over 1/2 acre? If the remainder of the 1/2 acre were clean, then a single hot spot would have to measure more than 225 ppm for that EU to pose an unacceptable risk.

The main goal of Phase 1 is to define the list of COCs for the site and estimate the risk posed to the public. To address these goals, some information on the spatial distribution of the contaminants must be collected. Based on the historical use of the site and aerial photos, the site was divided into three areas: administration, operations and storage; PCB contamination was expected to be lowest in administration, intermediate in storage, and highest in operations. This stratification should lead to a more precise estimate of the average PCB concentration on the site. The lis [illegible] COCs was confirmed on a subse [illegible] samples submitted for the full scan analysis. Region 4 had expected that PCBs would be the sole COC on the site. The initial data also indicated that PCBs were much greater than 1 ppm in the surface soil. If these expectations are met, then the data collected in Phase 1 will only have to describe the general location of PCBs across the site.

Because no reliable information on the distribution of PCBs and the presence of other contaminants was available, a pilot study was recommended. In the case that the problem was truly as simple as described above, the pilot study could give enough information to lead to the second phase of the RI/FS.

Before describing the development of the pilot and the results obtained, let us consider the decision rule and the data quality required in Phase 1. The decision is to find if any area of the Carolina Transformer site poses an unacceptable health risk to the public. The data quality for the decision are the acceptable probabilities of maki [illegible] e positive or false negative errors. [illegible] se positive is where the actual risk posed by the site is *less than* 1 in 1,000,000 addi-

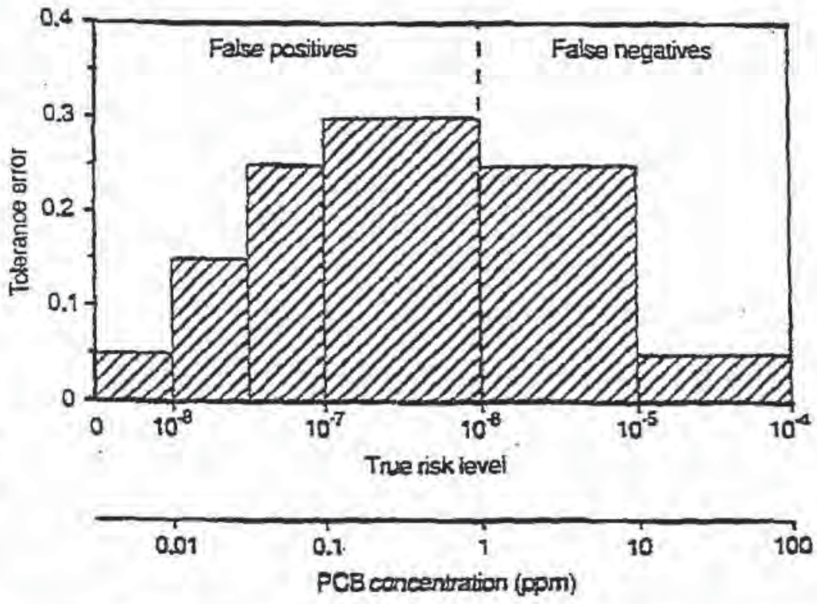
TABLE 1

Assumptions about the site used to design the pilot

Sub-unit	Area/acres	Probability 10' x 10' is contaminated	Number of samples
Administration	0.75	0.05	5
Storage	1.5	0.25	15
Operations	0.75	0.50	25

FIGURE 1

"Discomfort curve," or acceptable error rate for decision



onal cancers, but the risk is measured as being greater than 1 in 1,000,000 additional cancers. The consequences of a false positive are that resources (time and money) are diverted to sites that do not pose a significant risk. The possible consequences of a false negative (actual risk posed by the site is greater than 1 in 1,000,000 additional cancers but is measured as less) are additional cancers. Region 4 stated their *quantitative* discomfort with various magnitudes of false negatives and false positives (Figure 1).

The pilot survey was designed by using *simple assumptions* about the site. Based on the historical activities at the site, PCBs were assumed to be the most important (or only) contaminants on the site. Thus the Region agreed to run most of the soil samples through a quick-turnaround (QT) analysis procedure for PCBs. In addition to providing results more quickly, the QT method was also less expensive per analysis than the total contaminant list (TCL) scan ($150 vs. $1250). Based on the amount of data collected in other RI/FS Phase 1 surveys, approximately 45 QT soil samples could be analyzed. This amount is based on $30,000 total for Phase 1 analyses; spending one-half of the total in the pilot at $350 per analysis. An additional 10 samples were run by the TCL method to search for other contaminants. The 45 QT samples were allocated based on simple assumptions of the distribution of PCBs. PCB presence or absence was assumed to follow a binomial distribution on the scale of 10 ft by 10 ft areas (with no spatial correlation beyond 10 ft). The probability of presence was assumed to vary according to the sub-units of the site (Table 1).

The TCL samples taken in the pilot confirmed that PCBs were the only significant COC. The QT samples showed that the magnitude of PCB concentration did vary in the predicted manner among the three sub-units of the site. Table 2 shows these concentrations.

The concentration of PCBs was variable both within and between sub-units of the site. For example, stations close to a hot spot (e.g., 10 ppm) were not likely to measure 10 ppm. The spatial pattern of PCBs fits a "hot spot model"; the contamination is located in a binomial fashion, either contaminated or not contaminated. The most important result is that 41 of 45 samples were greater than 1 ppm PCBs; nearly the entire site is a "hot spot" from a risk perspective. Thus the initial assumptions about the frequency of "hot spots" were not correct.

Because the pilot identified PCBs as the only significant contaminant, we can restate the decision as: do any 1/2-acre areas of the site exceed 1 ppm PCBs? What is the approximate location of the contaminated soil? The Region had two options at this point: accept the results of the pilot survey for Phase 1, or conduct a Phase 1 survey where the number of samples is based on the results of the pilot.

Based on the laboratory measurement error for PCBs and the spatial sampling variation, the number of samples taken in the pilot did not meet all of the error constraints set by the Region. The false negative error rate for the Phase 1 decision based on the pilot data was slightly larger than the rate specified by the discomfort curve (7.5% vs. 5%). The advantage of accepting the pilot for the Phase 1 results is that Phase 2 can be started more quickly. False negatives are not important, since all 1/2 acre units were positives (i.e., PCBs >1 ppm), the Region decided to accept the results of the pilot in making the preliminary risk assessment for the site.

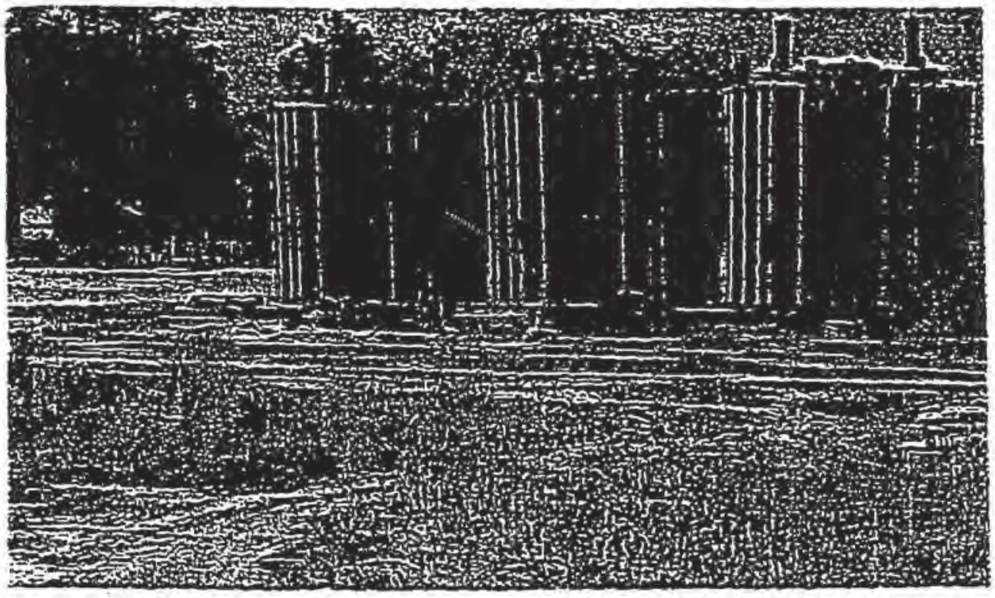
Phase 2

The purpose of the Phase 2 RI/FS survey is to define the location of the contamination and the cleanup costs. The cleanup costs are based on two components: a per unit volume cost and the total volume to remediate. The per volume remedial cost is dependent on the particular remedial sequence selected (for example: excavation, incineration, disposal, and back-filling with clean soil). We assume that the per volume remedial cost can be estimated exactly, so the only error is in the estimate of the volume of soil to be remediated. Thus the total volume can be computed from the location estimate.

EPA policy states that the cost should be estimated to within +30% and -50% of the actual RD/RA cost. To simplify the problem, the Region wanted the Phase 2 survey to be designed to estimate the cleanup cost to within 30% with 90% or greater probability. An obvious difficulty is that sub-surface contamination must be estimated before the surface soil is remediated. A simplifying assumption is that two discrete soil layers will be sampled. Soil above 1 ppm PCBs in the top 10 in. and soil below 10 in. and containing more than 10 ppm PCBs will be remediated.

TABLE 2
Results of the pilot survey

Sub-unit	Mean concentration (standard deviation, n)	Median
Administration	7.5 (10.7, 5)	1.1
Storage	19.3 (21.4, 15)	11.3
Operations	34.7 (24.5, 25)	32.4



Large electrical transformers at the site—a former transformer rehabilitation and storage facility

The data resolution needed for the location question is dependent on the spatial distribution of the contaminant within the exposure units (EU) (1/2 acres units in this example). Should an all-or-none approach be used for EU cleanup, or should remediation units (RUs) be defined as sub-units of EUs? In some cases, the additional sampling is cost-effective in that a "surgical" cleanup can remove hot spots of contamination (4). At a dioxin contaminated site in Missouri, the lowest total cost for sampling and cleanup was for RUs that were 1/24th the size of EUs (4). But in the present case, the pilot data indicated that there was little local pattern in the contamination, and that PCBs were nearly uniformly above 1 ppm. Field sampling and laboratory analysis costs were estimated for four sizes of RUs (1/2 acre, 1/8 acre, 1/18 acre, and 1/32 acre). Designs were evaluated by a Monte Carlo simulation approach (see Ref. 6 for additional examples; contact Dean Neptune for details on the simulations). Based on cost considerations, Region 4 selected 50 ft by 50 ft (about 1/18th acre) as the remedial unit size. This design has a cost of about $50,000 for sampling and laboratory analyses.

Each EU (or 1/2 acre) contains a three by three grid of RUs. Partial RUs (containing less than 1250 ft^2) are lumped with an adjacent RU. Sixty-two RUs were sampled in the legal boundaries of the site. Two soil samples were taken: a 0–2 in. sample that represented the 0–8 in. soil layer, and a 8–10 in. sample that represented the 8–16 in. soil layer. For each layer, 14 grab samples were taken in the Administration area, and 4 grabs elsewhere (Storage/Operations). The grabs were homogenized, and a single aliquot was bagged for laboratory analysis. Each aliquot contained enough material for four laboratory analyses. Two laboratory analyses were made of each aliquot in the Administration area and one analysis elsewhere.

The results of the Phase 2 RI/FS survey showed that PCBs are highly variable over the site (Table 3).

PCB concentration varied over four orders of magnitude in both soil layers. There was greater contamination in the 0–2 in. layer on average, as compared with the 8–10 in. layer (compare Figures 2,3). But in 13 of 61 RUs the 8–10 in. layer was more contaminated (in many locations, by an order of magnitude) than the 0–2 in. layer. We would expect that PCBs would ordinarily migrate slowly down through the soil profile, without some kind of mechanical disturbance (or churning) of the soil. To what extent the soil was churned as a result of the operations at the facility or by the actions taken during the Emergency Removal Action is not known.

To estimate the volume of contaminated soil, the following cleanup strategy (Figure 4) was developed. It was based on the depth that can excavated by a backhoe (about 8 and the two cleanup criteria. The surface soil is considered to be clean if the PCB concentration is less than 1 ppm. An excavated area can be backfilled with clean soil if the PCB concentration is less than 10 ppm at a depth below 10 inches. Three different depths are excavated (8, 10 or 16 in.), or no soil is removed based on the PCB concentration (Table 4). The total amount of soil to be excavated is estimated at 5389 yd^3.

In the Administration area, 6 of 16 RUs (62.5%) were greater than 1 ppm in the 0–2 in. layer, and in the Operations/Storage all 46 RUs measured greater than 1 ppm in the 0–2 in. layer. These numbers are similar to the assumptions used in the volume estimation design computations (50% contaminated assumed for Administration and 90% contaminated assumed for Operations/Storage).

Fifteen quality assessment (QA) samples were analyzed. The QA samples were laboratory sub-samples of the core composites. The relative standard deviation of these QA samples was 15%, excluding one outlier

Discussion

The goal of Superfund program is to

remediate sites that pose an unacceptable health hazard. Because resources [illegible]mited, the Superfund program must [illegible] able to rank sites and to rank the hazards within sites. The information for these rankings becomes more detailed at each step in the process. Three main questions about sites are: Does the site pose a hazard? What remedial plan will remove the hazard? How will I verify the site is "clean?"

The Data Quality Objectives (DQO) process provides a way for managers to define a general question about a site that is later refined to a quantitative decision rule. The other parallel effort in the DQO process is to define error tolerances. The initial error tolerances are qualitative, and these are later quantified. These two components (decision rule and error tolerances), are the building blocks for a statistically-based design.

In the case of the North Carolina transformer site, the managers in Region 4 asked for the lowest cost designs that would meet their error tolerances for selected cleanup unit (RU) sizes. They were able to compare the cost of these surveys against a survey that would es[illegible]ate the volume of soil that was contaminated. In this way they could balance the importance of these main questions in the Phase 2 survey.

The advantage of the DQO process is that the decision constraints (the decision rule and the error tolerances) are based on the initial responses of the decision-maker. The decision-maker can see how different ways of stating the decision rule can have profound implications on the proposed survey design. Where no proposed sampling design is within budget, then the decision-maker has the option to either increase the budget or modify some of the constraints (look at larger RUs).

Conclusions

We have shown that the Data Quality Objectives process can help define questions and the data quality in ways that can lead to statistically-based sampling designs. The DQO process allowed Region 4 to collect the right data at the right time. It should be noted that at each step from the pilot survey to the Phase 1 design, and finally for the Phase 2 study design, the question was further clarified and more information was gathered about PCB distribution across the site. One problem with the Superfund program in general has been to decide when enough data has been collected.

TABLE 3

Results of Phase 2 survey

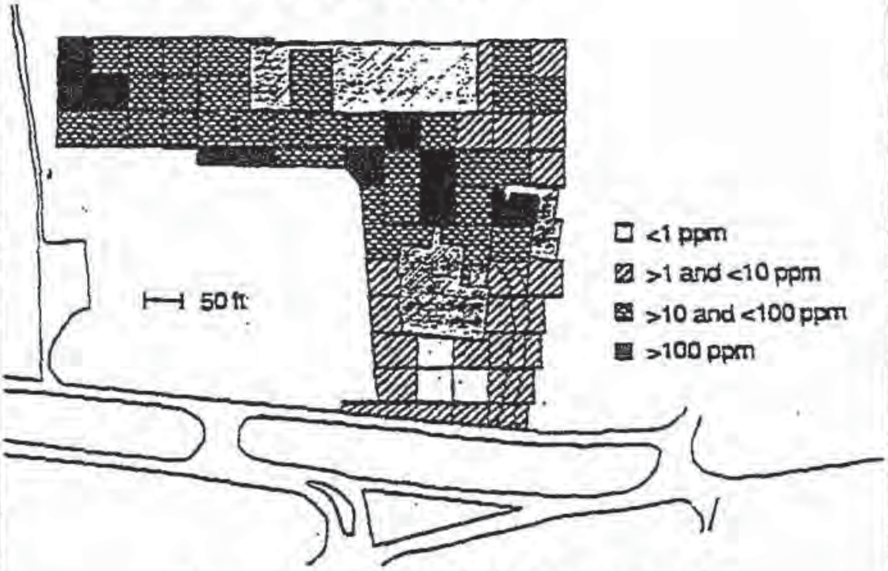
		Range		Number of RUs	
Soil layer	Median	low	high	<1 ppm	<10 ppm
0–2"[1]	21	0.4	2500	3	21
8–10"[2]	7.25	0.2	1100	18	36

[1] n=62

[2] n=61, one RU was concrete below the top 8"

FIGURE 2

PCB concentrations in 0–2 in. soil layer



Hatched areas represent buildings or concrete pads

FIGURE 3

PCB concentrations in 8–10 in. soil layer

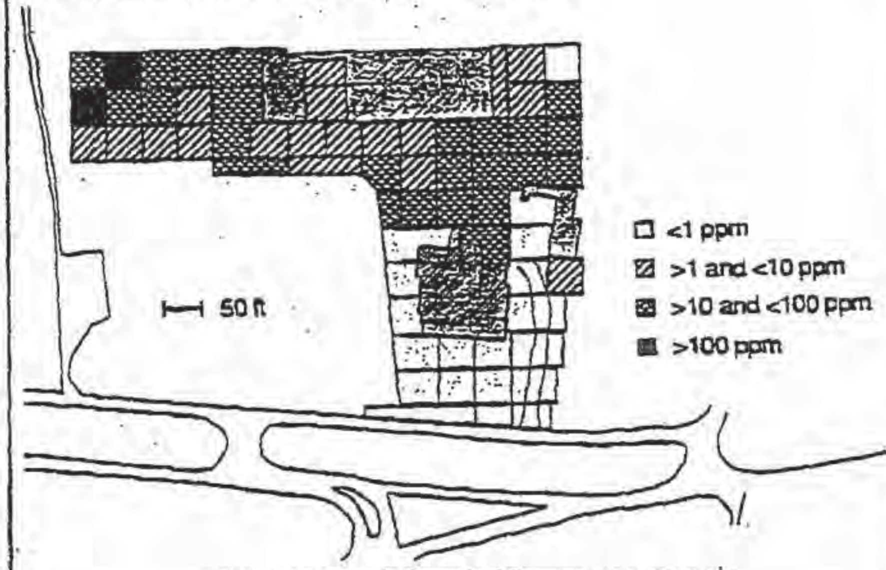


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TABLE 4

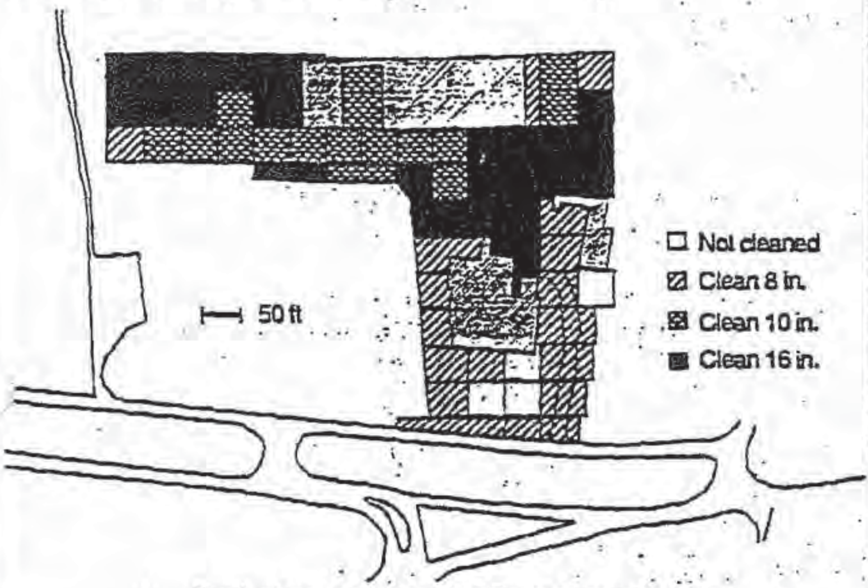
mmary of cleanup strategy

Soil depth and concentration	Depth to excavate	Number of RUs	Volume cubic yards
0–2" <1 ppm	0"	3	—
8–10" <1 ppm	8"	18	969
8–10" < 10 ppm	10"	18	1297
8–10" >10 ppm[1]	16"	22	3123

[1] These RUs need to be sampled at 16–18" to verify PCBs are <10 ppm

FIGURE 4

Cleanup strategy for the site



Hatched areas represent buildings or concrete pads

It is through the steps of the DQO process that the data user specifies the stopping point (the decision rule with error tolerances).

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Quantitative Decision Making in Superfund:

A Data Quality Objectives CASE STUDY

What type and quality of data are needed to answer key questions and how do we know when we have enough? Data quality objectives (DQOs) offer decision makers a tool to answer both questions. DQOs provide a qualitative and quantitative framework around which data collection surveys are designed, and can serve as performance criteria for assessing ongoing or completed remedial investigation/feasibility studies (RI/FSs). DQOs allow remedial project managers to make decisions based on RI/FS data with a predetermined and acceptable level of confidence.

Here we present a case study demonstrating the practicality and benefits of using the DQO process as an up-front planning tool for designing RI/FS data collection activities. The RI/FS decision maker and technical support staff (typically including environmental toxicologists and field and laboratory scientists) must work together to develop DQOs and associated RI/FS survey designs. With these individuals in mind, this article illustrates the issues raised during the DQO process, and demonstrates how the process can help resolve them at a Superfund site before an RI survey design is developed.

Development of DQOs involves a step-wise planning process (see box, "Data quality objectives") that may be applied to any problem involving the collection and use of environmental data (*1*). We begin the DQO process by carefully stating the environmental problem to be addressed or the decision to be made; then we identify the information required to select an appropriate course of action and carefully articulate the specific role data will play in making the selection. Specifications regarding the type of data needed, the way data will be used, and the desired degree of certainty in conclusions to be derived from the data are then developed through an iterative process that involves the decision maker and data generators (technical support staff).

When applied to Superfund sites, the DQO process provides a quantitative basis for designing rigorous, defensible, and cost-effective remedial investigations. The DQO planning process recognizes that decision making in Superfund is driven by risks to public health and that the uncertainty in decisions will be affected by the type and quality of data collected. The focus on planning, as presented here, is consistent with ideas developed as part of Superfund's endeavor to streamline its remedial process (*2*).

The case study was developed cooperatively by EPA's Region IV Waste Management Division and Environmental Services Division, and the Quality Assurance Management Staff. Our study involved a retrospective application of the DQO process to an actual Superfund site that had already been studied and the remedial investigation design already implemented. (The RI designs reported here were not actually implemented.) By using a completed site, Region IV expects to compare and contrast the DQO process with the current approach to planning such investigations. All decisions regarding the DQOs were made by Region IV personnel, just as they would for other sites where RIs are planned. We chose an actual site for several reasons: to avoid a purely hypothetical exercise; to ensure that realistic issues were confronted; and to facilitate an objective assessment of the practicality of implementing the DQO process for Superfund problems. Here we report the results of our planning efforts, following the generic structure illustrated in the box "Data quality objectives."

Problem statement

The starting point for any planning process is gathering background information on the specific problem at hand. The site addressed in this case study was used for storing and burning railroad ties and creosote-soaked timbers (*3*) (see photo). Information collected at various times (e.g., during previous site studies and during the Superfund site listing process) suggested that a logical exposure scenario consistent with future use of the site includes site workers and visitors as hazard targets.

Toxicologists determined that the exposure route of greatest concern for these targets is direct ingestion of contaminated surface soils; other routes of exposure are not addressed in the case study. Existing data from preliminary investigations and site visits also suggested that while several contaminants are to be expected in such surface soils, the most toxic are polyaromatic hydrocarbons (PAHs) associated with creosote.

Decisions and decision elements

The key decision posed by the RI/FS is: "What remedial actions, if any, must be taken to reduce the risk posed by the site to an acceptable level?" A logical starting point, and the focus of this study, is to determine whether the site poses an unacceptable risk in its current state—whether it is a problem.

The next step is to work logically toward increasingly specific and hence focused questions that will require environmental data for resolution. We know that PAH contamination of soil is the most likely source of public health risk from the site. Thus, the element of interest can be restated as a question: "Which, if any, surface soil areas have PAHs at concentrations that pose an unacceptable risk to the hazard targets?"

Domain and logic statement

The next step was to determine the concentrations of PAHs that, if present over some defined area, would pose an unacceptable risk. This approach to the problem raised three related questions:

- What level of public health risk from this site is acceptable to the remedial project manager?
- What concentration of PAHs is associated with the acceptable level of risk, given reasonable assumptions about target exposure?
- What is the smallest area on the site over which we can reasonably assume that the targets' exposure to contaminants may occur?

Addressing these issues required assumptions about the population at risk (people), their activities, exposure routes, and the risks associated with specific contaminants. Recognizing that the number of samples ultimately collected at a site depends in part on the smallest area of concern, we focused attention on defining the size of this area first, and then dealt with the issues of acceptable risk and corresponding concentrations.

To divide the site into discrete areas for study in a manner consistent with our interest in controlling risk, assumptions about exposure and activity patterns were used to define an area called an "exposure unit" (EU). An EU is the area over which people are expected to integrate exposure when routinely working at or visiting the site (see white grid on site photo).

A separate decision will be made for each EU: if an area is found to contain PAHs at a concentration that poses an unacceptable risk, that EU (and thus the site) will be considered a problem. Further investigations and remedial alternatives will address only the EUs found to

Data quality objectives

To build total quality into data operations, EPA quality assurance management staff have developed a planning tool for assuring that key planning steps are taken in a thoughtful, methodical manner. This tool, known as the Data Quality Objectives (DQO) process, begins with a careful statement of the environmental problem and produces a design for collecting the information needed to make an informed decision with a desired degree of confidence. The stepwise structure of the DQO process is to:

- state the problem, then
- identify decisions that address the problem, then
- select elements or factors that affect the decision, then
- specify the domain of the decision.
- Then develop a logic statement.
- establish constraints on uncertainty, and, finally,
- optimize the design for data collection.

The DQO process provides a logical, objective, and quantitative framework for finding an appropriate balance between the time and resources that will be used to generate the product (data) and the quality of that product.

DQOs enable EPA to develop, optimize, and evaluate statistically valid sampling and analysis designs that achieve the constraints on uncertainty. In general several options are developed for a range of costs that will generate the type and quality of data required to make a reliable decision. In the final step of the DQO process, the decision maker selects the design option that best fits his or her needs.

contain PAHs at concentrations posing unacceptable risks. If no such EUs are found, then a "no-action" alternative may be appropriate for the entire site.

Superfund risk assessment guidance stresses the importance of considering future land use and related reasonable exposure scenarios (*4*). According to the National Utility Contractor's Association, people working at or visiting a site such as this, where light industrial equipment is operated, would typically work within or traverse an area roughly one-half acre in size (about 2,000 m^2) on a given day (*5*). This is the area in which people can be expected to receive their daily dose of contamination. In a very real sense, people "sample" surface soil contaminants over this half-acre; hence the average concentration of contaminants over each half-acre is a meaningful basis for assessing risk. Thus, for this site, a half-acre area of soil is an EU. Since a separate estimate of the average surface soil concentration will be generated for each EU, and a separate decision made about whether each EU poses an unacceptable risk, the EU defines the spatial domain of the decision.

Based on discussions of the potential risks posed by the site, the EPA Region IV remedial staff decided that remedial action should be taken if the site (i.e., any EU at the site) poses an increased cancer risk greater than 10^{-4}. The 10^{-4} risk level is therefore the decision point between acceptable and unacceptable risk. This decision point is consistent with EPA's policy that 10^{-4} and 10^{-7} is the range for acceptable risk limits (*6*). (*Note:* The 10^{-4} level was used specifically for this case study and does not necessarily reflect EPA Region IV policy or standard practice for other sites.)

We used exposure assumptions and standard Superfund risk equations (*6*) to determine the surface soil contaminant concentration that corresponds to a risk level of 10^{-4}. Region IV typically treats total PAHs as though the sole contaminant is benzo[*a*]pyrene, the most toxic of the PAH family of compounds. This approach is conservative in that it will generally overestimate the risk posed by total PAHs. Risk calculations indicate that an EU is a problem (i.e., presents a 10^{-4} increased risk of cancer) when the average PAH concentration in the EU is at or above 122 ppm.

A "logic statement" is a concise quantitative summary of how data will be used to reach a decision. The logic statement follows directly from the formulation of the problem above.

Data collected during the remedial investigation will be used to determine the average surface soil concentration of PAHs within each half-acre. Average PAH concentrations will be compared to the risk-derived concentration of concern, 122 ppm, to determine which, if any, surface soil EUs have PAHs at concentrations that would pose an unacceptable risk.

If an EU has an unacceptable average PAH concentration ≥122 ppm, then further study should be undertaken to develop a list of remedial alternatives. This "if-then" logic statement will be applied for each of the EUs, and any EU posing an unacceptable risk will need to be remediated.

Constraints on uncertainty

If the estimates of average PAH concentration within EUs are inaccurate, decisions about whether an EU poses unacceptable risk may be incorrect. The remedial investigation should be designed to limit the probability of incorrect decisions to an acceptable level. After the logic statement was specified, the project manager developed constraints on uncertainty, expressed as acceptable false positive and false negative error rates. These are shown in Figure 1. The *y*-axis provides the acceptable error rates (probability of making an incorrect decision) given various possible true risk levels, shown on the upper *x*-axis.

Acceptable error rates were not assigned in the 61–122-ppm range because the manager considered either decision would acceptable in this range. The error rates expressed in Figure 1 provided the statistician with quantitative constraints to be used in developing survey designs, which specify the number, location, and type of samples needed in the remedial investigation.

Stated in terms of the risk-based decision point, decisions about EUs may be incorrect in two ways:

The first type of error occurs when it is decided that an EU does not pose an unacceptable risk when, in fact, the risk posed by the EU exceeds 10^{-4}. This is a false negative error. If the investigation leads to this false conclusion, the project manager may stop further investigations at the EU and people eventually may be exposed to unacceptable risks. The seriousness of this type of error, and therefore the project manager's desire to avoid it, becomes greater as the true level of risk gets larger and larger. To help the manager establish limits on false negatives, a toxicologist was consulted to assess the consequences for three ranges of incremental risk, all of which exceed 10^{-4}:

- 1.0×10^{-4} to 5.0×10^{-4};
- 5.0×10^{-4} to 1.0×10^{-3}; and
- above 1.0×10^{-3}.

After carefully considering the human health consequences, the project manager assigned acceptable probabilities for failing to detect a problem if the risk posed by the EU is actually within each of the above ranges (shown in the right-hand portion of Figure 1). The manager expressed differing levels of acceptable error rates for the three risk ranges. These error rates (probabilities), which reflect the manager's increasing desire to avoid false negative errors at higher and higher contaminant concentrations, are the maximum acceptable rates established for this type of error. Notice that the manager desired lower false negative rates when the true risk is above 1.0×10^{-3} because the consequences to the public and to workers on-site are potentially much more serious than the consequences associated with the other ranges of risk.

The second type of error occurs when it is decided that an EU poses an unacceptable risk when, in fact, the risk posed by the EU is less than 10^{-4}. This is a false positive error. If data collected during the remedial investigation lead to this false conclusion, the manager will decide, unnecessarily, to continue to study the EU. New data may eventually reveal that an EU is not a problem, and hence, correct the false positive error. Otherwise, unnecessary remedial action will be taken. A false positive error results in wasted time, money, and effort on EUs that are actually not a problem. The manager consulted with the toxicologist and site engineers to assess the consequences of such error for three risk ranges, all of which are below 10^{-4}:

- below 5×10^{-6};
- 5.0×10^{-6} to 1.0×10^{-5}; and
- 1.0×10^{-5} to 5.0×10^{-5}.

The project manager stated that the remedial investigation should be designed to have a low probability of false positives when very low risk levels exist at an EU (e.g., when the EU is "clean"). The manager was willing to tolerate higher probabilities of false positives for risk levels near the threshold. The manager assigned acceptable probabilities for determining when an EU is a problem when in reality it is not for each of the above ranges (shown in the left-hand portion of Figure 1). These values are the acceptable rates for this type of error.

Risk equations (*6*) were used to determine the PAH concentrations that correspond to the risk ranges for which acceptable error rates had been defined. These concentrations are shown on the lower *x*-axis in Figure 1.

The logic statement, discussed earlier, indicated that we want to conclude that an EU is a problem if the true average PAH concentration in the EU is >122 ppm. Figure 1 indicates that the project manager is willing to accept a 0.15 probability or less for making an incorrect decision at true concentrations of 122 ppm. It also indicates the manager's desire to avoid developing remedial alternatives for EUs that have PAH concentrations below 61 ppm. The figure specifies that for PAH concentrations falling between 122 ppm and 61 ppm, the manager will accept either decision (indicated by the grey region in Figure 1).

Because the project manager is indifferent about the decision in the range of 61–122 ppm, but wants to limit the probability of a false negative at 122 ppm or above, our original question was refined as follows: "Which, if any, surface soil EUs have an average PAH concentration above 61 ppm?" At 122 ppm and above, the manager has specified the false negative error rates that are acceptable. At values below 61 ppm, the manager also specified the false positive error rates that are acceptable. The qualitative and quantitative criteria established for addressing this question are the DQOs for the remedial investigation, and will focus the statistician's search for an optimal design (see box, "DQOs for case study").

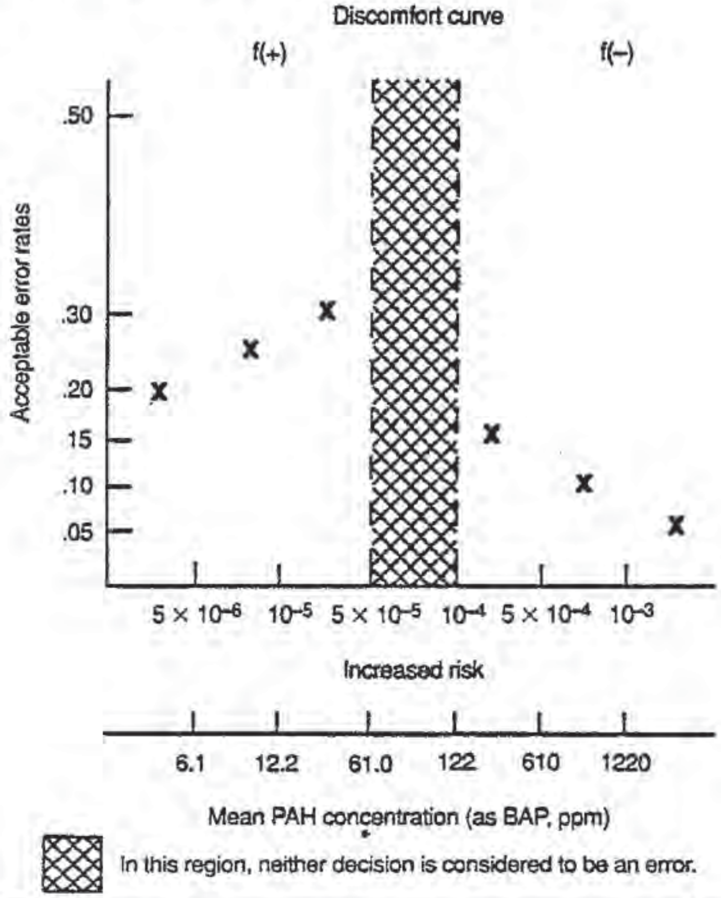
Design and optimization

After the DQOs were established, a statistician applied conventional techniques to explore and evaluate various designs for data collection. The statistician was asked to design a survey that, first, would attempt to identify any EUs that have average PAH concentrations >61 ppm; and second, would be subject to error rates no greater than those specified in the DQO statement from the project manager.

One concern the statistician noted was

FIGURE 1

Acceptable limits for decision error



DQOs for case study

Decision: Determine whether sections of the site pose unacceptable risks to human health or the environment and require remediation.

Domain: Exposure units are half-acre areas of surface soils. (Temporal aspects of the domain are not at issue because the contaminant of concern at this site is stable, not mobile.)

Logic statement: If the mean PAH concentration in an exposure unit exceeds 122 ppm (10^{-4} risk), then the exposure unit will require remediation.

Uncertainty constraints

PAH risk range	Concentration range (ppm)	Acceptable probability for false positives (%)
Below 5×10^{-6}	Below 6.1	20
5×10^{-6} to 1×10^{-5}	6.1–12.2	25
1×10^{-5} to 5×10^{-5}	12.2–61	30

PAH risk range	Concentration range (ppm)	Acceptable probability for false negatives (%)
1×10^{-4} to 5×10^{-4}	122–610	15
5×10^{-4} to 1×10^{-3}	610–1,220	10
Above 1×10^{-3}	Above 1,220	5

Workers collect soil samples at the Superfund site

that any attempt to divide the site into spatially distinct, uniform exposure units for testing runs the risk of missing an unacceptably contaminated area which lies across two or more EUs. This weakness is more than offset by two conservative measures included earlier: the assumption that the only PAH present is benzo[*a*]pyrene (the most toxic of the PAHs), and the decision to test for concentrations above 61 ppm when concern for false negative errors begins above 122 ppm.

The statistician framed the if–then logic statement as a statistical test that would allow us to determine whether PAHs within an EU are greater than 61 ppm, and began the search for designs that would control the decision uncertainty to the levels specified in the DQOs. To develop a statistically based sampling and analysis plan (the design), the statistician needed rough estimates of the spatial pattern and variability of the distribution of contaminant concentrations within EUs. He also required an estimate of the additional variability that would be introduced through the process of taking samples and analyzing them in the laboratory. Finally, since the statistician was asked to find the least expensive design that meets all the DQOs (the optimal solution), estimates of the costs of taking and analyzing a sample were required.

Since prior data on average PAHs across half-acre units were not available, the statistician used prior data from random samples of surface soils across the site (Figure 2). The statistician assumed that point-by-point spatial variability of PAHs within half-acre EUs was identical to the point-by-point variability of samples taken across the entire site, without grouping into half-acre units. This is probably a conservative assumption, since it is likely that there is some degree of similarity within EUs as compared to points that are more widely separated.

These data indicated the form of the distribution of contaminant concentrations (in this case a log-normal distribution) and provided the basis for estimating the variability of contaminant concentrations across the site. An estimate of the most probable total variance (on a log scale) is $\sigma_T^2 = 1.64$ (24 degrees of freedom). Quality control data from analyses of PAHs, using the same analytical methods as those used to generate historical data for this site, indicate that analytical imprecision is on the order of 25% relative standard deviation. If the statistician had determined the historical data were not suitable for estimating the distribution and variability of concentrations within EUs, a pilot study would have been required to obtain these estimates.

FIGURE 2

Frequency distribution of soil PAH concentrations

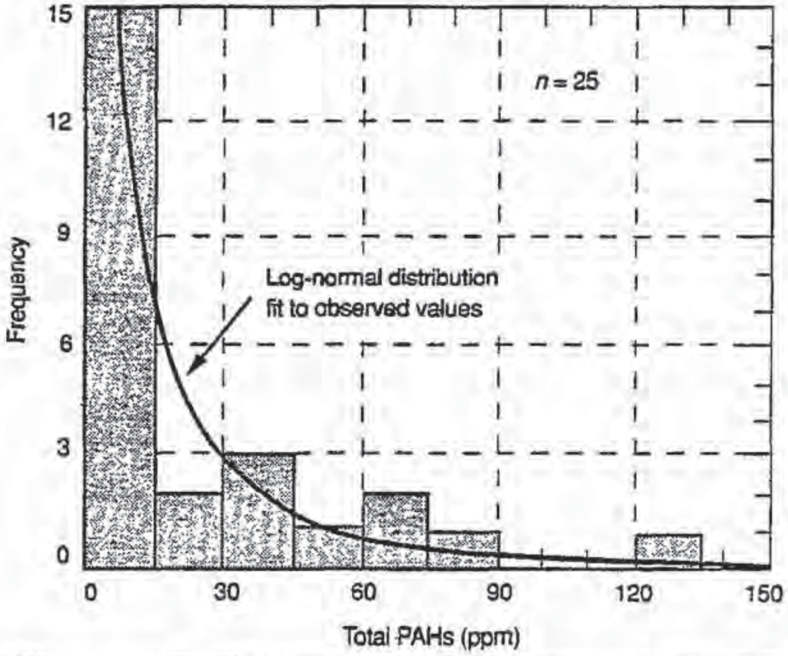


TABLE 1

Results of initial power calculations

No. scoops /analysis	No. analyses/EU	Cost /EU ($)	Probability of error[a]
1	4	3,520	.53
3	5	5,200	.15
4	2	2,240	.27
4	3	3,360	.18
4	4	4,480	.12
5	2	2,400	.20
5	3	3,600	.11

[a] When $\mu = 122$ ppm and $\alpha = .30$.
Note: α = probability of concluding EU is a problem when μ is 61 ppm.

Using the above information and the approximate per-sample costs of sampling ($80) and analysis ($800), the statistician began to evaluate various statistical sampling designs that would allow us to achieve the desired control over uncertainty. Recall that uncertainty is measured in terms of the probability of reaching an incorrect conclusion about whether an EU is a problem, i.e., the probability of false positives and false negatives. Among the options considered were uniform random sampling across the site, systematic sampling, stratified sampling, and sample compositing within each EU. After considering these options, the statistician recommended an approach that uses a compositing technique in which 10 or more scoops of soil, taken randomly within each EU, are combined, homogenized, and subsampled for analysis. When the potential difficulties and errors introduced through mixing and subsampling were recognized, five soil scoops were considered to be an efficient, practical number that could be combined routinely.

A statistical evaluation of several different designs, presented in Table 1, led to the following conclusions:

First, the expected performance data indicate that two survey designs have favorable cost and acceptable performance (i.e., were expected to meet or come close to meeting the 0.15 acceptable false negative and 0.3 false positive error rates specified over the range of important concentrations). The most favorable designs involved compositing five scoops per analytical sample. One design required the analysis of two composited samples per EU, while the other required three. Our notation for these designs are (5,2) and (5,3), respectively.

Second, compositing five scoops transformed the underlying log-normal distribution into one that is more like a normal distribution in shape. A computer simulation was needed to assess more accurately the anticipated performance of the two designs, i.e., the "power" or capability of each design to detect EUs with PAH concentrations above the criterion. (Details on the statistical evaluation may be obtained by writing author Dean Neptune.)

The (5,2) and (5,3) designs were evaluated by simulation to determine how well they can be expected to perform at the critical values of 122 and 61 ppm, and at other concentrations higher and lower than these values. The rough estimates of performance in Table 1 were based on the assumption that the distribution of total PAHs was log-normal with a total variability of 1.64. The true variability of concentrations within EUs may prove to be greater or less than this estimate. To determine the effect that more or less variability might have on reaching a correct conclusion with either of these designs, the performance of each design was evaluated at three different levels of total variability: 1.64 (most probable—our estimate of variability based on historical data), 1.00 (assumes less variability—a lower 95% confidence limit on the historical estimate), and 3.17 (assumes more variability—an upper 95% confidence limit on the historical estimate).

Figures 3 and 4 show the results of the simulations presented as expected performance curves. The shaded regions of the two figures are areas in which the constraints on uncertainty—control on false negative and false positive error rates—are achieved. In the region between 61 and 122 ppm, the shaded area shows that any amount of error can be tolerated. The shaded regions above 122 and below 61 ppm are those for which the error rates are of concern. A design performance curve that lies entirely in the shaded regions would satisfy all the DQOs (see box, "DQOs for the case study").

The figures show that the two designs can be expected to perform similarly and to achieve most of the constraints on uncertainty (most of the curve appears in the shaded region). If variability is 1.64, the figures reveal that both designs fail slightly when the true average PAH concentrations are between 50 and 60 ppm. Neither of the designs is likely to meet uncertainty constraints if the total variability is high (3.17). Points labeled "A" and "B" are slightly outside the regions of desired performance. Points labeled "A" are of concern if the variability is lower than we anticipate (1.00). Points labeled "B" are of concern if the variability is greater than we anticipate (3.17). Thus, if we use either the (5,2) or (5,3) design, and the variability of PAH concentrations within an EU is substantially lower or higher than assumed (1.64), we can expect slightly higher error rates than specified by the DQOs.

Considering the conservative measures built into the designs, the project manager determined that failing to meet uncertainty constraints at these specific points is not serious. Finally, because the design (5,2) represents a 33% cost savings over the (5,3) design, and its ability to achieve the uncertainty constraints is approximately equal to that of the (5,3) design, the (5,2) design was recommended for the remedial investigation.

Summary

The data quality objectives produced in the manner described do much more than simply guide the survey design. The DQOs provide a focused decision statement, boundaries on the domain of interest (the EU), an "if-then" logic statement that specifies how data will be used in the decision, and constraints on the amount of uncertainty (limits on both false positives and false negatives) acceptable. They provide the information needed to ensure that the number of samples per EU is adequate and the sampling and analysis methods used will provide the

FIGURE 3

Results of simulation for the (5,2) design

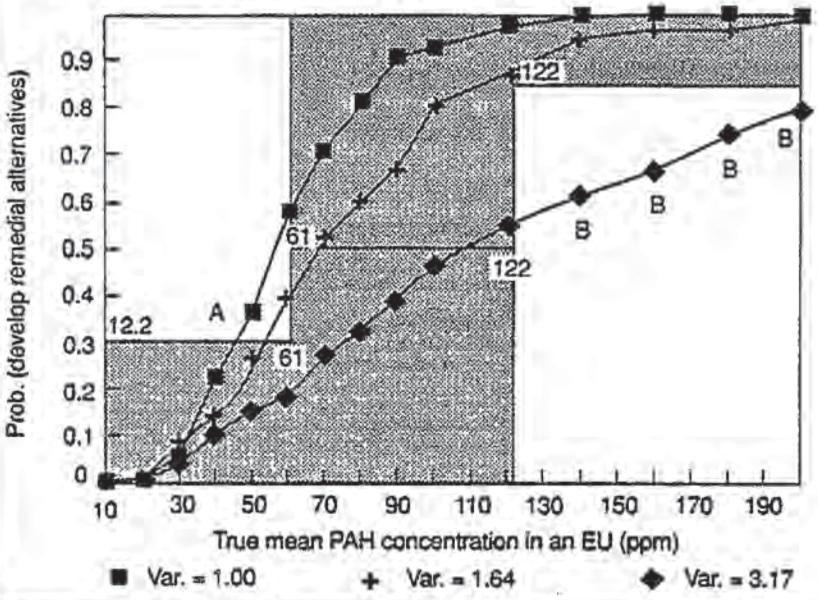
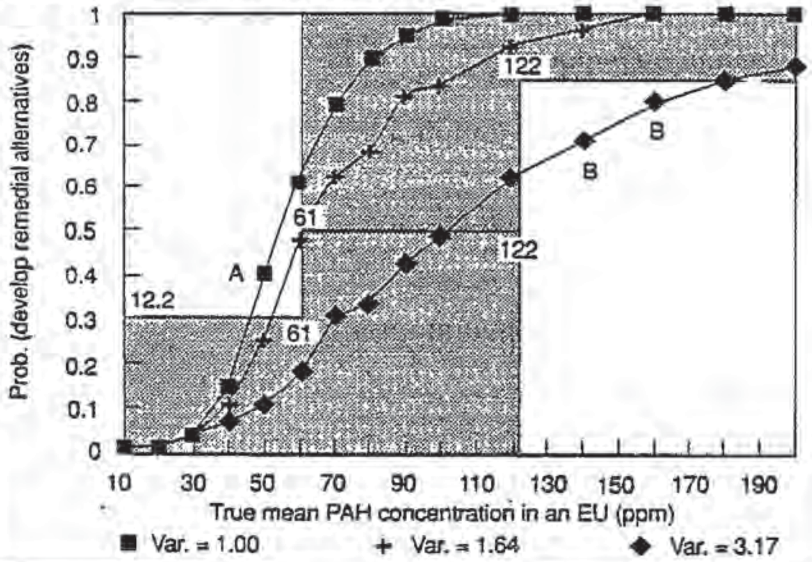


FIGURE 4

Results of simulation for the (5,3) design



quality of data required to support decisions with the desired certainty. The most important benefits of this approach are that the decisions regarding Superfund site remediation can be made at the desired level of certainty, and that the project manager has specific quantitative criteria for deciding how much data is enough.

References

(1) Quality Assurance Management Staff. "Development of Data Quality Objectives: Description of Stages I and II." In *EPA Information Guide:* EPA: Washington, D.C., July 1986.

(2) Environmental Protection Agency Office of Emergency and Remedial Response. "RI/FS Improvements Phase II, Streamlining Recommendations"; EPA: Washington, D.C., January 1989; OSWER Directive No. 9355.3-06.

(3) Environmental Protection Agency. "Region IV Remedial Investigation Report for this Uncontrolled Hazardous Waste Site"; EPA: Washington, D.C., 1988.

(4) Environmental Protection Agency. *Risk Assessment Guidance for Superfund: Human Health Evaluation Manual:* EPA: Washington, D.C., June 30, 1989; draft. *Note:* The calculations used to estimate reasonable maximum exposure in this case study are found in Reference 6.

(5) Connor, B., National Utility Contractor's Association, Arlington, Va., personal communication. Reasonableness of this estimate was confirmed by EPA ORD and Region IV risk assessment experts.

(6) Office of Emergency and Remedial Response. *Superfund Public Health Evaluation Manual;* OSWER/EPA: Washington, D.C., October 1986; EPA 540/1-86/060.

Acknowledgments

The individuals listed below played a substantive role in the development of the DQOs for this hazardous waste site. Region IV used the planning issues raised through the DQO process to set survey design constraints (the DQOs) for the case study. The DQOs then were used as the basis for optimizing the possible survey designs for this site. The DQO process and its adaptation to Superfund planning issues for the remedial investigation/feasibility study was led by the quality assurance management staff, with DQO application support from Research Triangle Institute, Montana State University, and NUS Corp. The authors of this paper have summarized the outputs of a series of activities in which all of these individuals participated directly: James Pickett, Ph.D., and Randall Ryti, Ph.D., Montana State University; Robert Hubbard, NUS Corp.; Eugene P. Brantly, C. Andrew Clayton, Daniel I. Michael, Michael Messner, Research Triangle Institute; Elmer Akin, Meredith Anderson, William Bokey, Beverly Houston, David Kleusner, M.D. Lair, William Patton, EPA Region IV; Dean Neptune, Ph.D., EPA Headquarters quality assurance management staff.

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E.3. KENTUCKY REGULATORY GUIDANCE

Copies of regulatory guidance listed below previously have been presented in this chapter. This regulatory guidance is available 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/R8/V1 (DOE 2017). Several guidance documents also are available online.

- Kentucky Risk Assessment Guidance, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, June 8, 2002.
  https://eec.ky.gov/Environmental-Protection/Waste/superfund/Documents/KY%20Risk%20Assessment%20Guidance%20_Final_.pdf

- Kentucky Guidance for Ambient Background Assessment, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, January 8, 2004.
  https://eec.ky.gov/Environmental-Protection/Waste/superfund/Documents/Kentucky%20Guidance%20for%20Ambient%20Background%20Assessment.pdf

- Kentucky Guidance for Groundwater Assessment Screening, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, January 15 2004.
  https://eec.ky.gov/Environmental-Protection/Waste/superfund/Documents/GroundwaterAssessmentScreening.pdf

- Trichloroethylene Environmental Levels of Concern, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, April 2004.
  Guidance is not available online. See https://www.epa.gov/iris for additional information.

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E.4. FLOWCHART FOR UNCERTAINTY MANAGEMENT FOR UNKNOWN AREAS OF CONTAMINATION

The annotated flowchart presented in this section was provided to KDWM under cover letter from the DOE Paducah Site Lead on April 1, 2008, (PPPO-02-130-08) as a condition to be met for DOE to receive an Environmental Indicator of “Yes” with regard to the Government Performance and Results Act milestone of having human exposures under control. The flowchart applies to newly identified areas of contamination that may be identified in the future on DOE-owned property licenses for use at PGDP, which are outside the controlled area and not currently assigned to an operable unit under the Federal Facility Agreement (FFA). The flowchart describes the uncertainty management for nonworker exposures associated with DOE-owned property described above.

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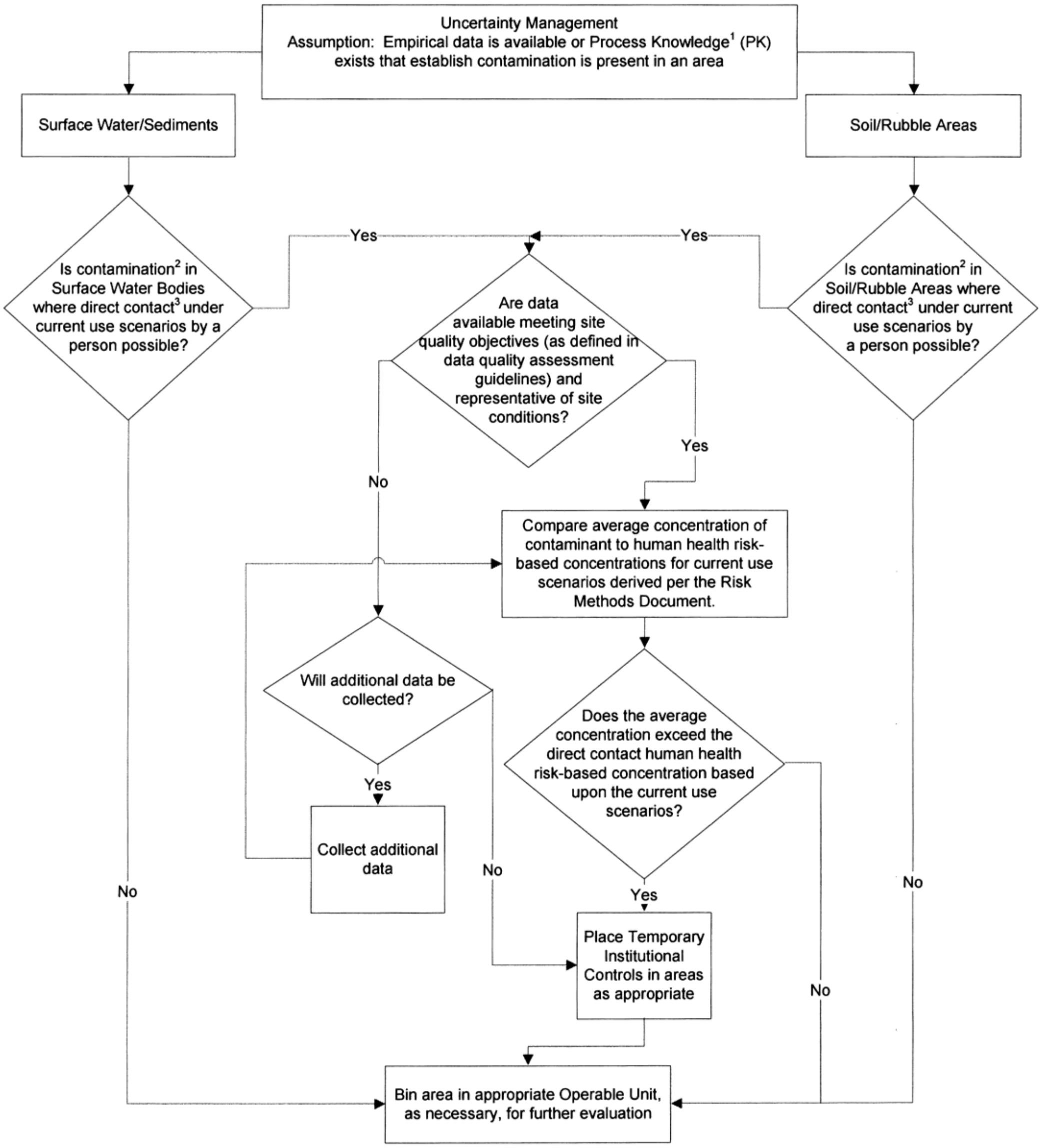
Enclosure

Flow Chart for Uncertainty Management

This flowchart applies to newly identified areas of contamination that may be identified in the future on DOE-owned property licensed for use at the Paducah Gaseous Diffusion Plant, which are outside the controlled area and not currently assigned to an operable unit under the federal Facility Agreement. The flowchart describes uncertainty management for non-worker exposures associated with DOE-owned property described above.



1 "Process Knowledge" is defined as information identifying releases from past or current processes at the PGDP.

2 "Contamination" is defined in the Risk Methods Document as the presence of a constituent at a concentration greater than background.

3 "Direct contact" is exposure by a human to environmental medium [i.e., surface soil, sediment, debris (e.g., rubble), and surface water] through ingestion, dermal contact, inhalation (particulates and vapors), or external exposure.

Enclosure
(Cont)
Further Explanation of Flow Chart Steps

Uncertainty Management Assumption: Empirical data is available or Process Knowledge[1] (PK) exists that establish contamination is present in an area	This flowchart applies to newly identified areas of contamination that may be identified in the future on DOE-owned property licensed for use at the Paducah Gaseous Diffusion Plant, which are outside the controlled area and not currently assigned to an operable unit under the federal Facility Agreement. The flowchart describes uncertainty management for non-worker exposures associated with DOE-owned property described above. Sufficient data or credible Process Knowledge must exist for this process to be activated.
Is contamination[2] in Surface Water Bodies or Soil/Rubble Areas where direct contact[3] under current use scenarios by a person possible?	Contamination definition is identified in Footnote 2. This process focuses on areas of surface soil, sediment, debris (e.g., rubble), and surface water that are located in the licensed area and available for direct contact exposure. Examples of exposure scenarios are riding horses or ATVs in the creek and bank areas, walking or hiking through wildlife habitat, or hunting.
Are data available meeting site quality objectives (as defined in data quality assessment guidelines) and representative of site conditions?	An evaluation of the available data will be performed to determine if data are of sufficient quality to be used for risk assessment. Additional data may be collected to determine appropriate protective actions.
Compare average concentration of contaminant to human health risk-based concentrations for current use scenarios derived per the Risk Methods Document.	Average concentrations from existing data will be compared to the human health risk-based concentrations. Risk-based concentrations used will be based on guidance in the current site Risk Methods Document.
Place Temporary Institutional Controls in areas as appropriate	Temporary institutional controls may vary depending on the nature of contamination. DOE may place temporary institutional controls under CERCLA, perform a maintenance action, or post under 10 *CFR* 835.
Bin area in appropriate Operable Unit, as necessary, for further evaluation	DOE, EPA, and KY will determine the appropriate Operable Unit under which the area may be placed for future evaluation in accordance with the FFA. These agencies will determine if immediate actions such as sampling or removal actions are warranted based on potential risk and exposure to the public.

E.5. COMPILED PARAMETERS FOR PROBABILISTIC RISK ASSESSMENTS

A probabilistic risk assessment (PRA) of migration of contaminants to groundwater was conducted for the *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant*, *Paducah*, *Kentucky*, DOE/OR/07-2180&D2/R1 (June 2007). The parameters used in that modeling effort were presented in Attachment 2 of Appendix F of the site investigation report. This set of parameter values is appropriate for use in modeling for other PRAs, though the information on these values should be reviewed during the PRA development to ensure the assumptions made in setting the values are appropriate for each site being evaluated. Parameter values should be modified, if necessary, to reflect conditions for the individual site under consideration.

Appendix F, Attachment 2, of the *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-2180&D2/R1.

INPUT PARAMETERS FOR PROBABILISTIC MODELING

1. INTRODUCTION

Probabilistic (stochastic) modeling was performed for the trichloroethene (TCE) sources at (Solid Waste Management Unit (SWMU) 1 and the C-720 Building areas in order to understand better the uncertainties in the transport modeling for these sources, to estimate the likely TCE concentrations at the points of exposure (POEs) using the most likely input parameters, and to determine the error bounds on the predicted TCE concentrations. This modeling was based upon the nature and extent discussion in the Site Investigation (SI) Report and the transport modeling results completed earlier.

The fate and transport modeling was performed using Spatial Analysis/Decision Assistance (SADA) software (UT 2002); Crystal Ball® (Decisioneering, Inc. 2000), an add-in to Microsoft Excel®; Seasonal Soil Compartment Model (SESOIL) (GSC 1996, Bonazountas and Wagner 1984); and Analytical Transient One-, Two-, and Three-Dimensional Simulation Model (AT123D) (GSC 1998, Yeh 1981). The key input parameters for the modeling were developed using SADA and Crystal Ball®, while the modeling itself was performed using SESOIL and AT123D.

2. INPUT PARAMETERS

The input parameters for the modeling were in two groups: fixed and variable. The values of the fixed parameters were from earlier work (DOE 2003). The values of the variable parameters were set considering earlier work and employing a probabilistic method. This was done by developing a distribution for each variable parameter and sampling the distribution using the Monte Carlo sampling technique provided in Crystal Ball®.

3. PARAMETER DISTRIBUTIONS

Several distributions were considered when selecting the best distribution for each of the variable input parameters. A general discussion of each distribution considered is provided below.

1. **Triangular Distribution:** This distribution is used to describe a variable with known minimum, maximum, and most likely values (Decisioneering, Inc. 2000). Three conditions underlying this distribution are as follows:

    - The minimum value of the variable is fixed.
    - The maximum value of the variable is fixed.

- The most likely value of the variable falls between the minimum and maximum values forming a triangular-shaped distribution and showing that values near the minimum and maximum are less likely to occur than those near the most likely values.

2. **Normal Distribution:** This is the most important distribution in the probability theory because it describes many natural phenomena (Decisioneering, Inc. 2000). Three conditions underlying this distribution are as follows:

    - Some value of the variable is the most likely (the mean of the distribution).
    - The value of the variable could as likely be below the mean as it could be above the mean (symmetrical about the mean).
    - The value of the variable is more likely to be near the mean than far away.

    Generally, if the coefficient of variability is less than 30%, a normal distribution is recommended. A skewness value between -0.5 and +0.5 indicates a fairly symmetrical distribution (Decisioneering, Inc. 2000).

3. **Log-Normal Distribution:** This distribution is widely used to describe a variable with values that are positively skewed (Decisioneering, Inc. 2000). The three conditions underlying this distribution are as follows:

    - The variable can increase without limits but cannot fall below zero.
    - The variable is positively skewed with most of the values near the lower limit.
    - The natural logarithm of the variable yields a normal distribution

    Generally, if the coefficient of variability is greater than 30%, a log-normal distribution is recommended. A skewness value less than -1 or greater than +1 indicates a highly skewed distribution (Decisioneering, Inc. 2000).

4. **Uniform Distribution:** This distribution is used to describe a variable when each value of the variable has the same probability of occurrence within a selected range. This distribution is often used when no information about variable's distribution is available. The three conditions underlying this distribution are as follows:

    - The minimum value of the variable is fixed.
    - The maximum value of the variable is fixed.
    - The probability of any value being selected within the range between the minimum and maximum values is equal.

4. SESOIL PARAMETERS

The SESOIL software was used to simulate contaminant transport through the Upper Continental Recharge System (UCRS) to the Regional Gravel Aquifer (RGA). The parameters used for SESOIL are listed in Tables F.2.1 and F.2.2. As mentioned earlier, there are two groups of parameters. Remarks for each parameter are provided in these tables to clarify the source of the value and the justification for its selected value. Additional remarks for each variable parameter, including the values input into Crystal Ball, are provided in Table F.2.3. Finally, summary statistics for each variable parameter output by

Crystal Ball are provided in Table F.2.4. Histograms of the values output by Crystal Ball for the variable parameters are in Figs. F.2.1 through F.2.18.

1. **Fixed Parameters:** These parameters are summarized in Tables F.2.1 and F.2.2.

   - **Soil Type:** The upper portion of the UCRS is loam, while the bottom portion of it is silty clay (DOE 1999). The soil type was considered to be silty loam for each area.

   - **Bulk Density:** The bulk density of the UCRS is 1.46 g/cm^3 (DOE 1999). The bulk density was set to this value for each area.

   - **Disconnectedness Index:** The disconnected index was set to a site-specific approximate value of 10 used in earlier work. The value was estimated by calibrating the deterministic model to an average recharge of 11.38 cm/yr.

   - **Porosity:** The porosity of the UCRS is 0.45 (DOE 1999). The porosity was set to this value for each area.

   - **Depth to Water Table:** The depth to the water table was estimated for each area considering site-specific data. The depths were estimated as 16.76 m (55 ft), and 18.29 m (60 ft) for SWMU 1 and C-720 areas, respectively.

   - **Freundlich Equation Exponent:** The Freundlich equation exponent typically ranges from 0.9 to 1.4; the default value of 1.0 is recommended if the actual value is not known (GSC 1996). The exponent was set to 1 for each area.

   - **Contaminant of Concern (COC):** The COC of interest was TCE.

   - **Source Area:** The source area was developed analyzing site-specific data for each area. Soil concentration for the area was analyzed layer-by-layer using SADA. A limitation of SESOIL required that all layers have the same area. Source areas and the average soil concentration in each layer were estimated, and the source area with the maximum contaminant mass was identified and set as the "uniform area." Concentrations within each layer were then normalized against the "uniform area" (discussed later). The "uniform areas" used for SWMU 1 and the C-720 area were 324 m^2 and 1394 m^2, respectively.

   - **Molecular Weight:** The molecular weight was set to 131 g/gm-mol (EPA 1994).

   - **Solubility in Water:** The solubility in water was set to 1100 mg/L (EPA 1996).

   - **Diffusion in Air:** The diffusion in air was set to 0.08 cm^2/sec (EPA 1996).

   - **Henry's Constant:** The Henry's constant was set to 0.0103 atm-m^3/mol (EPA 1996).

   - **Soil Organic Carbon/Water Partition coefficient (K_{oc}):** The K_{oc} was set to 94 L/kg (EPA 1996).

2. **Variable Parameters:** These parameters are summarized in Tables F.2.1 through F.2.4.

- **Intrinsic Permeability:** Site-specific data were available for the vertical hydraulic conductivity of the UCRS. Therefore, the intrinsic permeability was estimated from vertical hydraulic conductivity using the following equation.

  $$K = k\frac{g}{\nu} \qquad (1)$$

  where K = vertical hydraulic conductivity of soil, k = intrinsic permeability of soil, ν = kinematic viscosity of water, and g = gravitational acceleration (Bear 1979). Taking ν = 0.01 cm^2/sec and g = 981 cm/sec^2 (Mills et al. 1985), and substituting in Equation 1 leads to

  $$k\left(cm^2\right) = \frac{K\left(cm/\sec\right)}{9.81\,x\,10^4\left(1/cm - \sec\right)} \qquad (2)$$

  The intrinsic permeability was estimated from the saturated vertical hydraulic conductivity using Equation 2.

  The site-specific vertical hydraulic conductivities measured earlier were assumed to be representative of that expected in the UCRS at each area. Summary statistics for the site-specific data are in Table F.2.3. A set of 13 results was available (DOE 1997a, DOE 1997b). These results ranged from 1.00E-08 cm/sec to 2.00E-04 cm/sec with a likeliest (mean) value of 1.64E-05 cm/sec. The coefficient of variation was estimated as 336%, and the skewness was estimated as 3.6. Next, the statistics were studied. The maximum value, when used in SESOIL produced an unreasonable recharge; therefore, a second estimate of maximum was sought through calibration. The maximum was re-estimated as 3.20E-05 through calibration to a recharge of 22 cm/yr (DOE 2000). Given that a range and a most likely value could be determined from the site-specific data, a triangular distribution was assumed. The vertical hydraulic conductivity was assumed not correlated to any other parameter. The summary statistics for the values output by Crystal Ball are in Table F.2.4. Histograms for the output values for the resulting intrinsic permeabilities for each of the two source areas are in Figs. F.2.1 and F.2.2.

- **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. Histograms for the output values for organic carbon content for each of the two source areas are in Figs. F.2.3 and F.2.4.

- **Soil Concentration:** Site-specific data were available for the TCE soil concentrations in each source area. Summary statistics for each layer are in Table F.2.3. For SWMU 1, a set of 135 results was available. The coefficient of variation for these results was estimated as 523%, and the skewness was estimated as 6.42. Given the coefficient of variation and skewness, a log-normal distribution was assumed. Using site-specific data, the correlation between Layers 1 and 2 soil concentrations was determined to be 0.92. (Please see Section 4.3 for additional discussion of correlations between layers.) Similar analyses led to choosing the log-normal distribution for Layer 1 at the C-720 area. The correlation coefficients between Layers 1 and 2 for the C-720 area were determined to be 0 and -0.50, respectively. Site-specific data were also available for the soil concentrations in Layer 2 through Layer 6. Summary statistics for each of these layers at each location are in Table F.2.3. For each layer at each location, a log-normal distribution was chosen, and correlations between layers were derived.

As mentioned earlier, a limitation of the SESOIL model required normalization of soil concentrations in each layer at each location to a “uniform area.” To accomplish this, the layer with the maximum contaminant mass at each source was used as that source’s “uniform area,” and a simple ratio was used to normalize each layer’s concentration to that of the “uniform area.” The summary statistics for the value output by Crystal Ball are in Table F.2.4. Histograms for each layer at each location are in Figs. F.2.5 through F.2.16.

- **Degradation Half-Life/Degradation Rate:** Site-specific data were limited for the degradation half-life of TCE in the UCRS; therefore, a range of half-lives estimated for the RGA (3.2 to 11.3 years) were selected with uniform distribution for the UCRS. (Please see Attachment F.3 of Appendix F for additional information on the estimation of degradation half-life of TCE in the RGA at PGDP.) The degradation half-life was assumed not correlated to any other parameter. Summary statistics for the values output by Crystal Ball are in Table F.2.4. Histograms of the output values for degradation rate for each of the two source areas are in Figs. F.2.17 and F.2.18. Note that only histograms of degradation rate are presented because the rate, and not the half-life, was the value input into SESOIL. Where, the degradation rate is derived from the degradation half-life using the following expression:

$$\lambda = \frac{\ln 2}{t_{1/2}} \qquad (3)$$

where λ = degradation rate (day^{-1}), and $t_{1/2}$ = degradation half-life (days).

An additional scenario termed the “fixed degradation scenario” was also assessed in the probabilistic analysis. The degradation half-life was set equal to 26.6 years for these runs, while the remaining parameters listed above were allowed to vary.

5. AT123D PARAMETERS AND SOURCE TERM MODELING PARAMETERS

The AT123D software was used to simulate contaminant transport from the source areas through the RGA to the POEs. The parameters used for AT123D modeling are listed in Tables F.2.5, F.2.6, and F.2.7. Remarks for each parameter are provided in the table to clarify the source and justification of selected values. Additional remarks for each variable parameter are provided in Table F.2.8. Finally, the summary statistics for each variable parameter sampled output by Crystal Ball and used in the runs for AT123D and source term modeling are provided in Table F.2.9. Histograms of the values output by Crystal Ball for the variable parameters are in Figs. F.2.19 through F.2.24.

1. **Fixed Parameters:** These parameters are summarized in Tables F.2.5, F.2.6, and F.2.7.

   - **Dispersivity:** The longitudinal dispersivity was set to 1.5 m for each area (DOE 1999). Similarly, the transverse (lateral) dispersivity and the vertical dispersivity were set to 1.5 m and 0.03 m, respectively, for the area.

   - **Bulk Density:** The bulk density of the RGA is 1670 kg/m^3 (DOE 1999). The bulk density was set to this value for each area.

   - **Density of Water:** The density of water was set to 1000 kg/m^3 (Mills et al. 1985).

   - **COC:** As mentioned earlier, the COC was TCE.

   - **Source Area:** The area used in AT123D modeling for each source was the “uniform area” developed for the source in SESOIL modeling.

   - **Diffusion in Water:** The diffusion in water was set to 3.28E-6 m^2/hr (EPA 1996).

   - **K_{oc}:** As mentioned earlier, the K_{oc} was set to 94 L/kg (EPA 1996).

   - **Distance to POEs:** The distance from the center of each source area to the POEs was estimated from plant maps. Each of the POEs was placed at the centerline of the estimated path of contaminant migration.

2. **Variable Parameter:** These parameters are summarized in Tables F.2.5 through F.2.9.

   - **Aquifer Depth (Thickness):** The aquifer depth was allowed to vary in order to account for changes in the thickness of RGA as a contaminant migrates from a source area to the Ohio River. Site-specific data were available from field measurements, and these data were assumed to be applicable to the RGA at each source area and along the estimated contaminant flow paths. A set of 24 results was available. The coefficient of variation was estimated as 31%, and the skewness was estimated as -0.61. Given the coefficient of variation and skewness, the distribution was assumed to be normal. The aquifer depth was assumed not correlated to any other parameter. Summary statistics for the values output by Crystal Ball® and used in runs for AT123D modeling are provided in Table F.2.9. A histogram of the output values for aquifer depth is in Fig. F.2.19. (Note that each source area used the same set of parameters in AT123D modeling; therefore, only one histogram is presented for each of the AT123D variable parameters.)

   - Hydraulic Conductivity: Site specific data were available for the hydraulic conductivity of the RGA, and these data were assumed to be applicable to the RGA at each source area and along the contaminant flow paths. A set of 62 results was available. The data ranged from 1.00E-04 ft/day to 8.50E+05 ft/day with a likeliest value of 1.93E+04 ft/day. The coefficient of variation was estimated as 563%, and the skewness was estimated as 7.53. A value of 1500 ft/day was used in DOE 1999. During model set-up, the range was judged to be too variable given the site-specific soil condition, and a second estimate was sought from the PGDP groundwater flow model. This estimate was developed using an analysis based upon a plan area from the PGDP site-wide groundwater model and the path of contaminant migration from the source areas to the Ohio River (please see Fig.5.1 of the main report). Based upon this analysis, the minimum, maximum, and most likely values chosen were 75, 1500, and 967 ft/day, respectively. The coefficient of variation was estimated as 65%, and the skewness was estimated as -0.35. Subsequently, the selected most likely value was determined to be inconsistent with probable site conditions, and after consultation with site experts these value was changed to 350 ft/day (i.e., the geometric mean of the minimum and maximum in the plan area). The standard deviation was assumed equal to the likeliest value yielding a coefficient of variation of 100%. Given this coefficient of variation and the skewness from the earlier analyses (i.e., that related to site-specific data and plan area), a log-normal distribution was assumed. In addition, the hydraulic conductivity was assumed correlated to the hydraulic gradient and the porosity. The correlation coefficients selected by site experts were -0.50 and 0.20 for correlating the hydraulic conductivity to the hydraulic gradient and to the porosity, respectively. Summary statistics for the values output by Crystal Ball® and used in runs for AT123D modeling are provided in Table F.2.9. A histogram of the output values for hydraulic conductivity is in Fig. F.2.20.

Hydraulic Gradient: Site-specific data were available for the hydraulic gradient of the RGA, and these data were assumed applicable to the RGA at each source area and along the contaminant flow paths. A set of 12 results was available. The coefficient of variation was estimated as 111%, and the skewness was estimated as 1.95. Given the coefficient of variation and skewness, a log-normal distribution was assumed with minimum, maximum, and most likely values of 1.00E-04, 4.00E-03, and 1.01E-03 m/m, respectively. The standard deviation was set at 1.12E-03 m/m. Additionally, the hydraulic gradient was assumed correlated to the hydraulic conductivity and the porosity. The correlation coefficients were assumed as -0.50 and -0.20 for correlating the hydraulic gradient to the hydraulic conductivity and to the porosity, respectively. Summary statistics for the values output by Crystal Ball® and used in runs for AT123D modeling are provided in Table F.2.9. A histogram of the output values for hydraulic gradient is in Fig. F.2.21.

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.

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

- **Organic Carbon Content:** Site-specific data were available for the organic carbon content of the RGA, and these data were assumed applicable to the RGA at each source area and along the contaminant flow paths. A set of 38 results was available. The minimum, maximum, and most likely values selected were 3.0E-03, 2.53E-01, and 3.5E-02%, respectively. The coefficient of variation was estimated as 1.05%, and the skewness was estimated as 4.0. 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. Summary statistics for the values output by Crystal Ball® and used in runs for AT123D modeling are provided in Table F.2.9. A histogram of the output values for organic carbon content is in Fig. F.2.23.

- **Degradation Half-Life:** Recently, as part of response actions, the U.S. Department of Energy (DOE) has developed revised biodegradation rates that were incorporated into the SI modeling. Attachment F.3 to this appendix presents a detailed discussion of the derivation of the degradation rates. Additionally, the degradation half-life was observed to be correlated with groundwater flow which is a direct function of hydraulic conductivity and hydraulic gradient. However, for this analysis the degradation half-life was assumed 100% correlated to the hydraulic gradient. Summary statistics for the values output by Crystal Ball® and used in runs for AT123D modeling are provided in Table F.2.9. A histogram of the output values for degradation rate is in Fig. F.2.24. Note that only histograms of degradation rate are presented because the rate, and not the half-life, was the value input into AT123D. It should be noted here that although hydraulic gradient assumed a normal distribution, Crystal Ball output for degradation rate presented in Fig. F2.24 does not appear to be normally distributed. An additional scenario termed the “fixed degradation scenario” was also assessed in the probabilistic analysis. No degradation was assumed for these runs, while the remaining parameters listed above were allowed to vary.

6. CORRELATION MATRIX

As mentioned earlier, the soil concentration in each layer was assumed correlated to the adjacent layers for a given area. To estimate the correlation coefficient between two adjacent layers, sets of ordered pairs of concentrations were analyzed. Because data were sparse, ordered pairs were difficult to establish using the sampling date; therefore, the source developed using SADA was used for the estimation. For SADA data, the size and shape of the source areas in the adjacent layers differed; therefore, an ordered pair was formed only in the parts of the source where two layers overlapped.

The correlation values are presented in Table F.2.3.

7. SENSITIVITY ANALYSIS

Although there was not any sensitivity analysis performed under this task to select the parameters that were allowed to vary, previous groundwater modeling efforts at the PGDP have included sensitivity analyses of several of the parameters input into SESOIL and AT123D in order to understand some of the modeling uncertainties. The analyses are included in these documents:

- U-Landfill Design and Analysis (DOE 2002)
- K_d-Sensitivity Analysis (SAIC 2002)
- Northeast and Northwest Plume Groundwater Modeling (BJC 2003)
- Recharge- and Ohio River Stage-Sensitivity Analysis (DOE 2002)

Based on these analyses, the following parameters were determined to be the most sensitive parameters for fate and transport modeling using SESOIL and AT123D:

- Contaminant's concentration in the soil/source term,
- Contaminant's degradation half-life,
- Contaminant's distribution coefficient (K_d) (i.e., directly related to the organic carbon content of source soils for organic compounds)
- Percolation rate (controlled by source vertical permeability)
- Saturated hydraulic conductivity,
- Hydraulic gradient,
- Effective porosity, and
- Aquifer thickness

The contaminant concentration in the source term is one of the most sensitive parameters; increasing the source term concentration increases the predicted groundwater concentration at the POE by increasing contaminant flux and lengthening the time required for depletion of contaminant in the source. The percolation rate is also a very sensitive parameter; increasing the percolation rate results in increased contaminant flux to the RGA and, potentially, a greater peak concentration at the POE. An increased percolation rate, however, is related to faster depletion of contaminant in the source. The contaminant's distribution coefficient, K_d, is a very sensitive parameter for the SESOIL and AT123D models and may rank only behind contaminant concentration in terms of importance. Sensitivity analyses have shown that increasing the K_d of any layer included in the SESOIL model or of the RGA included in the AT123D model decreases contaminant concentrations at the POE because of retardation and attenuation due to sorption. Therefore, with higher K_d's the rate of source depletion is slowed, and the time required for source depletion is increased. Degradation half-life is also important if the time taken for source depletion or required for contaminant migration from the source to the POE is long relative to the contaminant's degradation half-life (i.e., 3 or more times half-life). This is the case because, under this condition, the rate of contaminant degradation in the source or as the contaminant migrates from the source to the POE results in markedly lower contaminant concentrations at the POE.

For AT123D modeling, the earlier sensitivity analyses have identified three additional input parameters. These parameters are hydraulic conductivity, hydraulic gradient, and effective porosity. In the AT123D model, hydraulic conductivity, hydraulic gradient, and effective porosity work together to control seepage velocity (i.e., seepage velocity equals hydraulic conductivity times hydraulic gradient divided by effective porosity), and an increase in seepage velocity increases the rate of contaminant migration to the POE. The values chosen for the Southwest Plume model indicates that the hydraulic gradient varies over a relatively narrow range in the RGA. Therefore, the impact of hydraulic gradient on seepage velocity is expected to be relatively smaller than that of hydraulic conductivity. Table 2.10

presents an overall summary of qualitative sensitivity of modeling results to input parameters for this analysis.

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Table F.2.1. Sil-specific parameters for SESOIL modeling (see Table F.46a)

Input Parameter	Unit	SWMU 1	C-720 Building	Remark
Soil Type	-	Silty Loam	Silty Loam	DOE 1999
Bulk Density	g/cm^3	1.46	1.46	DOE 1999
Intrinsic Permeability	cm^2	Variable	Variable	Probabilistic method
Disconnectedness Index	-	10	10	Site-specific (to PGDP) approximate value used in earlier work
Porosity	-	0.45	0.45	DOE 1999
Depth to Water Table	m	16.76	18.29	Site-specific (to RGA) field data
Organic Carbon Content	%	Variable	Variable	Probabilistic method
Freundlich Equation Exponent	-	1	1	Default

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Table F.2.2. Chemical-specific parameters for SESOIL modeling (see Table F.46b)

Input Parameter	Unit	SWMU 1	C-720 Building	Remark
Contaminant of Concern	-	Trichloroethene	Trichloroethene	
Source Area	m^2	324	1394	Site-specific (to TCE) SADA analysis
Soil Concentration - Layer 1	mg/kg	Variable	Variable	Probabilistic method
Soil Concentration - Layer 2	mg/kg	Variable	Variable	Probabilistic method
Soil Concentration - Layer 3	mg/kg	Variable	Variable	Probabilistic method
Soil Concentration - Layer 4	mg/kg	Variable	Variable	Probabilistic method
Soil Concentration - Layer 5	mg/kg	Variable	Variable	Probabilistic method
Soil Concentration - Layer 6	mg/kg	Variable	Variable	Probabilistic method
Molecular Weight	g/gmol	131	131	EPA 1994
Solubility in Water	mg/L	1100	1100	EPA 1996
Diffusion in Air	cm^2/s	0.08	0.08	EPA 1996
Henry’s Constant	$atm.m^3/mol$	0.0103	0.0103	EPA 1996
Koc	L/kg	94	94	EPA 1996
Degradation Rate	day^{-1}	Variable	Variable	Probabilistic method

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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	%	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
Soil Concentration - Layer 1	Minimum	mg/kg	0.00E+00	0.00E+00	Site-specific (to PGDP) field data
	Likeliest	mg/kg	2.14E+00	1.56E+00	Site-specific (to PGDP) field data
	Maximum	mg/kg	8.70E+01	1.70E+01	Site-specific (to PGDP) field data
	Standard Deviation	mg/kg	1.12E+01	5.12E+00	Site-specific (to PGDP) field data
	Count	#	135	11	Site-specific (to PGDP) field data
	Coefficient of Variation	%	522.90	328.48	Site-specific (to PGDP) field data
	Skew	-	6.42	3.32	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	see Layer 2	see Layer 2	Site-specific (to TCE) SADA analysis
	Correlation Coefficient	-	see Layer 2	see Layer 2	Site-specific (to TCE) SADA analysis

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

Input Parameter	Statistics	Unit	SWMU 1	C-720 Building	Remark
Soil Concentration - Layer 2	Minimum	mg/kg	0.00E+00	0.00E+00	Site-specific (to PGDP) field data
	Likeliest	mg/kg	1.59E+01	1.22E+00	Site-specific (to PGDP) field data
	Maximum	mg/kg	4.39E+02	1.90E+01	Site-specific (to PGDP) field data
	Standard Deviation	mg/kg	7.87E+01	4.23E+00	Site-specific (to PGDP) field data
	Count	#	31	36	Site-specific (to PGDP) field data
	Coefficient of Variation	%	494.84	347.17	Site-specific (to PGDP) field data
	Skew	-	5.53	3.81	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	Layer 1 and Layer 2	Layer 1 with Layer 2	Site-specific (to TCE) SADA analysis
	Correlation Coefficient	-	9.20E-01	-5.00E-01	Site-specific (to TCE) SADA analysis
Soil Concentration - Layer 3	Minimum	mg/kg	0.00E+00	0.00E+00	Site-specific (to PGDP) field data
	Likeliest	mg/kg	7.60E+00	5.94E+00	Site-specific (to PGDP) field data
	Maximum	mg/kg	8.50E+01	6.80E+01	Site-specific (to PGDP) field data
	Standard Deviation	mg/kg	1.82E+01	1.54E+01	Site-specific (to PGDP) field data
	Count	#	32	23	Site-specific (to PGDP) field data
	Coefficient of Variation	%	238.82	258.66	Site-specific (to PGDP) field data
	Skew	-	3.15	3.49	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	Layer 2 and Layer 3	Layer 2 with Layer 3	Site-specific (to TCE) SADA analysis
	Correlation Coefficient	-	3.50E-01	5.90E-01	Site-specific (to TCE) SADA analysis
Soil Concentration - Layer 4	Minimum	mg/kg	0.00E+00	0.00E+00	Site-specific (to PGDP) field data
	Likeliest	mg/kg	5.12E+00	3.87E-01	Site-specific (to PGDP) field data
	Maximum	mg/kg	7.40E+01	1.80E+00	Site-specific (to PGDP) field data
	Standard Deviation	mg/kg	1.46E+01	6.50E-01	Site-specific (to PGDP) field data
	Count	#	27	33	Site-specific (to PGDP) field data
	Coefficient of Variation	%	285.55	168.18	Site-specific (to PGDP) field data
	Skew	-	4.37	1.44	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	Layer 3 and Layer 4	Layer 3 with Layer 4	Site-specific (to TCE) SADA analysis
	Correlation Coefficient	-	2.10E-01	1.60E-01	Site-specific (to TCE) SADA analysis

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

Input Parameter	Statistics	Unit	SWMU 1	C-720 Building	Remark
Soil Concentration - Layer 5	Minimum	mg/kg	0.00E+00	0.00E+00	Site-specific (to PGDP) field data
	Likeliest	mg/kg	5.95E+00	2.00E-01	Site-specific (to PGDP) field data
	Maximum	mg/kg	6.60E+01	1.30E+00	Site-specific (to PGDP) field data
	Standard Deviation	mg/kg	1.42E+01	3.69E-01	Site-specific (to PGDP) field data
	Count	#	33	30	Site-specific (to PGDP) field data
	Coefficient of Variation	%	238.99	184.61	Site-specific (to PGDP) field data
	Skew	-	3.24	2.04	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	Layer 4 with Layer 5	Layer 4 with Layer 5	Site-specific (to TCE) SADA analysis
	Correlation Coefficient	-	4.00E-01	9.90E-01	Site-specific (to TCE) SADA analysis
Soil Concentration - Layer 6	Minimum	mg/kg	0.00E+00	0.00E+00	Site-specific (to PGDP) field data
	Likeliest	mg/kg	7.20E-01	1.17E-01	Site-specific (to PGDP) field data
	Maximum	mg/kg	3.40E+00	6.30E-01	Site-specific (to PGDP) field data
	Standard Deviation	mg/kg	1.07E+00	2.04E-01	Site-specific (to PGDP) field data
	Count	#	12	16	Site-specific (to PGDP) field data
	Coefficient of Variation	%	148.61	174.34	Site-specific (to PGDP) field data
	Skew	-	1.71	1.61	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	Layer 5 with Layer 6	Layer 5 with Layer 6	Site-specific (to TCE) SADA analysis
	Correlation Coefficient	-	9.20E-01	5.00E-01	Site-specific (to TCE) SADA analysis
Degradation Half-life	Minimum	yr	3.20E+00	3.20E+00	See Attachment F.3
	Likeliest	yr	NA	NA	NA
	Maximum	yr	1.13E+01	1.13E+01	See Attachment F.3
	Standard Deviation	yr	NA	NA	NA
	Distribution	-	Uniform	Uniform	See Section 4.0, Degradation Half-Life
	Correlation Pair	-	None	None	See Section 4.0, Degradation Half-Life
	Correlation Coefficient	-	NA	NA	NA

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

[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.

Table F.2.4. Statistics of variable inputs used in Monte Carlo runs for SESOIL modeling (see Table F.47)

Input Parameter	Statistics	Unit	SWMU 1	C-720 Building
Vertical Hydraulic Conductivity[a]	Minimum	cm/sec	2.75E-06	2.75E-06
	Median	cm/sec	1.64E-05	1.64E-05
	Maximum	cm/sec	2.82E-05	2.83E-05
	Arithmetic Mean	cm/sec	1.60E-05	1.58E-05
	Standard Deviation	cm/sec	6.57E-06	6.73E-06
Intrinsic Permeability[a]	Minimum	cm^2	2.80E-11	2.80E-11
	Median	cm^2	1.67E-10	1.67E-10
	Maximum	cm^2	2.87E-10	2.89E-10
	Arithmetic Mean	cm^2	1.63E-10	1.61E-10
	Standard Deviation	cm^2	6.70E-11	6.86E-11
Organic Carbon Content[b]	Minimum	mg/kg	2.53E+02	2.67E+02
	Median	mg/kg	6.76E+02	6.86E+02
	Maximum	mg/kg	2.78E+03	3.47E+03
	Arithmetic Mean	mg/kg	7.90E+02	8.37E+02
	Standard Deviation	mg/kg	4.71E+02	5.14E+02
Organic Carbon Content (%)[b]	Minimum	%	2.53E-02	2.67E-02
	Median	%	6.76E-02	6.86E-02
	Maximum	%	2.78E-01	3.47E-01
	Arithmetic Mean	%	7.90E-02	8.37E-02
	Standard Deviation	%	4.71E-02	5.14E-02
Soil Concentration - Layer 1[c]	Minimum	mg/kg	2.86E-03	2.33E-03
	Median	mg/kg	5.73E-01	2.37E-01
	Maximum	mg/kg	3.58E+01	4.63E+00
	Arithmetic Mean	mg/kg	2.37E+00	6.46E-01
	Standard Deviation	mg/kg	5.15E+00	1.03E+00
Soil Concentration - Layer 2[c]	Minimum	mg/kg	6.03E-02	5.20E-03
	Median	mg/kg	3.64E+00	2.14E-01
	Maximum	mg/kg	1.88E+02	5.80E+00
	Arithmetic Mean	mg/kg	1.41E+01	5.95E-01
	Standard Deviation	mg/kg	3.09E+01	1.12E+00
Soil Concentration - Layer 3[c]	Minimum	mg/kg	1.28E-01	2.34E-02
	Median	mg/kg	5.80E+00	1.67E+00
	Maximum	mg/kg	1.02E+02	4.82E+01
	Arithmetic Mean	mg/kg	1.14E+01	5.08E+00
	Standard Deviation	mg/kg	1.63E+01	8.66E+00
Soil Concentration - Layer 4[c]	Minimum	mg/kg	1.28E-01	5.11E-03
	Median	mg/kg	2.78E+00	7.76E-02
	Maximum	mg/kg	1.15E+02	5.91E-01
	Arithmetic Mean	mg/kg	8.93E+00	1.24E-01
	Standard Deviation	mg/kg	1.62E+01	1.23E-01
Soil Concentration - Layer 5[c]	Minimum	mg/kg	1.26E-01	1.01E-03
	Median	mg/kg	4.39E+00	3.56E-02
	Maximum	mg/kg	7.50E+01	4.01E-01
	Arithmetic Mean	mg/kg	1.04E+01	6.09E-02
	Standard Deviation	mg/kg	1.44E+01	6.68E-02

Table F.2.4. Statistics of variable inputs used in Monte Carlo runs for SESOIL modeling (see Table F.47) (continued)

Input Parameter	Statistics	Unit	SWMU 1	C-720 Building
Soil Concentration - Layer 6[c]	Minimum	mg/kg	5.30E-02	7.50E-04
	Median	mg/kg	1.04E+00	1.95E-02
	Maximum	mg/kg	6.65E+00	1.92E-01
	Arithmetic Mean	mg/kg	1.55E+00	3.31E-02
	Standard Deviation	mg/kg	1.53E+00	3.63E-02
Degradation Half-Life[d]	Minimum	yr	3.2	3.2
	Median	yr	4.9	4.9
	Maximum	yr	11.3	11.3
	Arithmetic Mean	yr	4.9	4.9
	Standard Deviation	yr	NA	NA
Degradation Rate[d]	Minimum	/hr	7.13E-06	7.21e-06
	Median	/hr	1.22E-05	1.13E-05
	Maximum	/hr	2.43E-05	2.43E-05
	Arithmetic Mean	/hr	1.32E-05	1.30E-05
	Standard Deviation	/hr	NA	NA

[a] Intrinsic permeability (cm^2) was estimated from the vertical hydraulic conductivity (cm/sec) using a conversion factor of 1.019E-5.

[b] Organic carbon content (%) was estimated from organic carbon content (mg/kg) using a conversion factor of 1E-4.

[c] Soil concentrations are normalized using the volume of the layer with the largest mass.

[d] Degradation rate was estimated from degradation half-life in units of days using the formula: rate = [(ln 2)/degradation half-life].

Table F.2.5. Hydrogeology-specific parameters for AT123D modeling (see Table F.49)

Input Parameter	Unit	SWMU 1	C-720 Building	Remark
Aquifer Thickness	m	Variable	Variable	Probabilistic method
Hydraulic Conductivity	m/hr	Variable	Variable	Probabilistic method
Hydraulic Gradient	m/m	Variable	Variable	Probabilistic method
Effective Porosity	-	Variable	Variable	Probabilistic method
Organic Carbon Content	%	Variable	Variable	Probabilistic method
Dispersivity - Longitudinal	m	15	15	DOE 1999
Dispersivity - Transverse	m	1.5	5	DOE 1999
Dispersivity - Vertical	m	0.03	5	DOE 1999
Bulk Density	kg/m^3	1670	1670	DOE 1999
Density of Water	kg/m^3	1000	1000	Mills et al. 1985

DOE 1999. *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky,* DOE/OR/07-1777/V4&D2, June.

Mills, W. B., D. B. Porcella, M. J. Ungs, S. A. Gherini, K. V. Summers, Lingfung Mok, G. L. Rupp, G. L. Bowie, and D. A. Hadith, 1985. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants, Parts II,* EPA-600/6-85/002b, September, U.S. Environmental Protection Agency, Environmental Research Laboratory, Office of Research and Development, Athens, GA.

Table F.2.6. Chemical-specific parameters for AT123D modeling (see Table F.49)

Input Parameter	Unit	SWMU 1	C-720 Building	Remark
Contaminant of Concern	-	Trichloroethene	Trichloroethene	Selected for analysis
Source Area	m^2	324	1394	Site-specific (to TCE) SADA analysis
Diffusion in Water	m^2/hr	3.28E-06	3.28E-06	EPA 1996
Koc	L/kg	94	94	EPA 1996
Degradation Rate (half-life)[a]	hr^{-1} (year)	Variable	Variable	Attachment F.3

[a] Degradation rate was estimated from degradation half-life (see text).

EPA 1996. *Soil Screening Guidance: Technical Background Document*, Office of Solid Waste and Emergency Response, Washington, D.C.

Table F.2.7. POE-specific parameters for AT123D modeling (see Table F.51)

Input Parameter	Unit	SWMU 1	C-720 Area	Remark
Distance to Plant Boundary	m (ft)	170 (558)	762 (2500)	See Fig. F.20
Distance to Property Boundary	m (ft)	915 (3000)	1460 (4789)	See Fig. F.20
Distance to Ohio River	m (ft)	7317 (24000)	7927 (26000)	See Fig. F.20

Table F.2.8. Statistics of variable inputs used in Monte Carlo sampling for AT123D modeling (see Table F.48)

Input Parameter	Statistics	SWMU 1 and C-720 Building				Remark
		Crystal Ball	Unit	AT123D	Unit	
Aquifer Thickness	Minimum Value	10.00	ft	3.05	m	DOE 1995, DOE 1997a, DOE 1997b, DOE 2000a, DOE 2000b, DOE 2004, KY 1992b
	Likeliest Value	38.71	ft	11.80	m	DOE 1995, DOE 1997a, DOE 1997b, DOE 2000a, DOE 2000b, DOE 2004, KY 1992b
	Maximum Value	63.50	ft	19.36	m	DOE 1995, DOE 1997a, DOE 1997b, DOE 2000a, DOE 2000b, DOE 2004, KY 1992b
	Standard deviation	11.84	ft	3.61	m	DOE 1995, DOE 1997a, DOE 1997b, DOE 2000a, DOE 2000b, DOE 2004, KY 1992b
	Count	24	#	24	#	DOE 1995, DOE 1997a, DOE 1997b, DOE 2000a, DOE 2000b, DOE 2004, KY 1992b
	Coefficient of Variation	30.59	%	30.59	%	DOE 1995, DOE 1997a, DOE 1997b, DOE 2000a, DOE 2000b, DOE 2004, KY 1992b
	Skew	-0.61	-	-0.61	-	DOE 1995, DOE 1997a, DOE 1997b, DOE 2000a, DOE 2000b, DOE 2004, KY 1992b
	Distribution	Normal	-	Normal	-	DOE 1995, DOE 1997a, DOE 1997b, DOE 2000a, DOE 2000b, DOE 2004, KY 1992b
	Correlation pair	None	-	None	-	Assumed none
	Correlation coefficient	NA	-	NA	-	NA
Hydraulic Conductivity	Minimum Value	1.00E-04	ft/day	1.27E-06	m/hr	[a] BJC 2001a, BJC 2001b, DOE 1997a, DOE 1997b, DOE 1999a, DOE 1999b, DOE 1999c, KY 1992a
	Likeliest Value	1.93E+04	ft/day	2.46E+02	m/hr	[a] BJC 2001a, BJC 2001b, DOE 1997a, DOE 1997b, DOE 1999a, DOE 1999b, DOE 1999c, KY 1992a
	Maximum Value	8.50E+05	ft/day	1.08E+04	m/hr	[a] BJC 2001a, BJC 2001b, DOE 1997a, DOE 1997b, DOE 1999a, DOE 1999b, DOE 1999c, KY 1992a
	Standard deviation	1.09E+05	ft/day	1.38E+03	m/hr	[a] BJC 2001a, BJC 2001b, DOE 1997a, DOE 1997b, DOE 1999a, DOE 1999b, DOE 1999c, KY 1992a
	Count	62	#	62	#	[a] BJC 2001a, BJC 2001b, DOE 1997a, DOE 1997b, DOE 1999a, DOE 1999b, DOE 1999c, KY 1992a
	Coefficient of Variation	563.17	%	563.17	%	[a] BJC 2001a, BJC 2001b, DOE 1997a, DOE 1997b, DOE 1999a, DOE 1999b, DOE 1999c, KY 1992a
	Skew	7.53	-	7.53	-	[a] BJC 2001a, BJC 2001b, DOE 1997a, DOE 1997b, DOE 1999a, DOE 1999b, DOE 1999c, KY 1992a

Table F.2.8. Statistics of variable inputs used in Monte Carlo sampling for AT123D modeling (see Table F.48) (continued)

Input Parameter	Statistics	SWMU 1 and C-720 Building				Remark
		Crystal Ball	Unit	AT123D	Unit	
Hydraulic Conductivity	Minimum Value	75.00	ft/day	0.95	m/hr	[a] PGDP Groundwater flow model
	Likeliest Value	966.85	ft/day	12.28	m/hr	[a] PGDP Groundwater flow model
	Maximum Value	1500.00	ft/day	19.05	m/hr	[a] PGDP Groundwater flow model
	Standard deviation	628.74	ft/day	7.99	m/hr	[a] PGDP Groundwater flow model
	Count	12166	#	12166	#	[a] PGDP Groundwater flow model
	Coefficient of Variation	65.03	%	65.03	%	[a] PGDP Groundwater flow model
	Skew	-0.35	-	-0.35	-	[a] PGDP Groundwater flow model
Hydraulic Conductivity	Minimum Value	75.00	ft/day	0.95	m/hr	[a,b] Minimum of the site-specific (to PGDP) groundwater flow model
	Likeliest Value	350.00	ft/day	4.45	m/hr	[a,b] Assumed approximate geomean of the minimum and maximum of the site-specific (to PGDP) groundwater flow model
	Maximum Value	1500.00	ft/day	19.05	m/hr	[a,b] Maximum of the site-specific (to PGDP) groundwater flow model
	Standard deviation	350.00	ft/day	4.45	m/hr	[a,b] Assumed equal to likeliest value
	Coefficient of Variation	100.00	%	100.00	%	[a,b] Assumed equal to likeliest value
	Distribution	Log normal	-	Log normal	-	BJC 2001a, BJC 2001b, DOE 1997a, DOE 1997b, DOE 1999a, DOE 1999b, DOE 1999c, KY 1992a
	Correlation pair	Hydraulic Conductivity and Porosity	-	Hydraulic Conductivity and Porosity	-	Assumed
	Correlation coefficient	NA	-	NA	-	NA
Hydraulic Gradient	Minimum Value	1.00E-04	ft/ft	1.00E-04	m/m	BJC 2001a, DOE 1997a, DOE 1997b, DOE 1997, KY 1992a, KY 1997
	Likeliest Value	1.01E-03	ft/ft	1.01E-03	m/m	BJC 2001a, DOE 1997a, DOE 1997b, DOE 1997, KY 1992a, KY 1997
	Maximum Value	4.00E-03	ft/ft	4.00E-03	m/m	BJC 2001a, DOE 1997a, DOE 1997b, DOE 1997, KY 1992a, KY 1997
	Standard deviation	1.12E-03	ft/ft	1.12E-03	m/m	BJC 2001a, DOE 1997a, DOE 1997b, DOE 1997, KY 1992a, KY 1997
	Count	12	#	12	#	BJC 2001a, DOE 1997a, DOE 1997b, DOE 1997, KY 1992a, KY 1997
	Coefficient of Variation	110.89	%	110.89	%	BJC 2001a, DOE 1997a, DOE 1997b, DOE 1997, KY 1992a, KY 1997
	Skew	1.95	-	1.95	-	BJC 2001a, DOE 1997a, DOE 1997b, DOE 1997, KY 1992a, KY 1997
	Distribution	Normal	-	Normal	-	BJC 2001a, DOE 1997a, DOE 1997b, DOE 1997, KY 1992a, KY 1997
Hydraulic Gradient	Correlation pair	Hydraulic Conductivity and Hydraulic Gradient	-	Hydraulic Conductivity and Hydraulic Gradient	-	Assumed

Table F.2.8. Statistics of variable inputs used in Monte Carlo sampling for AT123D modeling (see Table F.48) (continued)

Input Parameter	Statistics	SWMU 1 and C-720 Building				Remark
		Crystal Ball	Unit	AT123D	Unit	
	Correlation coefficient	-0.50	-	-0.50	-	Assumed
Porosity [c]	Minimum Value	27.00	%	27.00	%	DOE 1997a, DOE 1999a, DOE 1999c
	Likeliest Value	39.11	%	39.11	%	DOE 1997a, DOE 1999a, DOE 1999c
	Maximum Value	54.00	%	54.00	%	DOE 1997a, DOE 1999a, DOE 1999c
	Standard deviation	5.98	%	5.98	%	DOE 1997a, DOE 1999a, DOE 1999c
	Count	28	#	28	#	DOE 1997a, DOE 1999a, DOE 1999c
	Coefficient of Variation	15.29	%	15.29	%	DOE 1997a, DOE 1999a, DOE 1999c
	Skew	0.43	-	0.43	-	DOE 1997a, DOE 1999a, DOE 1999c
	Distribution	Normal	-	Normal	-	DOE 1997a, DOE 1999a, DOE 1999c
	Correlation pair	Hydraulic Gradient and Porosity	-	Hydraulic Gradient and Porosity	-	Assumed
	Correlation coefficient	-0.20	-	-0.20	-	Assumed
Organic Carbon Content	Minimum Value	0.003	%	0.003	%	KY 1992a, DOE 1997a, BJC 2006
	Likeliest Value	0.035	%	0.035	%	KY 1992a, DOE 1997a, BJC 2006
	Maximum Value	0.253	%	0.253	%	KY 1992a, DOE 1997a, BJC 2006
	Standard deviation	0.037	%	0.037	%	KY 1992a, DOE 1997a, BJC 2006
	Count	38	#	38	#	KY 1992a, DOE 1997a, BJC 2006
	Coefficient of Variation	1.05	%	1.05	%	KY 1992a, DOE 1997a, BJC 2006
	Skew	4.00	-	4.00	-	KY 1992a, DOE 1997a, BJC 2006
	Distribution	Log normal	-	Log normal	-	KY 1992a, DOE 1997a, BJC 2006
	Correlation pair	None	-	None	-	Assumed
	Correlation coefficient	NA	-	NA	-	NA

Table F.2.8. Statistics of variable inputs used in Monte Carlo sampling for AT123D modeling (see Table F.48) (continued)

		SWMU 1 and C-720 Building				
Input Parameter	**Statistics**	**Crystal Ball**	**Unit**	**AT123D**	**Unit**	**Remark**
Degradation Half-Life	Minimum Value	3.2	yr	NA	-	[d] See Attachment F.3
	Likeliest Value	NA	-	NA	-	NA
	Maximum Value	11.3	yr	NA	-	[d] See Attachment F.3
	Standard deviation	NA	-	NA	-	NA
	Count	NA	-	NA	-	NA
	Coefficient of Variation	NA	-	NA	-	NA
	Skew	NA	-	NA	-	NA
	Distribution	Uniform	-	NA	-	[d] See Attachment F.3
	Correlation pair	Hydraulic Gradient and Degradation Rate	-	NA	-	Assumed
	Correlation coefficient	-1.00	-	NA	-	[d] See Attachment F.3
Degradation Rate	Minimum Value	NA	-	7.01E-06	/hr	[d] See Attachment F.3
	Likeliest Value	NA	-	NA	-	NA
	Maximum Value	NA	-	2.45E-05	/hr	[d] See Attachment F.3
	Standard deviation	NA	-	NA	-	NA
	Count	NA	-	NA	-	NA
	Coefficient of Variation	NA	-	NA	-	NA
	Skew	NA	-	NA	-	NA
	Distribution	NA	-	Uniform	-	[d] See Attachment F.3
	Correlation pair	NA	-	Hydraulic Gradient and Degradation Rate	-	Assumed
	Correlation coefficient	NA	-	-1.00	-	[d] See Attachment F.3

[a] Multiple values were noted.
[b] The value selected for probabilistic method.
[c] Field observation was available for porosity. Therefore, effective porosity was estimated from porosity.
[d] Degradation rate was estimated from degradation half-life in units of hours using the formula: rate = [(ln 2)/degradation half-life].
BJC 2001a. C-746-U Solid Waste Landfill Groundwater Monitoring Plan Paducah Gaseous Diffusion Plant Paducah, Kentucky. BJC/PAD-205/R1, December.
BJC 2001b. Groundwater Monitoring Plan for the C-746-S Residential Landfill Paducah Gaseous Diffusion Plant Paducah, Kentucky. BJC/PAD-268/R1, December.

Table F.2.8. Statistics of variable inputs used in Monte Carlo sampling for AT123D modeling (see Table F.48) (continued)

		SWMU 1 and C-720 Building				
Input Parameter	**Statistics**	**Crystal Ball**	**Unit**	**AT123D**	**Unit**	**Remark**

BJC 2006.

DOE 1995. *Northeast Plume Preliminary Characterization Summary Report,* DOE/OR/07-1339/V2 & D2, July.

DOE 1997a. *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 1997b. *Ground-Water Conceptual Model for the Paducah Gaseous Diffusion Plant Paducah, Kentucky,* DOE/OR/06-1628&D0, August.

DOE 1999a. *Remedial Investigation Report for Waste Area Grouping 6 at Paducah Gaseous Diffusion Plant Paducah, Kentucky*, DOE/OR/07-1727V1&D2, May.

DOE 1999b. R*emedial Investigation Report for Waste Area Grouping 27 at Paducah Gaseous Diffusion Plant Paducah, Kentucky,* DOE/OR/07-1777V1&D2, June.

DOE 1999c. *Remedial Investigation Report for Waste Area Grouping 6 at Paducah Gaseous Diffusion Plant Paducah, Kentucky*, DOE/OR/07-1727V2&D2, May.

DOE 2000a. *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1845/D1, January.

DOE 2000b. *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plan, Paducah, Kentucky*, DOE/OR/07-1895/V2&D1, September.

DOE 2004. *Site Investigation Report for the Southwest Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-2180&D0, October.

KY 1992a. R*eport of the Paducah Gaseous Diffusion Plan Groundwater Investigation Phase III*, KY/E-150, November 25.

KY 1992b. *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant*, KY/SUB/13B-97777C P-03/1991/1, April.

KY 1997. *Analysis and Interpretation of Water Levels in Observations Wells at the Paducah Gaseous Diffusion Plant 1990-1997,* KY/EM-210, June 30.

Table F.2.9. Statistics of variable inputs used in Monte Carlo runs for Source Term development and AT123D modeling (see Table F.50)

Input Parameter	[c]	Statistics	Unit	SWMU 1 and C-720 Building
Aquifer Depth		Minimum	m	3.38
		Median	m	11.30
		Maximum	m	18.50
		Arithmetic Mean	m	10.90
	[c]	Standard Deviation	m	3.44
Hydraulic Conductivity		Minimum	m/hr	0.97
		Median	m/hr	3.54
		Maximum	m/hr	17.60
		Arithmetic Mean	m/hr	4.77
	[c]	Standard Deviation	m/hr	3.70
Hydraulic Gradient		Minimum	m/m	1.63E-04
		Median	m/m	1.37E-03
		Maximum	m/m	3.98E-03
		Arithmetic Mean	m/m	1.49E-03
	[c]	Standard Deviation	m/m	9.20E-04
Porosity	[a]	Minimum	%	27.16
		Median	%	38.27
		Maximum	%	53.09
		Arithmetic Mean	%	39.51
	[c]	Standard Deviation	%	6.17
Effective Porosity	[a]	Minimum	-	0.22
		Median	-	0.31
		Maximum	-	0.43
		Arithmetic Mean	-	0.32
	[c]	Standard Deviation	-	0.05
Organic Carbon Content		Minimum	%	0.003
		Median	%	0.024
		Maximum	%	0.228
		Arithmetic Mean	%	0.034
	[c]	Standard Deviation	%	0.034
Degradation Half-Life	[b]	Minimum	yr	3.2
		Median	yr	4.9
		Maximum	yr	11.3
		Arithmetic Mean	yr	4.9
	[c]	Standard Deviation	yr	NA
Degradation Rate	[b]	Minimum	/hr	7.20E-06
		Median	/hr	1.62E-05
		Maximum	/hr	2.45E-05
		Arithmetic Mean	/hr	1.61E-05
	[c]	Standard Deviation	/hr	NA

Table F.2.9. Statistics of variable inputs used in Monte Carlo runs for AT123D modeling (see Table F.50) (continued)

Input Parameter	[c] Statistics	Unit	SWMU 1 and C-720 Building
Groundwater Concentration in the RGA[c]	Minimum	μg/L	2.92
	Median	μg/L	362.7
	Maximum	μg/L	25311
	Arithmetic Mean	μg/L	2138.6
	[c] Standard Deviation	μg/L	4534.8
Total Soil Concentration Derived from Groundwater Concentrations[c]	Minimum	mg/kg	7.25E-04
	Median	mg/kg	9.73E-02
	Maximum	mg/kg	5.68E+00
	Arithmetic Mean	mg/kg	5.72E-01
	[c] Standard Deviation	mg/kg	1.18E+00

[a] Effective porosity was estimated from porosity (see text).

[b] Degradation rate was estimated from degradation half-life in units of hours using the formula: rate = [(ln 2)/degradation half-life].

[c] This parameter was only used for secondary source term modeling.

Table F.2.10. Qualitative sensitivity of modeling results to input parameters for the Southwest Plume SI Report

Input Parameter	Degree of sensitivity Low	Medium	High
Bulk density	√		
Effective porosity		√	
Horizontal hydraulic conductivity in the RGA		√	
Vertical hydraulic conductivity in the UCRS	√		
Percolation rate		√	
Horizontal hydraulic gradient in the RGA		√	
Aquifer thickness	√		
Longitudinal dispersivity	√		
Soil-water partition coefficient (K_d)			√
Fraction of organic carbon (%)			√
Biodegradation half-life			√
Molecular diffusion	√		
Source Area		√	
Source term in the UCRS			√

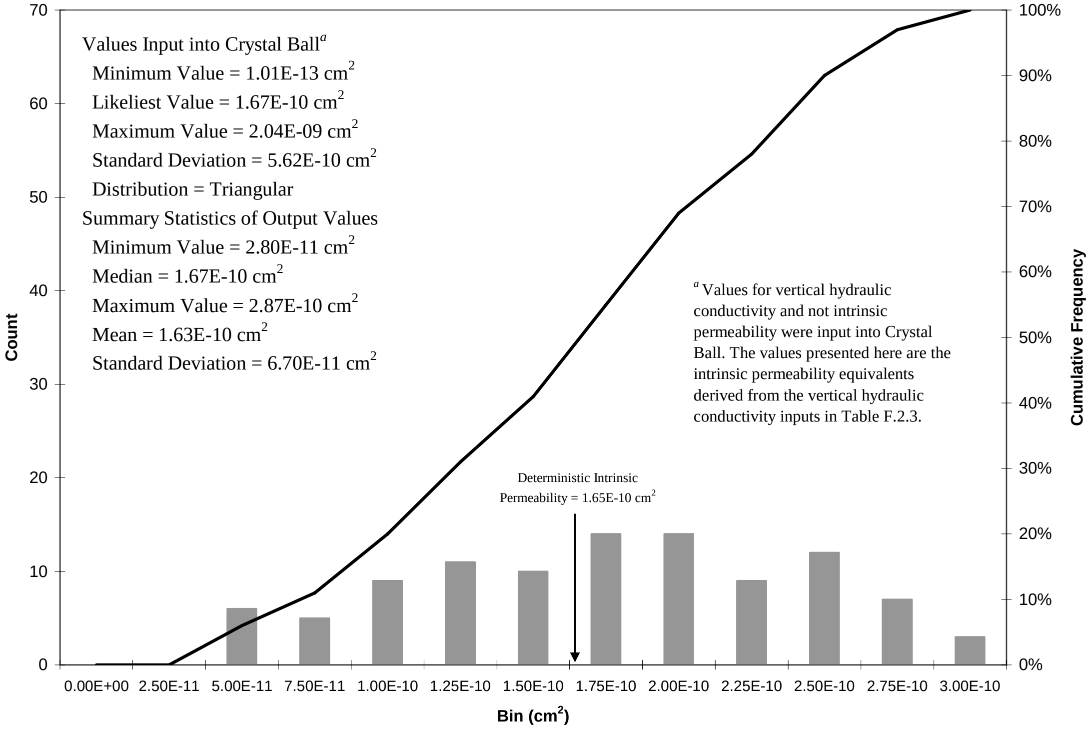
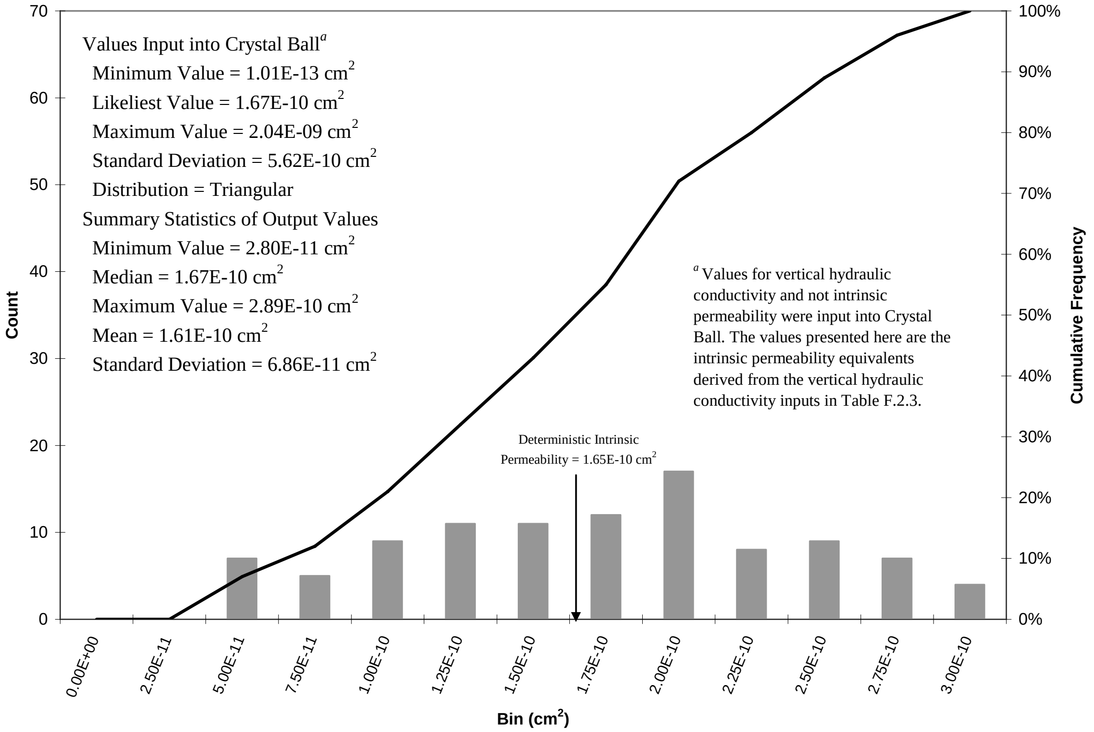


Fig. F.2.1. Histogram of Intrinsic Permeability SESOIL inputs for SWMU 1.

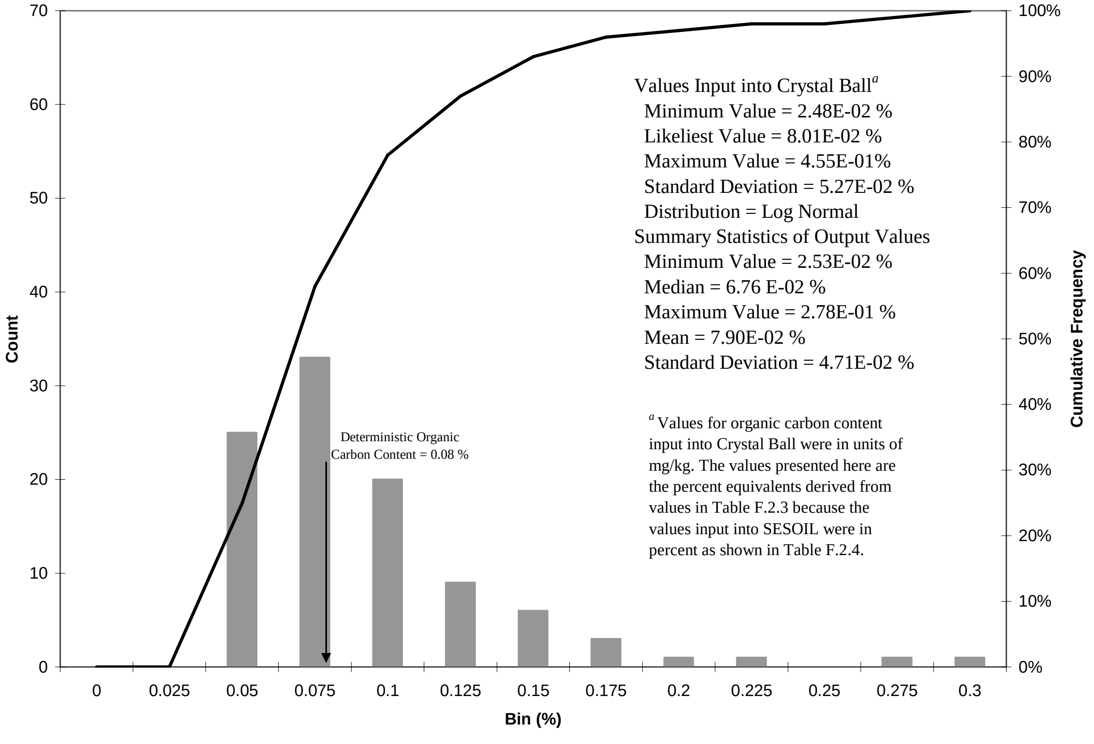


Values Input into Crystal Ball[a]
Minimum Value = 1.01E-13 cm^2
Likeliest Value = 1.67E-10 cm^2
Maximum Value = 2.04E-09 cm^2
Standard Deviation = 5.62E-10 cm^2
Distribution = Triangular
Summary Statistics of Output Values
Minimum Value = 2.80E-11 cm^2
Median = 1.67E-10 cm^2
Maximum Value = 2.89E-10 cm^2
Mean = 1.61E-10 cm^2
Standard Deviation = 6.86E-11 cm^2

[a] Values for vertical hydraulic conductivity and not intrinsic permeability were input into Crystal Ball. The values presented here are the intrinsic permeability equivalents derived from the vertical hydraulic conductivity inputs in Table F.2.3.

Deterministic Intrinsic Permeability = 1.65E-10 cm^2

Fig. F.2.2. Histogram of Intrinsic Permeability SESOIL inputs for the C-720 Area.

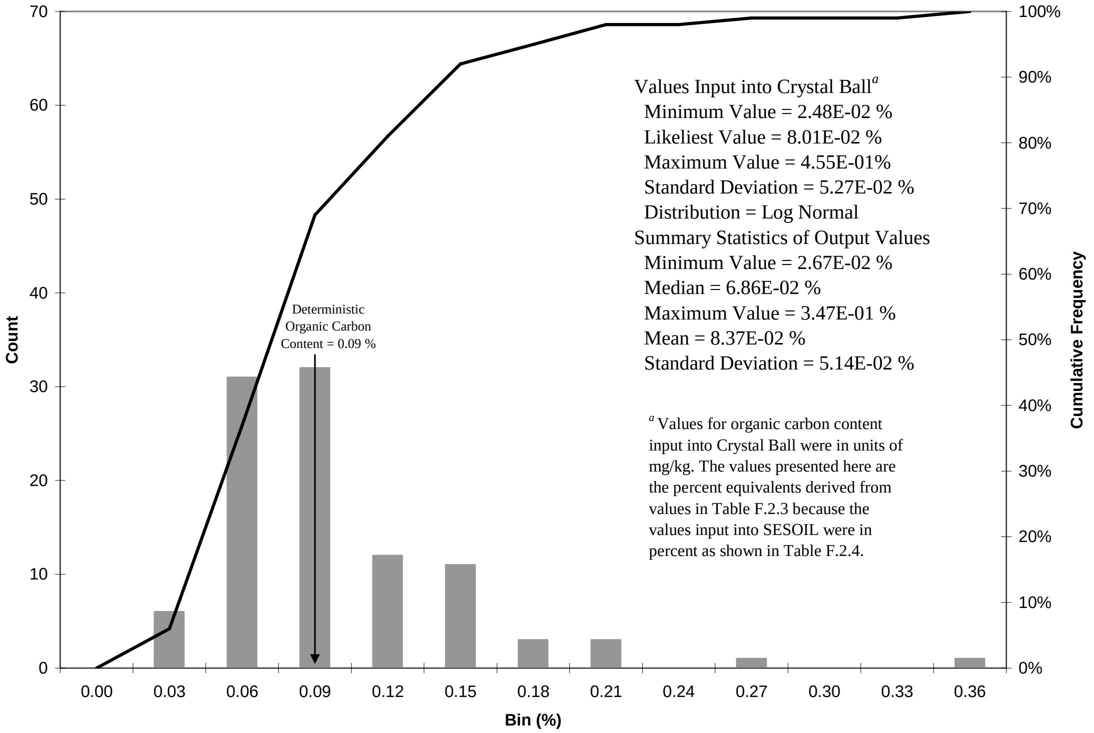


Values Input into Crystal Ball[a]
Minimum Value = 2.48E-02 %
Likeliest Value = 8.01E-02 %
Maximum Value = 4.55E-01%
Standard Deviation = 5.27E-02 %
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 2.53E-02 %
Median = 6.76 E-02 %
Maximum Value = 2.78E-01 %
Mean = 7.90E-02 %
Standard Deviation = 4.71E-02 %

[a] Values for organic carbon content input into Crystal Ball were in units of mg/kg. The values presented here are the percent equivalents derived from values in Table F.2.3 because the values input into SESOIL were in percent as shown in Table F.2.4.

Deterministic Organic Carbon Content = 0.08 %

Fig. F.2.3. Histogram of Organic Carbon Content SESOIL inputs for SWMU 1.

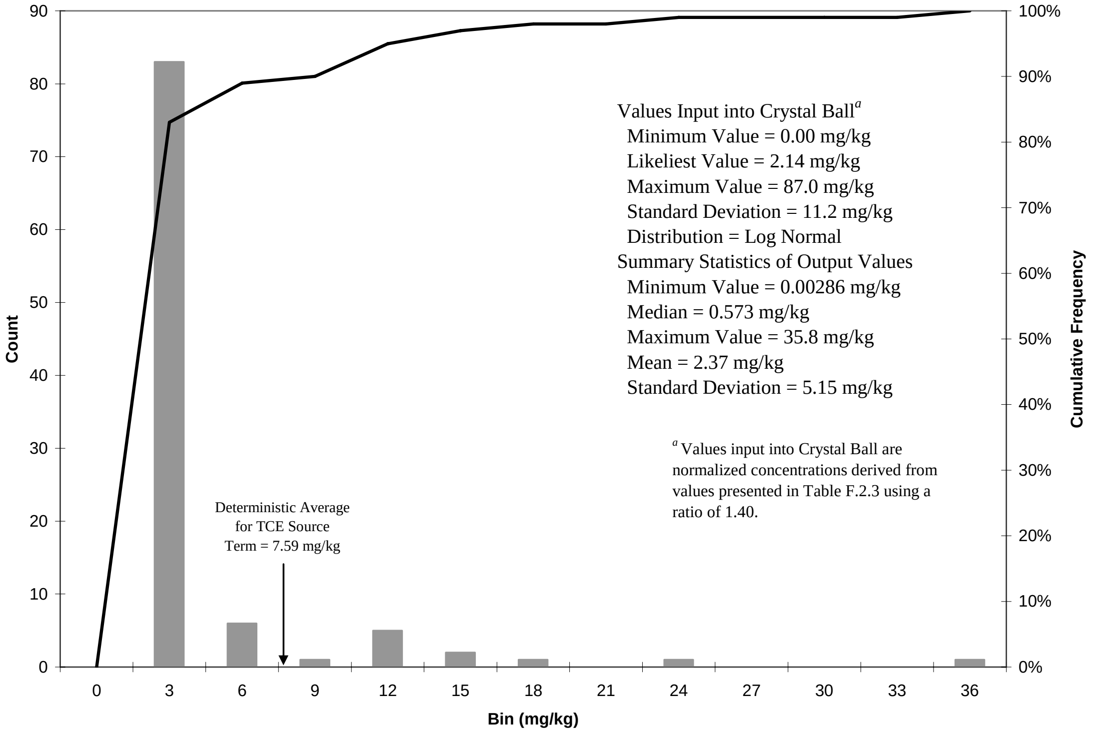


Deterministic Organic Carbon Content = 0.09 %

Values Input into Crystal Ball[a]
Minimum Value = 2.48E-02 %
Likeliest Value = 8.01E-02 %
Maximum Value = 4.55E-01%
Standard Deviation = 5.27E-02 %
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 2.67E-02 %
Median = 6.86E-02 %
Maximum Value = 3.47E-01 %
Mean = 8.37E-02 %
Standard Deviation = 5.14E-02 %

[a] Values for organic carbon content input into Crystal Ball were in units of mg/kg. The values presented here are the percent equivalents derived from values in Table F.2.3 because the values input into SESOIL were in percent as shown in Table F.2.4.

Fig. F.2.4. Histogram of Organic Carbon Content SESOIL inputs for the C-720 Area.

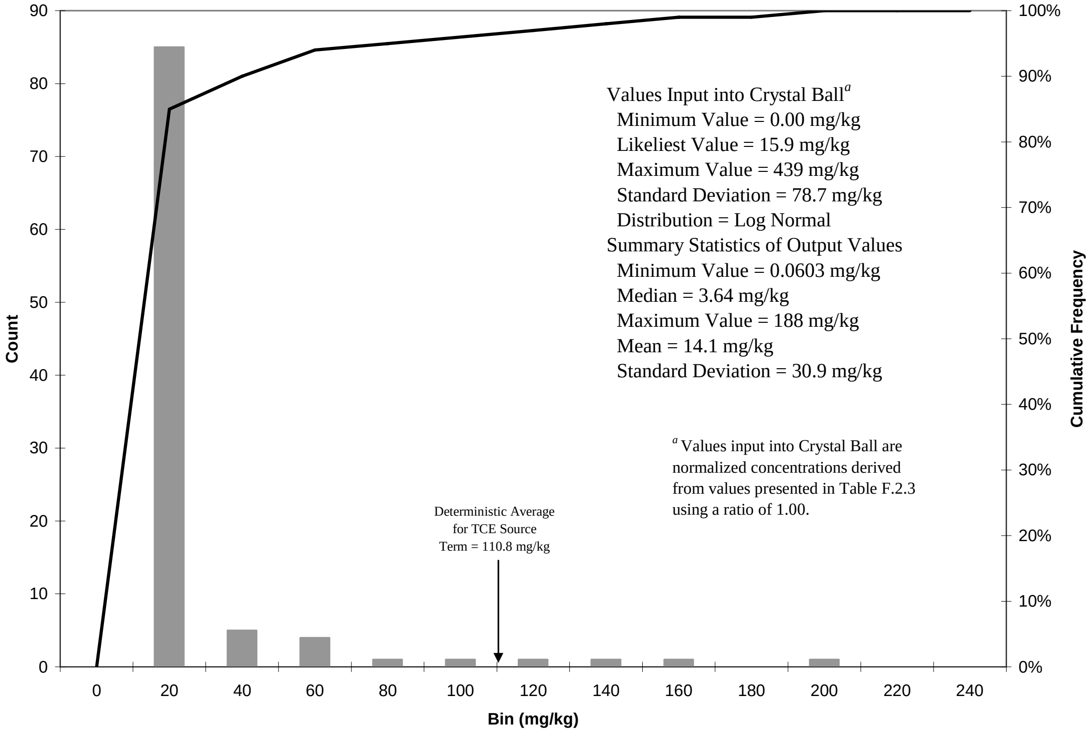


Deterministic Average for TCE Source Term = 7.59 mg/kg

Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 2.14 mg/kg
Maximum Value = 87.0 mg/kg
Standard Deviation = 11.2 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.00286 mg/kg
Median = 0.573 mg/kg
Maximum Value = 35.8 mg/kg
Mean = 2.37 mg/kg
Standard Deviation = 5.15 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.3 using a ratio of 1.40.

Fig. F.2.5. Histogram of Layer 1 TCE concentrations at SWMU 1 used as SESOIL inputs.



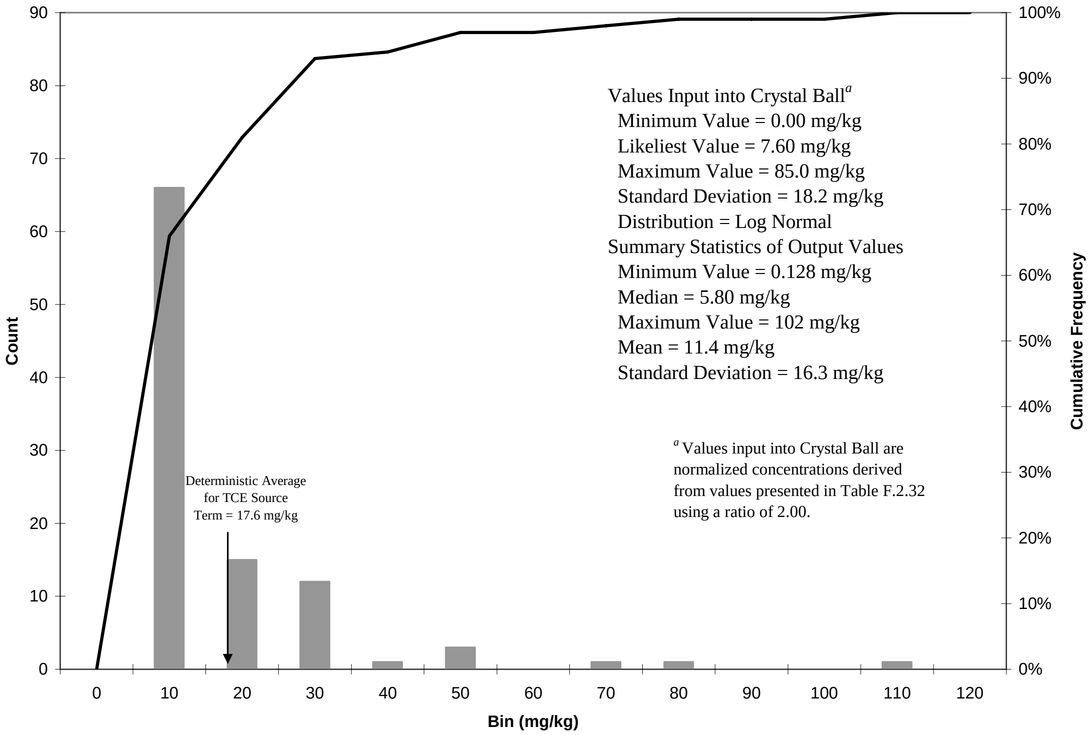
Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 15.9 mg/kg
Maximum Value = 439 mg/kg
Standard Deviation = 78.7 mg/kg
Distribution = Log Normal

Summary Statistics of Output Values
Minimum Value = 0.0603 mg/kg
Median = 3.64 mg/kg
Maximum Value = 188 mg/kg
Mean = 14.1 mg/kg
Standard Deviation = 30.9 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.3 using a ratio of 1.00.

Deterministic Average for TCE Source Term = 110.8 mg/kg

Fig. F.2.6. Histogram of Layer 2 TCE concentrations at SWMU 1 used as SESOIL inputs.

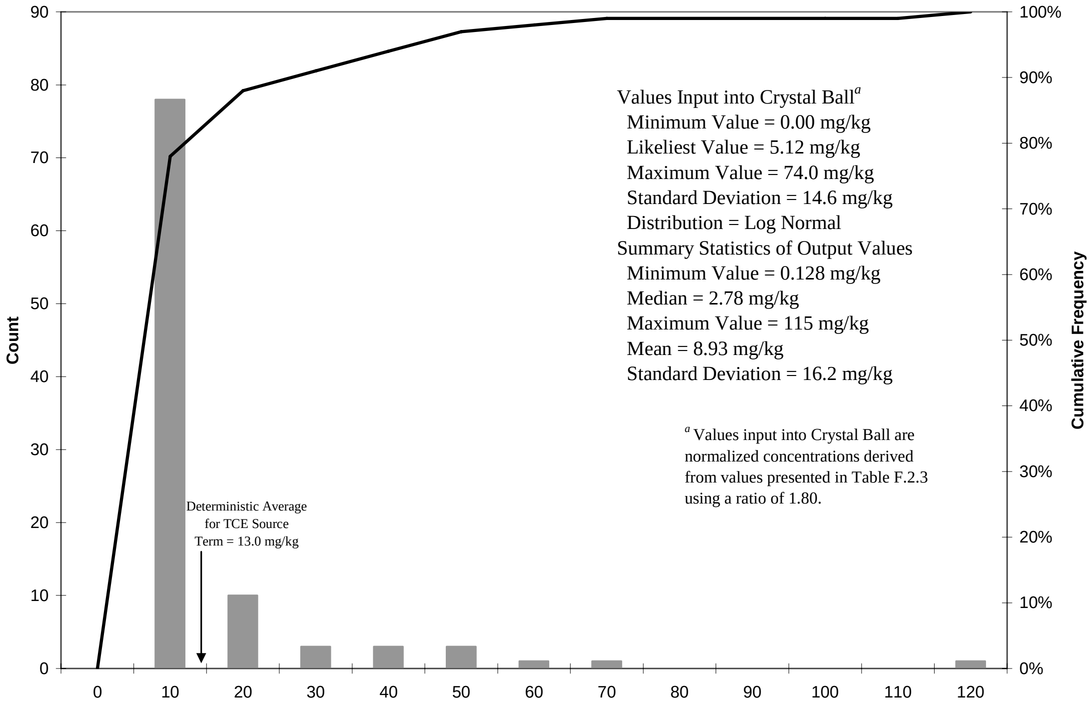


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 7.60 mg/kg
Maximum Value = 85.0 mg/kg
Standard Deviation = 18.2 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.128 mg/kg
Median = 5.80 mg/kg
Maximum Value = 102 mg/kg
Mean = 11.4 mg/kg
Standard Deviation = 16.3 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.32 using a ratio of 2.00.

Deterministic Average for TCE Source Term = 17.6 mg/kg

Fig. F.2.7. Histogram of Layer 3 TCE concentrations at SWMU 1 used as SESOIL inputs.

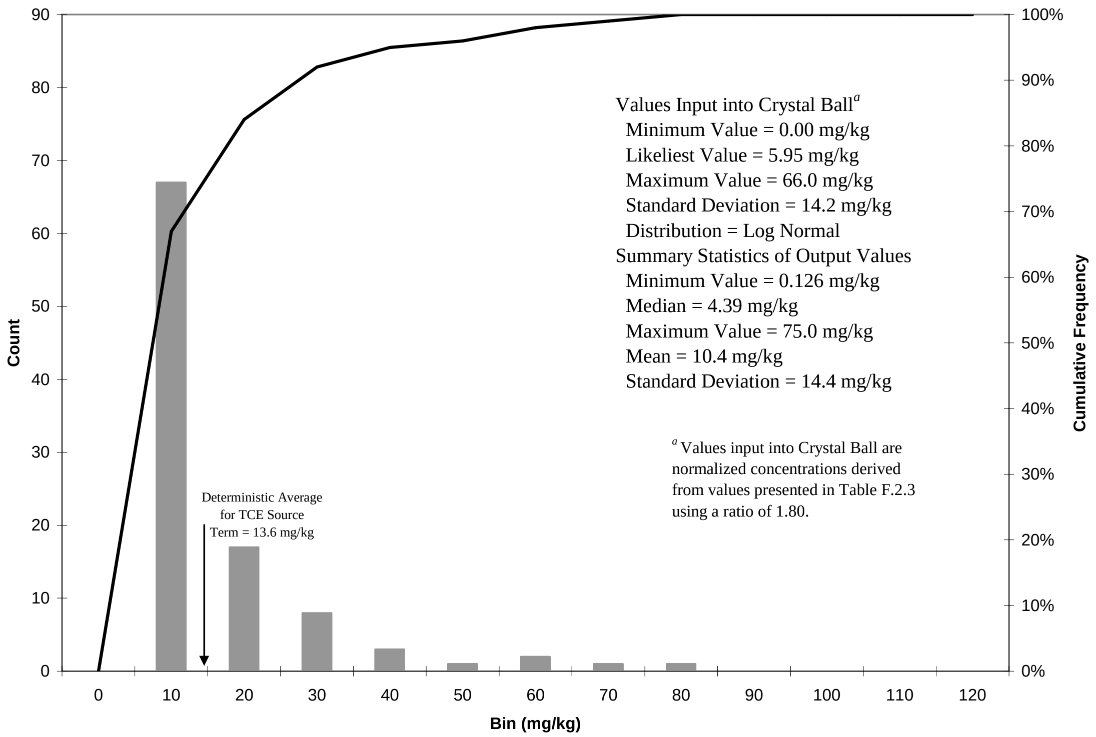


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 5.12 mg/kg
Maximum Value = 74.0 mg/kg
Standard Deviation = 14.6 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.128 mg/kg
Median = 2.78 mg/kg
Maximum Value = 115 mg/kg
Mean = 8.93 mg/kg
Standard Deviation = 16.2 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.3 using a ratio of 1.80.

Deterministic Average for TCE Source Term = 13.0 mg/kg

Fig. F.2.8. Histogram of Layer 4 TCE concentrations at SWMU 1 used as SESOIL inputs.

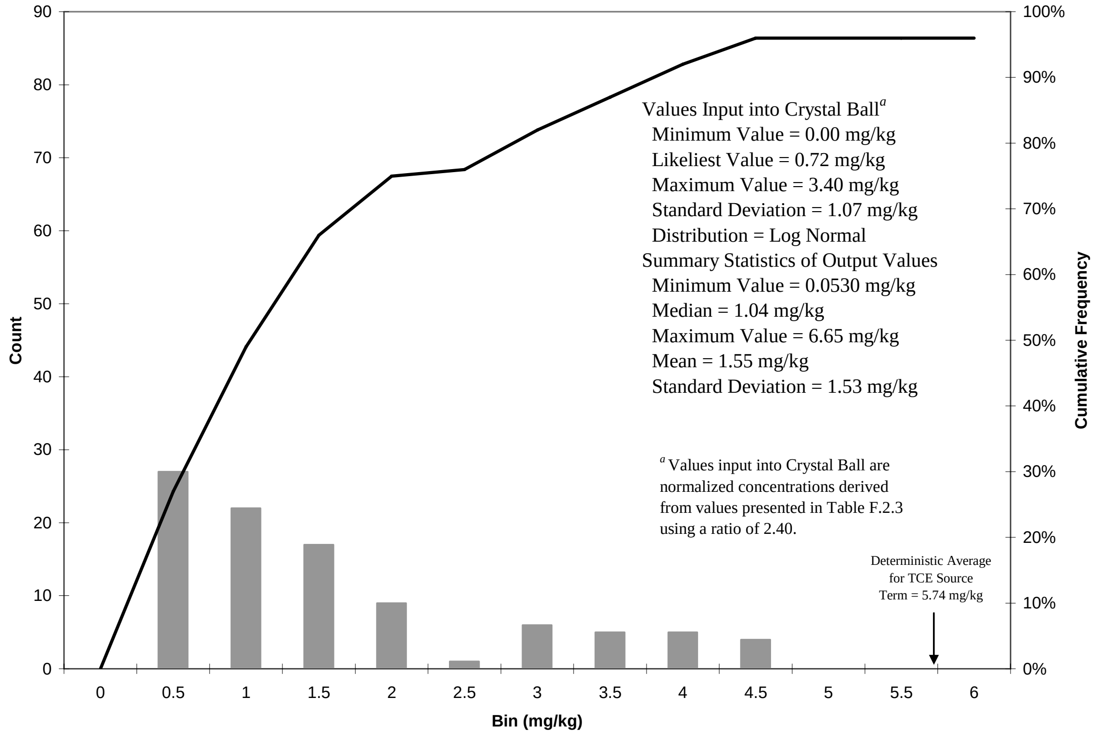


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 5.95 mg/kg
Maximum Value = 66.0 mg/kg
Standard Deviation = 14.2 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.126 mg/kg
Median = 4.39 mg/kg
Maximum Value = 75.0 mg/kg
Mean = 10.4 mg/kg
Standard Deviation = 14.4 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.3 using a ratio of 1.80.

Deterministic Average for TCE Source Term = 13.6 mg/kg

Fig. F.2.9. Histogram of Layer 5 TCE concentrations at SWMU 1 used as SESOIL inputs.

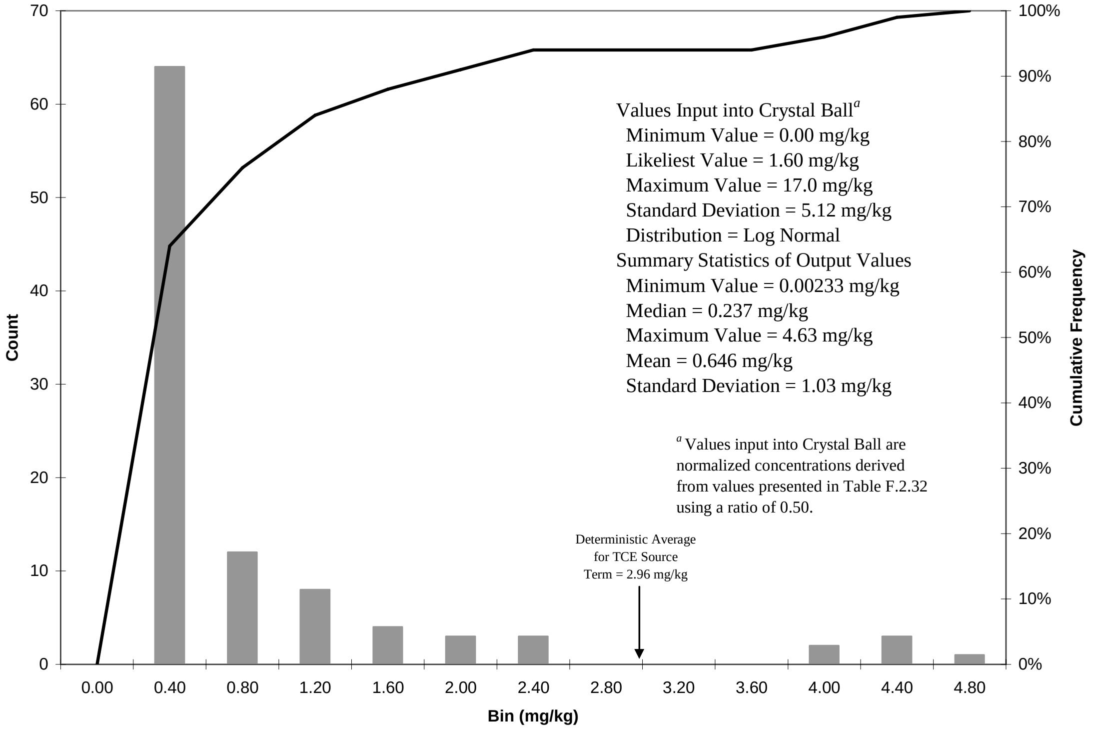


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 0.72 mg/kg
Maximum Value = 3.40 mg/kg
Standard Deviation = 1.07 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.0530 mg/kg
Median = 1.04 mg/kg
Maximum Value = 6.65 mg/kg
Mean = 1.55 mg/kg
Standard Deviation = 1.53 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.3 using a ratio of 2.40.

Deterministic Average for TCE Source Term = 5.74 mg/kg

Fig. F.2.10. Histogram of Layer 6 TCE concentrations at SWMU 1 used as SESOIL inputs.

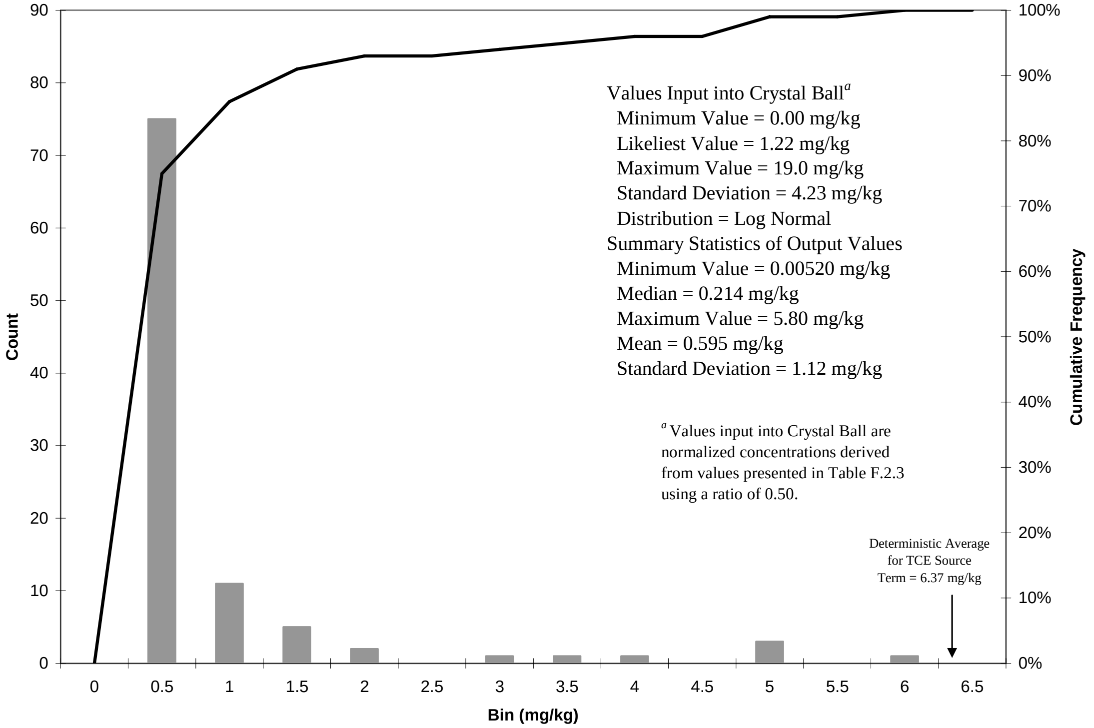


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 1.60 mg/kg
Maximum Value = 17.0 mg/kg
Standard Deviation = 5.12 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.00233 mg/kg
Median = 0.237 mg/kg
Maximum Value = 4.63 mg/kg
Mean = 0.646 mg/kg
Standard Deviation = 1.03 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.32 using a ratio of 0.50.

Deterministic Average for TCE Source Term = 2.96 mg/kg

Fig. F.2.11. Histogram of Layer 1 TCE concentrations at C-720 Area used as SESOIL inputs.

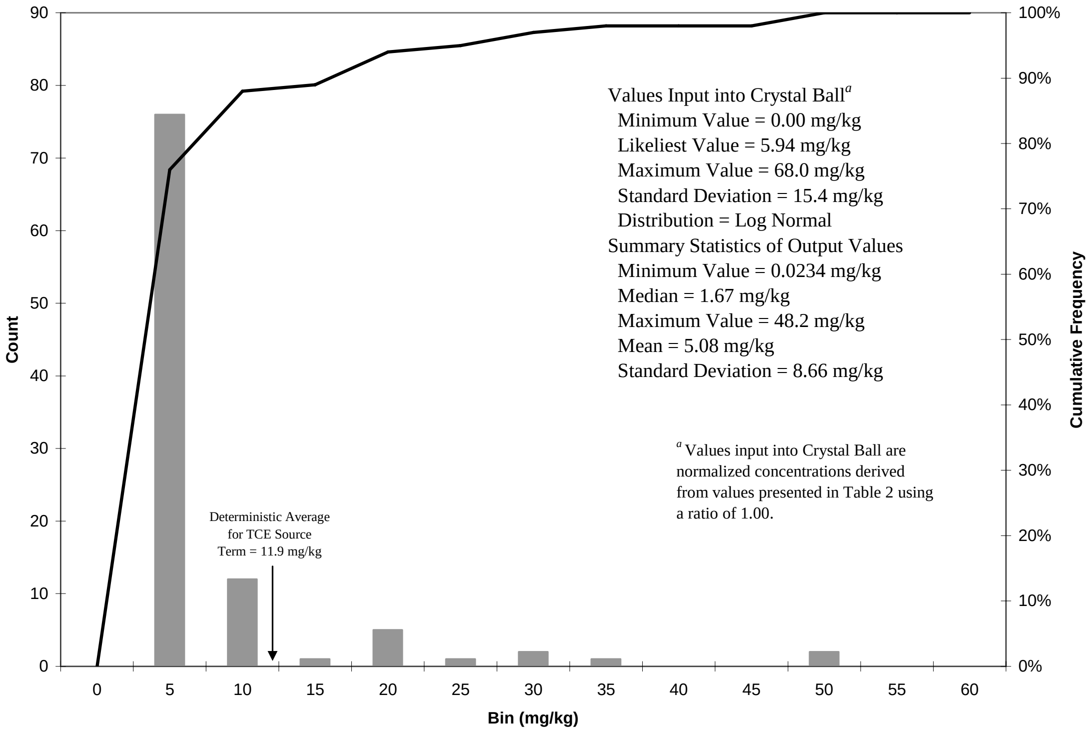


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 1.22 mg/kg
Maximum Value = 19.0 mg/kg
Standard Deviation = 4.23 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.00520 mg/kg
Median = 0.214 mg/kg
Maximum Value = 5.80 mg/kg
Mean = 0.595 mg/kg
Standard Deviation = 1.12 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.3 using a ratio of 0.50.

Deterministic Average for TCE Source Term = 6.37 mg/kg

Fig. F.2.12. Histogram of Layer 2 TCE concentrations at C-720 Area used as SESOIL inputs.

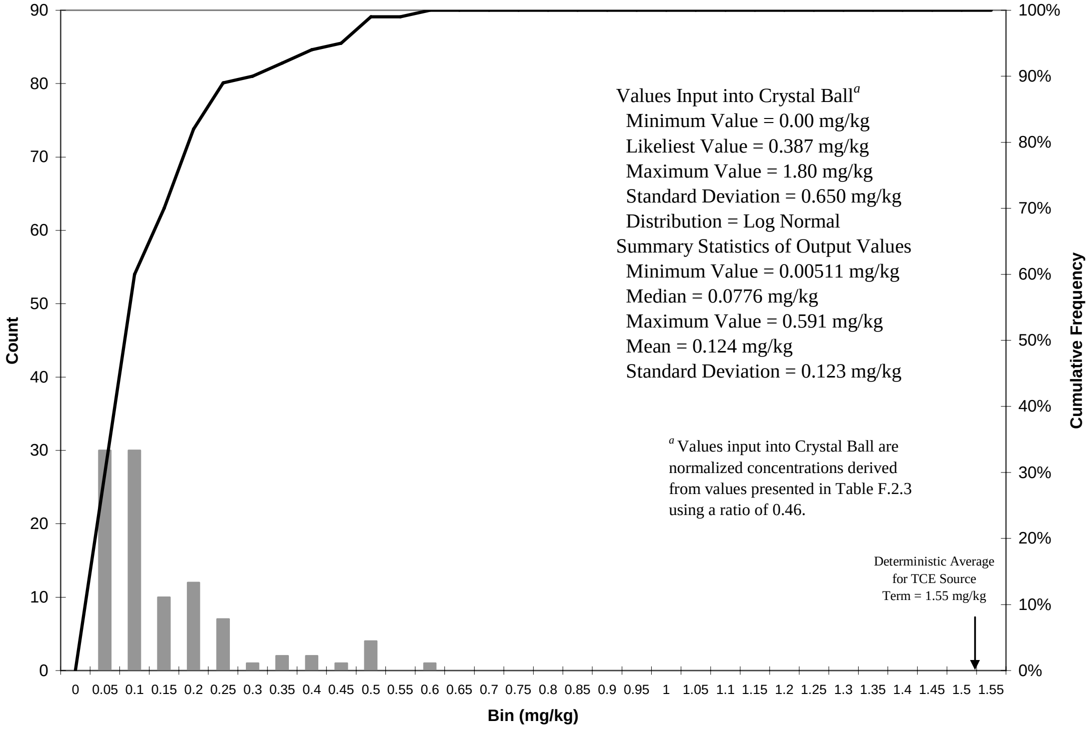


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 5.94 mg/kg
Maximum Value = 68.0 mg/kg
Standard Deviation = 15.4 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.0234 mg/kg
Median = 1.67 mg/kg
Maximum Value = 48.2 mg/kg
Mean = 5.08 mg/kg
Standard Deviation = 8.66 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table 2 using a ratio of 1.00.

Deterministic Average for TCE Source Term = 11.9 mg/kg

Fig. F.2.13. Histogram of Layer 3 TCE concentrations at C-720 Area used as SESOIL inputs.



Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 0.387 mg/kg
Maximum Value = 1.80 mg/kg
Standard Deviation = 0.650 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.00511 mg/kg
Median = 0.0776 mg/kg
Maximum Value = 0.591 mg/kg
Mean = 0.124 mg/kg
Standard Deviation = 0.123 mg/kg

[a] Values input into Crystal Ball are normalized concentrations derived from values presented in Table F.2.3 using a ratio of 0.46.

Deterministic Average for TCE Source Term = 1.55 mg/kg

Fig. F.2.14. Histogram of Layer 4 TCE concentrations at C-720 Area used as SESOIL inputs.

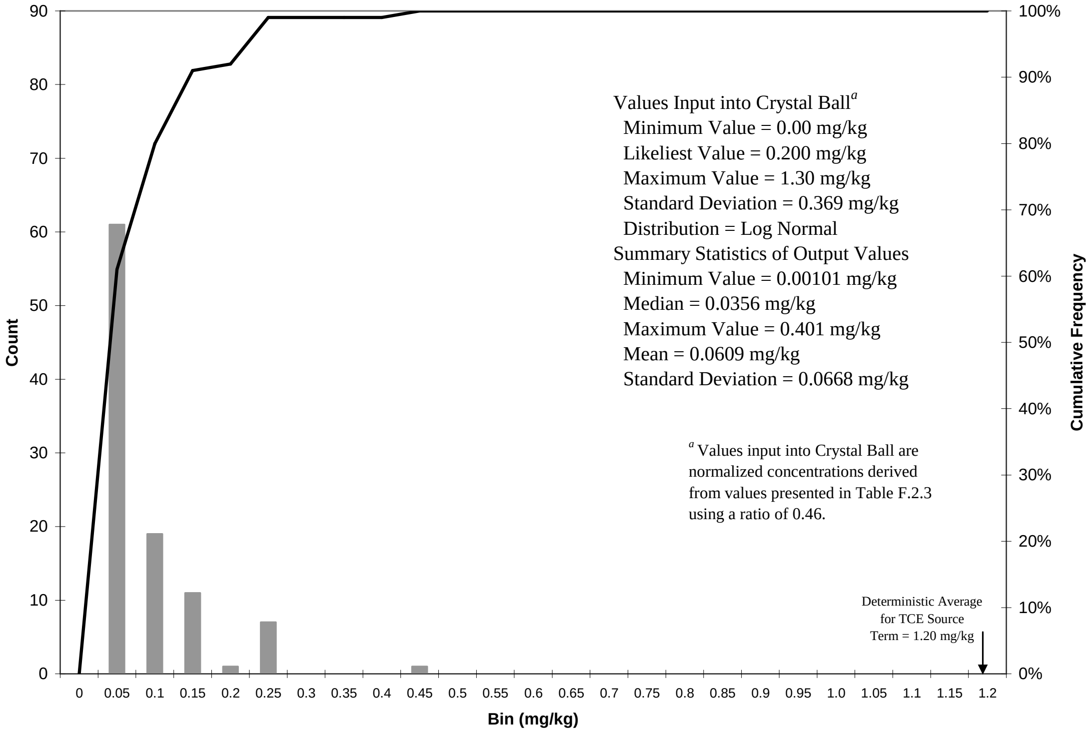


Fig. F.2.15. Histogram of Layer 5 TCE concentrations at C-720 Area used as SESOIL inputs.

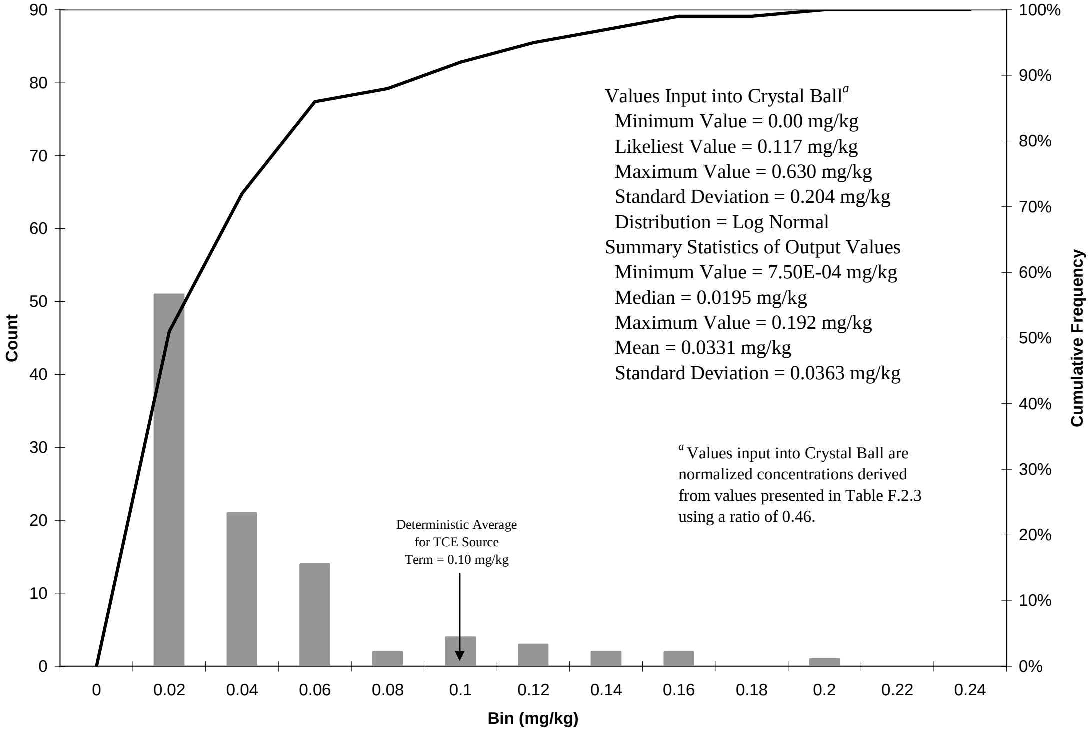
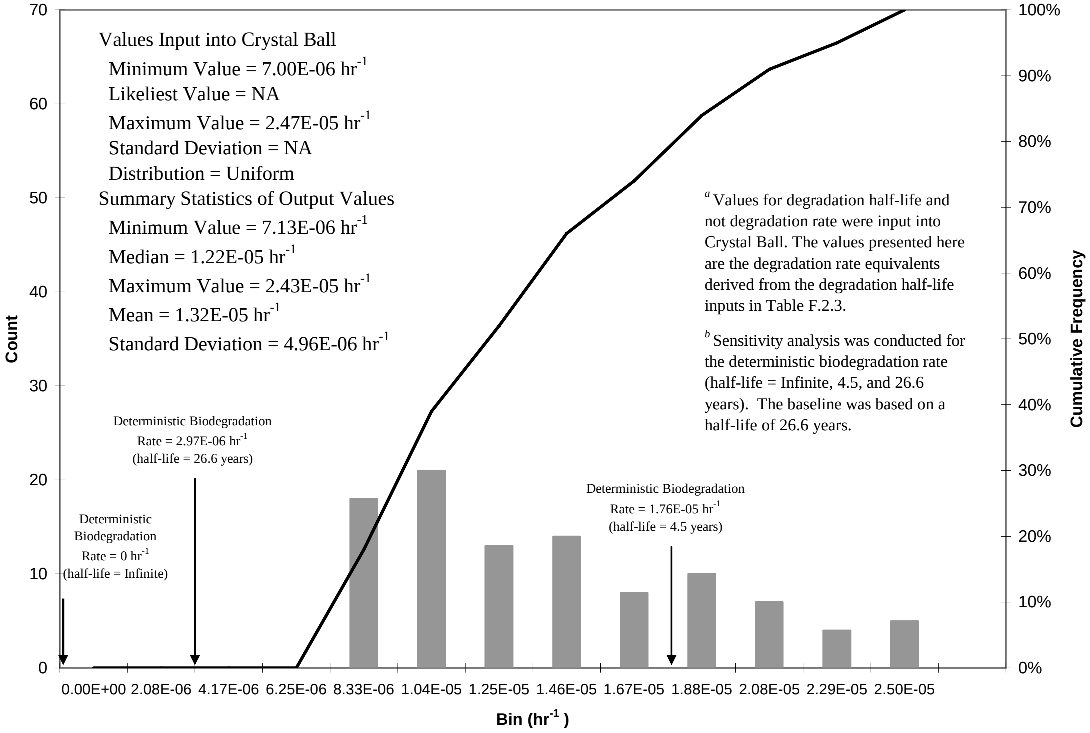


Fig. F.2.16. Histogram of Layer 6 TCE concentrations at C-720 Area used as SESOIL inputs.



Values Input into Crystal Ball
Minimum Value = 7.00E-06 hr^{-1}
Likeliest Value = NA
Maximum Value = 2.47E-05 hr^{-1}
Standard Deviation = NA
Distribution = Uniform
Summary Statistics of Output Values
Minimum Value = 7.13E-06 hr^{-1}
Median = 1.22E-05 hr^{-1}
Maximum Value = 2.43E-05 hr^{-1}
Mean = 1.32E-05 hr^{-1}
Standard Deviation = 4.96E-06 hr^{-1}

Deterministic Biodegradation
Rate = 0 hr^{-1}
(half-life = Infinite)

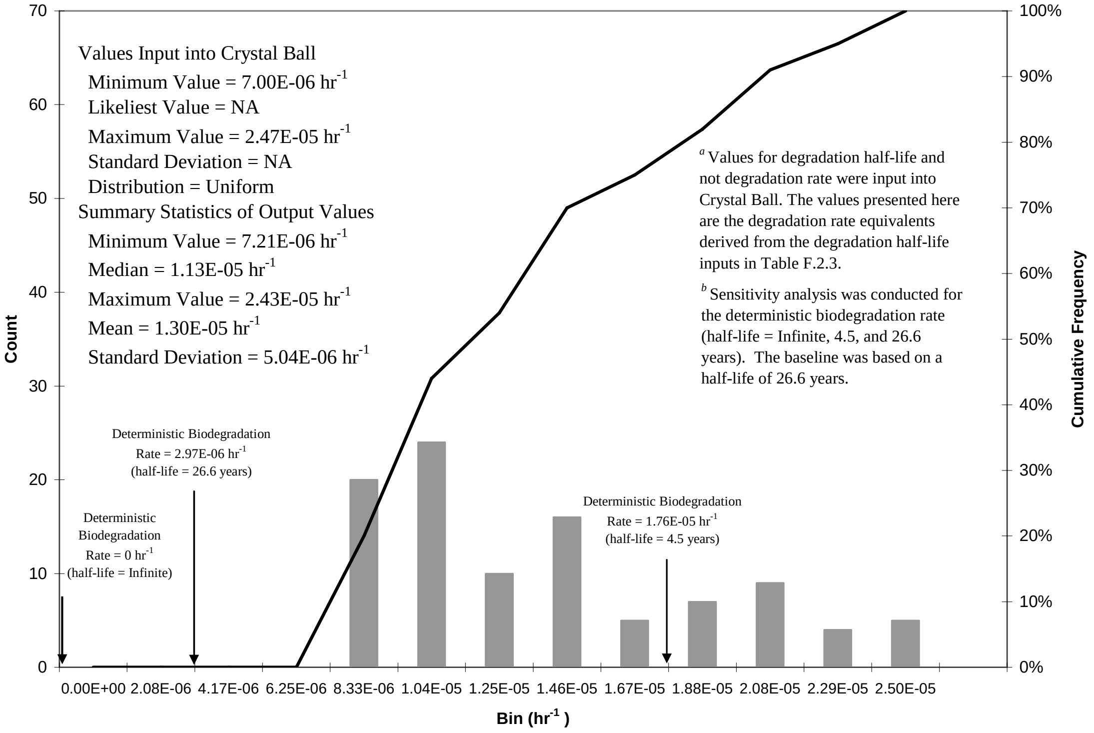
Deterministic Biodegradation
Rate = 2.97E-06 hr^{-1}
(half-life = 26.6 years)

Deterministic Biodegradation
Rate = 1.76E-05 hr^{-1}
(half-life = 4.5 years)

[a] Values for degradation half-life and not degradation rate were input into Crystal Ball. The values presented here are the degradation rate equivalents derived from the degradation half-life inputs in Table F.2.3.

[b] Sensitivity analysis was conducted for the deterministic biodegradation rate (half-life = Infinite, 4.5, and 26.6 years). The baseline was based on a half-life of 26.6 years.

Fig. F.2.17. Histogram of Degradation Rate SESOIL inputs for SWMU 1.



Values Input into Crystal Ball
Minimum Value = 7.00E-06 hr^{-1}
Likeliest Value = NA
Maximum Value = 2.47E-05 hr^{-1}
Standard Deviation = NA
Distribution = Uniform
Summary Statistics of Output Values
Minimum Value = 7.21E-06 hr^{-1}
Median = 1.13E-05 hr^{-1}
Maximum Value = 2.43E-05 hr^{-1}
Mean = 1.30E-05 hr^{-1}
Standard Deviation = 5.04E-06 hr^{-1}

[a] Values for degradation half-life and not degradation rate were input into Crystal Ball. The values presented here are the degradation rate equivalents derived from the degradation half-life inputs in Table F.2.3.

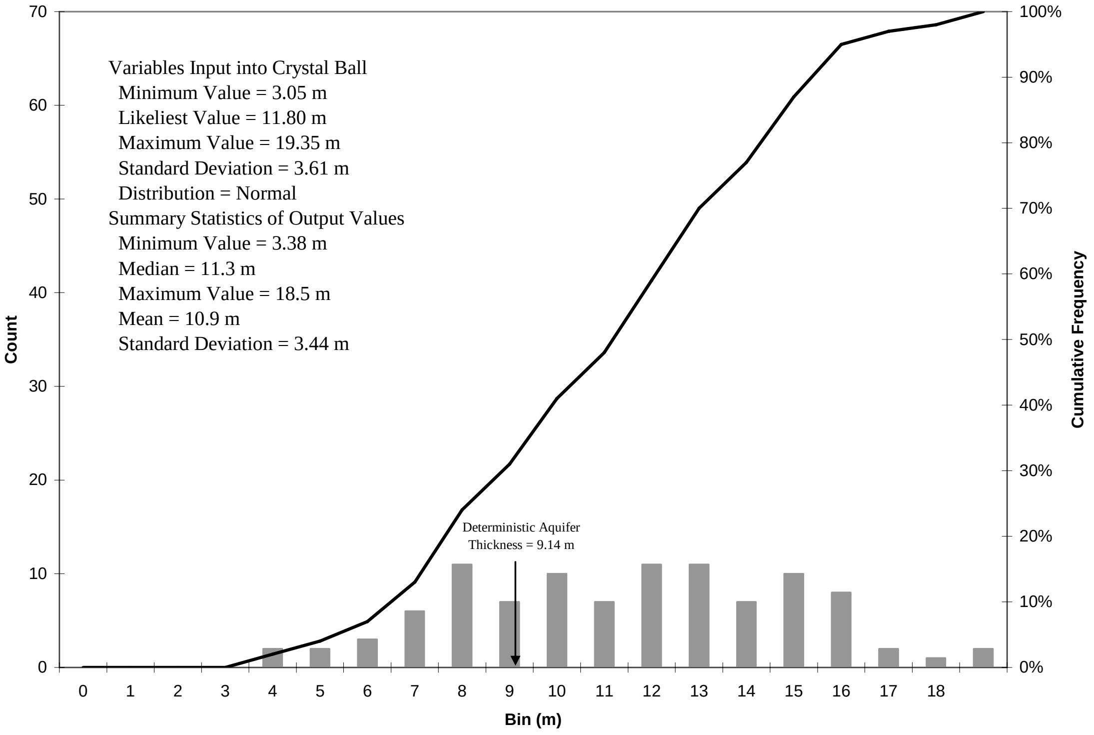
[b] Sensitivity analysis was conducted for the deterministic biodegradation rate (half-life = Infinite, 4.5, and 26.6 years). The baseline was based on a half-life of 26.6 years.

Deterministic Biodegradation Rate = 0 hr^{-1} (half-life = Infinite)

Deterministic Biodegradation Rate = 2.97E-06 hr^{-1} (half-life = 26.6 years)

Deterministic Biodegradation Rate = 1.76E-05 hr^{-1} (half-life = 4.5 years)

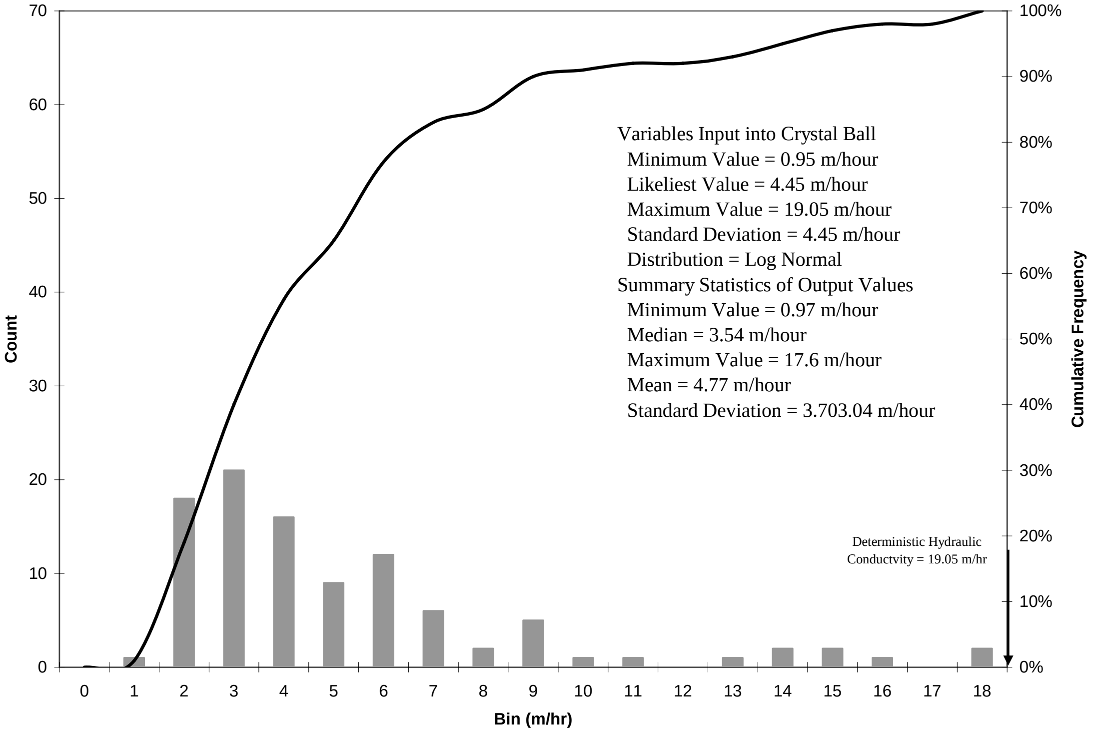
Fig. F.2.18. Histogram of Degradation Rate SESOIL inputs for C-720 Area.



Variables Input into Crystal Ball
Minimum Value = 3.05 m
Likeliest Value = 11.80 m
Maximum Value = 19.35 m
Standard Deviation = 3.61 m
Distribution = Normal
Summary Statistics of Output Values
Minimum Value = 3.38 m
Median = 11.3 m
Maximum Value = 18.5 m
Mean = 10.9 m
Standard Deviation = 3.44 m

Deterministic Aquifer Thickness = 9.14 m

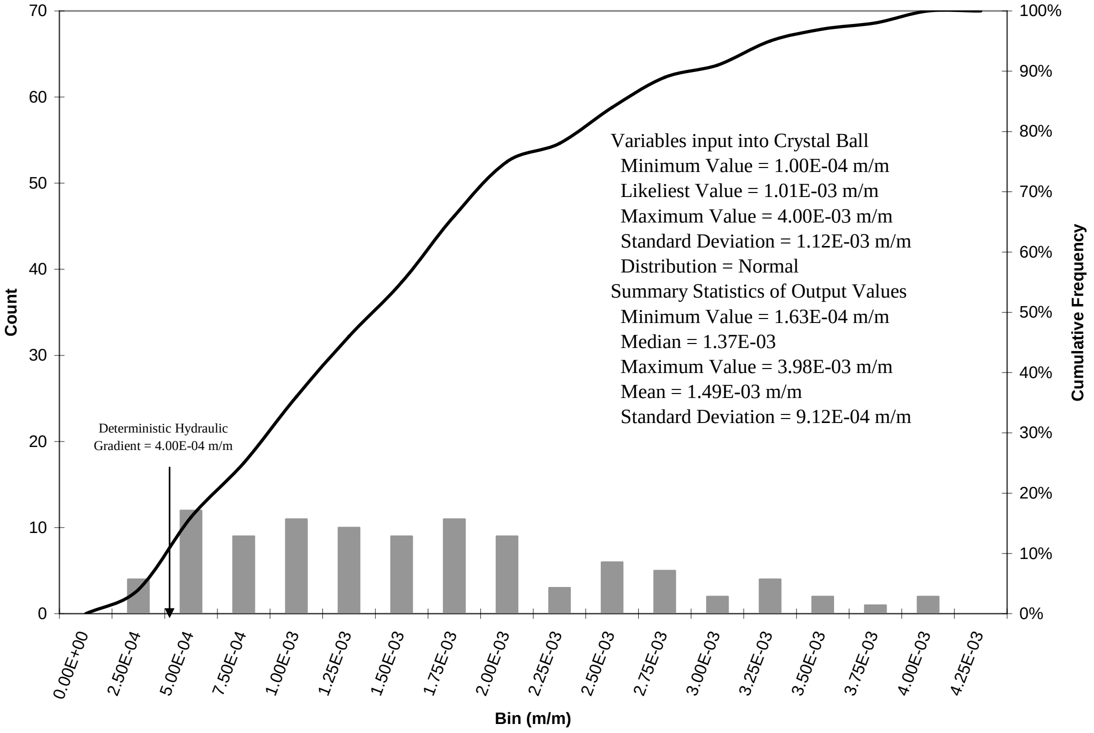
Fig. F.2.19. Histogram of Aquifer Thickness AT123D inputs for SWMU 1 and the C-720 Area.



Variables Input into Crystal Ball
Minimum Value = 0.95 m/hour
Likeliest Value = 4.45 m/hour
Maximum Value = 19.05 m/hour
Standard Deviation = 4.45 m/hour
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.97 m/hour
Median = 3.54 m/hour
Maximum Value = 17.6 m/hour
Mean = 4.77 m/hour
Standard Deviation = 3.703.04 m/hour

Deterministic Hydraulic
Conductvity = 19.05 m/hr

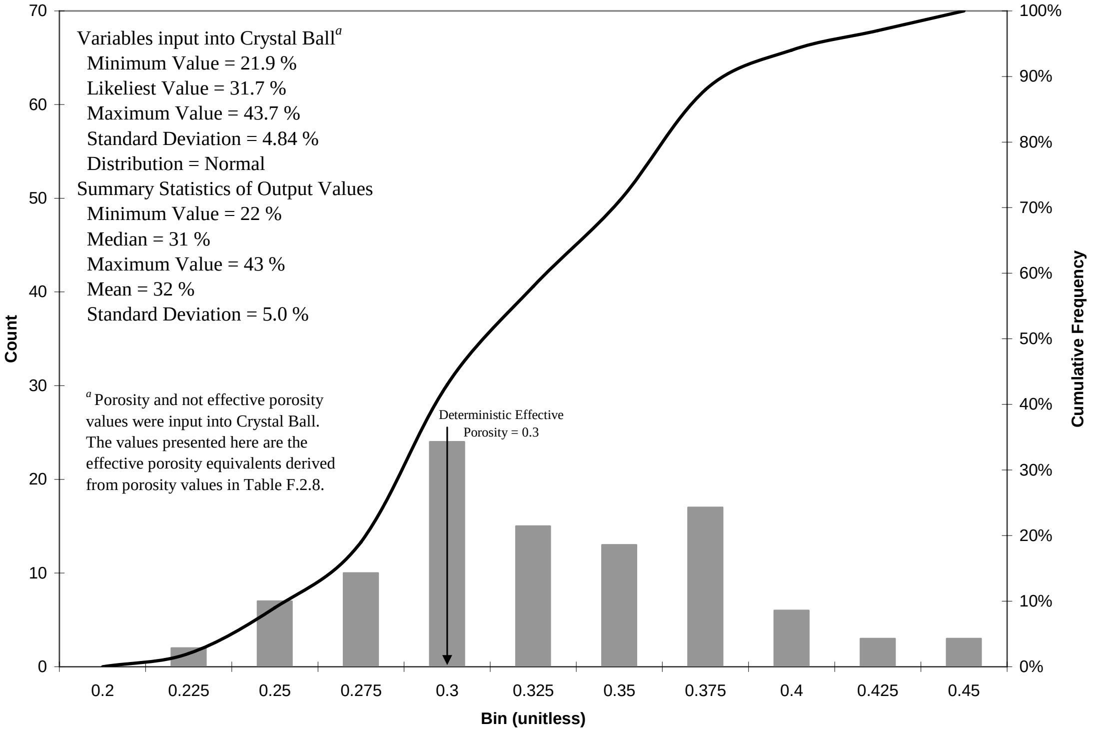
Fig. F.2.20. Histogram of Hydraulic Conductivity AT123D inputs for SWMU 1 and the C-720 Area.



Variables input into Crystal Ball
Minimum Value = 1.00E-04 m/m
Likeliest Value = 1.01E-03 m/m
Maximum Value = 4.00E-03 m/m
Standard Deviation = 1.12E-03 m/m
Distribution = Normal
Summary Statistics of Output Values
Minimum Value = 1.63E-04 m/m
Median = 1.37E-03
Maximum Value = 3.98E-03 m/m
Mean = 1.49E-03 m/m
Standard Deviation = 9.12E-04 m/m

Deterministic Hydraulic
Gradient = 4.00E-04 m/m

Fig. F.2.21. Histogram of Hydraulic Gradient AT123D inputs for SWMU 1 and the C-720 Area.

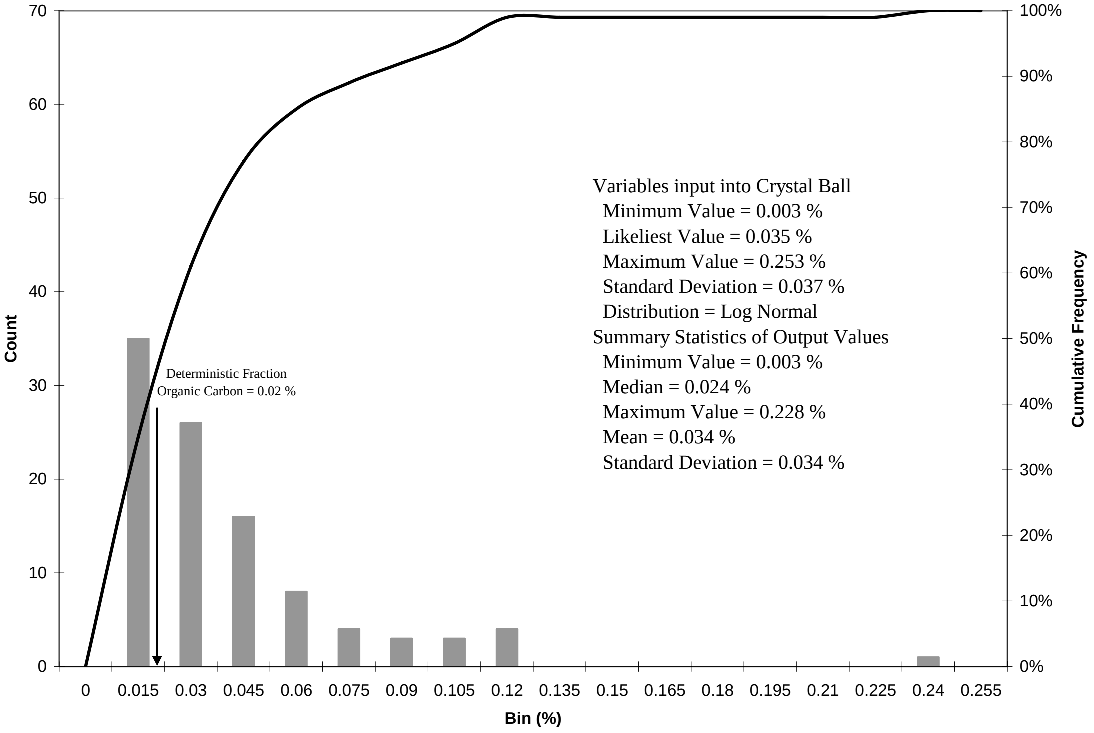


Variables input into Crystal Ball[a]
Minimum Value = 21.9 %
Likeliest Value = 31.7 %
Maximum Value = 43.7 %
Standard Deviation = 4.84 %
Distribution = Normal
Summary Statistics of Output Values
Minimum Value = 22 %
Median = 31 %
Maximum Value = 43 %
Mean = 32 %
Standard Deviation = 5.0 %

[a] Porosity and not effective porosity values were input into Crystal Ball. The values presented here are the effective porosity equivalents derived from porosity values in Table F.2.8.

Deterministic Effective Porosity = 0.3

Fig. F.2.22. Histogram of Effective Porosity AT123D inputs for SWMU 1 and the C-720 Area.



Variables input into Crystal Ball
Minimum Value = 0.003 %
Likeliest Value = 0.035 %
Maximum Value = 0.253 %
Standard Deviation = 0.037 %
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.003 %
Median = 0.024 %
Maximum Value = 0.228 %
Mean = 0.034 %
Standard Deviation = 0.034 %

Deterministic Fraction Organic Carbon = 0.02 %

Fig. F.2.23. Histogram of Organic Carbon Content AT123D inputs for SWMU 1 and the C-720 Area.

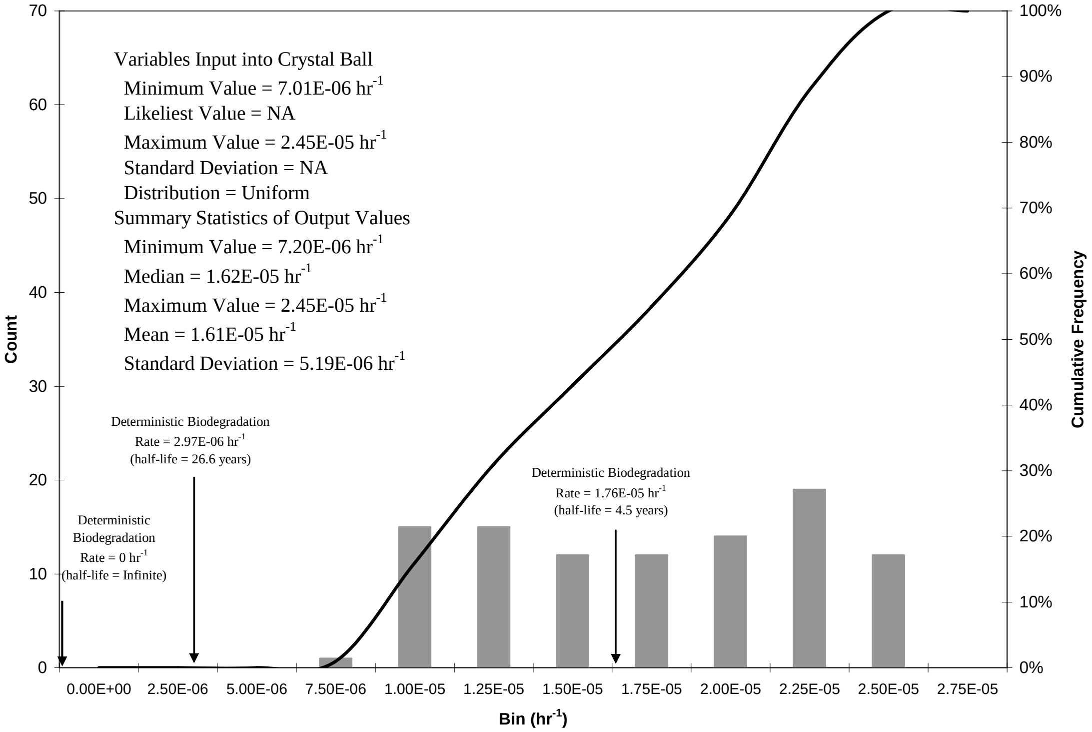


Fig. F.2.24. Histogram of Degradation Rate inputs for SWMU 1, and the C-720 Area.

E.6. LEAD-210 AT PGDP

Lead-210 is a radioactive form of lead, having an atomic weight of 210. It is one of the last elements created by the radioactive decay of the isotope uranium-238 (see Figure E.7). Lead-210 forms naturally in the sediments and rocks that contain uranium-238, as well as in the atmosphere, a by-product of radon gas. Within 10 days of its creation from radon, lead-210 falls out of the atmosphere. It accumulates on the surface of the earth where it is stored in soils, lake and ocean sediments, and glacial ice. The lead-210 eventually decays into a non-radioactive form of lead. Lead-210 has a half-life of 22.3 years and is a significant source of beta radiation (USGS 2012; EPA 2012).[1]

Lead-210 is not an easy analysis to perform and typically is not included in a regular gamma radiological scan; it has a peak at 46 KeV and requires a thin window detector and an efficiency curve using a standard with lead-210. Therefore, historical data was reviewed to ensure the analysis was necessary. Because lead-210 is found significantly down the decay chain for uranium-238 through radon-222, activities performed over the past 60 years at PGDP cannot have resulted in PGDP-sourced lead-210.

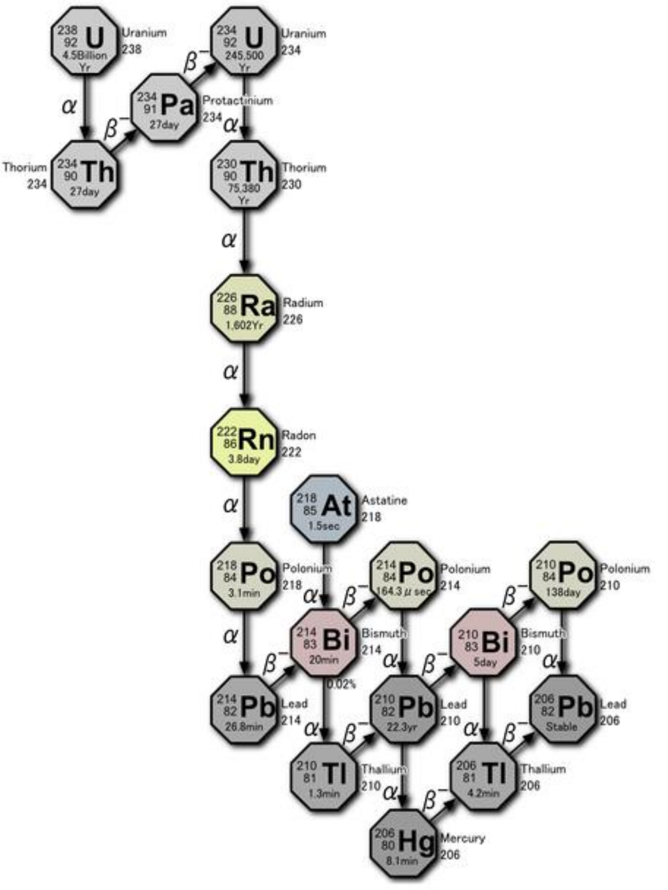


Figure E.7. Lead-210 Decay Chain

Available PGDP lead-210 data was plotted to estimate an approximate background value. This map is shown in Figure E.8. Because the majority of the available data is historical, data quality is not certain; however, it appears that the higher lead-210 activities within the PGDP boundaries are at background values.

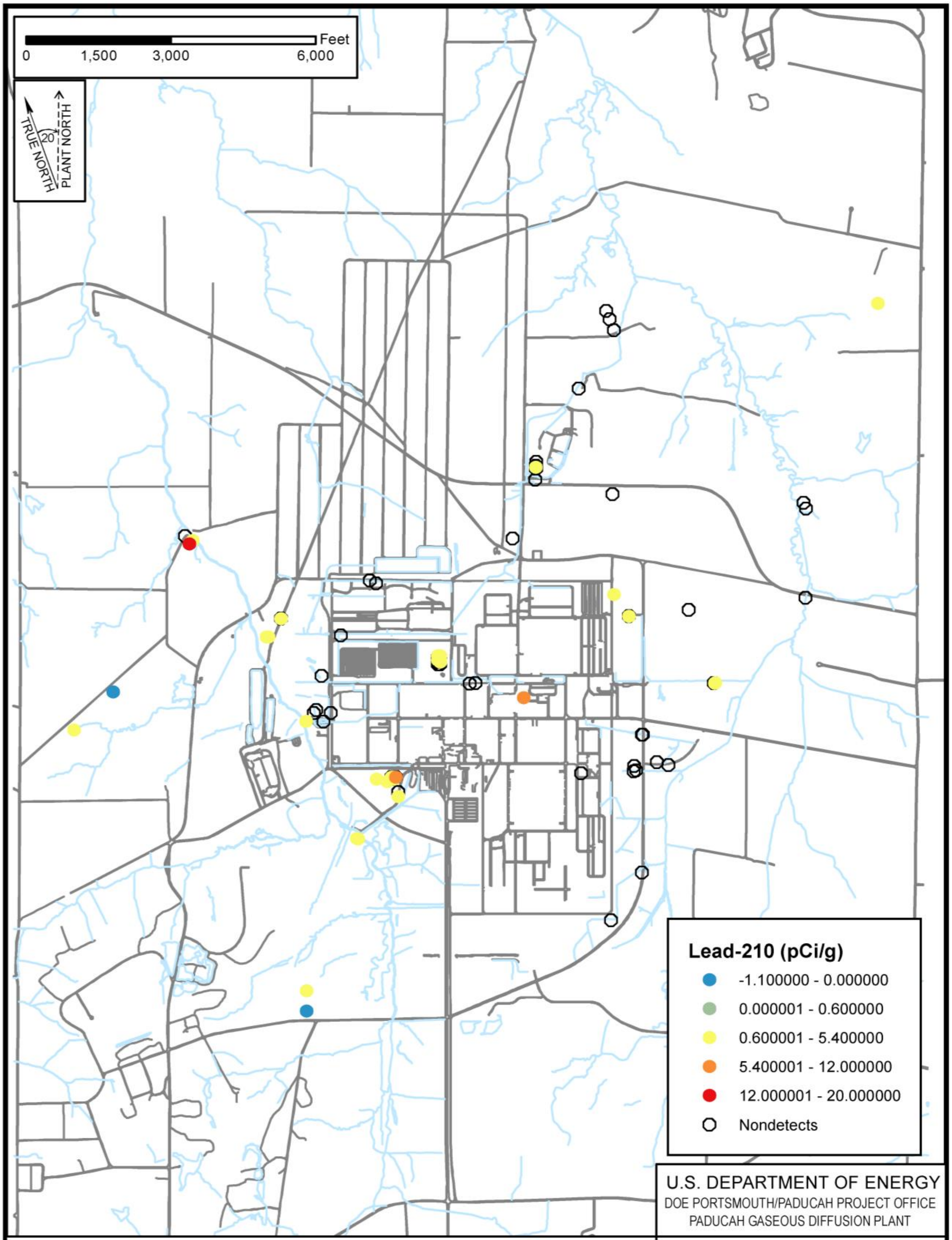


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Figure E.8. Lead-210 Soil/Sediment Samples

LATA Environmental Services of Kentucky, LLC

Figure No. Lead-210_Soil.mxd
DATE 11-01-2012

Data indicate higher levels of lead-210 inside the PGDP boundary at SWMU 222, although radium-226 was not reported for the majority of these samples. The one sample that had radium-226 reported had a significant difference in activity between the radium-226 and its ingrowth radionuclides, lead-214 and bismuth-214. If radium-226 is truly at 11 pCi/g, as reported in that sample, and the analysis was conducted properly (ingrowth for 30 days in a sealed container), the lead-214 and bismuth-214 activity should have equaled the radium-226 activity. Under these analysis conditions the activity of lead-210 would not be in secular equilibrium with radium-226. The fact that the lead-210 is elevated in the samples suggests a possible separate source of lead-210 rather than ingrowth. Lead-210, which has a 22-year half-life, is included in the list of short-lived radionuclides associated with radium-226 for completeness, as this isotope and its short-lived decay products typically are present with radium-226.

After processing, radionuclides with half-lives of less than one year will reestablish equilibrium conditions with their longer-lived parent radionuclides within several years. For this reason, at processing sites what was once a single, long decay series (for example the series for uranium-238) may be present as several smaller decay series headed by the longer-lived decay products of the original series (that is, headed by uranium-238, uranium-234, thorium-230, radium-226, and lead-210 in the case of uranium-238). Each of these sub-series can be considered to represent a new, separate decay series. Understanding the physical and chemical processes associated with materials containing uranium, thorium, and radium is important when addressing associated radiological risks.

Detected lead-210 results available for PGDP were listed alongside radium-226 and uranium-238 results in Table E.4. Lead-210 would be expected to be in equilibrium (i.e., similar activity results) with uranium-238 for instances of natural uranium. Lead-210 would be expected to be in equilibrium with radium-226 for instances of enriched uranium. No split samples are available; however, a surrogate to a “split” could be simply looking at the uranium-238 to lead-210 ratio in samples, where available. For example, if lead-210 is a true contaminant, then it should exceed the uranium-238 level, when the uranium-238 is at background in at least some samples.

A further check of the available data was performed by filtering the activity results against minimum detectable activities and counting uncertainties. The only samples that passed both checks are shown in Table E.5. Recent Soils Operable Unit (OU) soils data passed both checks.

Table E.4. Sample Results for Lead-210, Radium-226, and Uranium-238 in Soil and Sediment

		Depth	Lab	Lead-210 (pCi/g)					Radium-226 (pCi/g)					Uranium-238 (pCi/g)				
Station	Sample ID	(ft bgs)	Code	Results	MDA	Rad Error	TPU	Detect?	Results	MDA	Rad Error	TPU	Detect?	Results	MDA	Rad Error	TPU	Detect?
194-01,02	301043	9	LOCK	20.00	0.02			Yes					No	0.60		0.10		Yes
JP-0092	DOJ1-99-0092		PGDP	14.55	18.18	29.10	29.10	No	0.77	0.31	1.53	1.53	No	4386.00	4.20	89.00	1117.00	Yes
194-01,02	301048	20	LOCK	12.00	0.05			Yes					No	1.30		0.16		Yes
SWMU222-4	2010-53093[a]		KYRAD	10.60	2.05	1.03		Yes					No	27.80	1.62	1.12		Yes
SWMU222-4	2010-53093		KYRAD	10.60	2.05	1.03		Yes					No	27.80	0.03	2.33		Yes
SWMU222-5	2010-53094[b]		KYRAD	8.60	1.47	0.76		Yes					No	32.30	0.04	2.66		Yes
SWMU222-1	2010-53090 [b]		KYRAD	8.44	1.71	0.87		Yes					No	23.70	0.13	2.10		Yes
194-01,02	301044	11.33	LOCK	8.00	0.03			Yes					No	0.61		0.11		Yes
SWMU222-2	2010-53091 [b]		KYRAD	6.98	1.41	0.71		Yes					No	22.10	0.04	1.94		Yes
SWMU222-3	2010-53092 [b]		KYRAD	6.81	1.14	0.61		Yes					No	16.70	0.03	1.51		Yes
SOU195-120A	2010-51253 [a]	1	KYRAD	6.57	9.25	3.83		No	2.53	2.08	0.94		Yes	3.94	2.41	1.36		Yes
SOU195-014C	2010-51264 [a]	10	KYRAD	6.01	5.28	2.16		Yes	1.44	1.27	0.57		Yes	2.25	0.93	0.84		Yes
194-01,02	301047	18.6	LOCK	5.40	0.00			Yes					No	0.90		0.13		Yes
SWMU222-1	2010-52457 [b]		KYRAD	4.92	0.82	0.41		Yes					No	31.30	0.05	3.59		Yes
JP-0160	DOJ1-99-0160		PGDP	4.31	1.79	2.11	2.28	Yes	0.71	1.64	1.42	1.42	No	2.70	0.93	0.52	1.41	Yes
BCBOKYRAD01	2010-50535 [a]		KYRAD	4.27	0.46	0.25		Yes	2.35	0.87	0.39		Yes	2.22	0.47	0.22		Yes
LBC2L020	LBCSOSU2S1-04	1	STLMO	4.20	2.00		1.70	Yes	0.80	0.21		0.25	Yes	3.90	1.50		1.40	Yes
RSO3	110013[c]		STLMO	3.90	1.90	1.90		Yes					No					No
JP-0152	DOJ1-99-0152		PGDP	3.76	5.96	7.52	7.52	No	0.84	0.12	1.69	1.69	No	208.00	0.04	3.30	42.00	Yes
H01,05,15	301025	0.7	LOCK	3.70	0.00			Yes					No	0.96		0.10		Yes
SOU195-014A	2010-51258 [a]	10	KYRAD	3.56	5.07	2.13		No	1.40	1.10	0.50		Yes	1.54	0.90	0.79		Yes
RSO3	110012[c]		STLMO	3.50	1.40	1.20		Yes					No					No
BC5KYRAD01	2010-50537 [a]		KYRAD	3.43	0.36	0.21		Yes	2.06	0.71	0.32		Yes	1.37	0.32	0.15		Yes
C12,18,19	301012[d]	2	LOCK	3.20	0.00			Yes					No	0.97		0.09		Yes
A10	PLDJNSA10-01SO	2.5	PGDP	3.10	5.90	6.20	6.20	No	0.16	0.07	0.01	0.08	Yes	6.60	0.05	0.35	0.89	Yes
LBC2L015	LBCSOSU2S1-03	1	STLMO	3.00	2.90		2.40	Yes	1.21	0.26		0.30	Yes	1.25	0.01		0.18	Yes
JP-0161	DOJ1-99-0161		PGDP	2.92	1.93	2.07	2.10	Yes	0.83	0.17	1.66	1.66	No	2.30	1.02	0.51	3.21	No
SOU200-004	2010-51270 [a]	4	KYRAD	2.81	5.18	2.19		No	2.51	1.31	0.61		Yes	1.48	0.88	1.19		Yes
F04,02,29	301005	0.8	LOCK	2.80	0.00			Yes					No	0.82		0.08		Yes
SOU195-120C	2010-51252 [a]	1	KYRAD	2.70	0.62	0.32		Yes	1.67	0.90	0.41		Yes	1.02	0.52	0.29		Yes
K008-AIP-RP	030301	0	STLMO	2.70	1.20	1.10		Yes					No	1.71	0.33	0.98		Yes
C07,08,09	301013 [d]	0.9	LOCK	2.70	0.00			Yes					No	1.04		0.09		Yes
NST2S04	BJC2041SS	8	PGDP	2.65	2.40	2.50	2.60	Yes	2.43	0.33	4.85	4.85	No	4.11	1.24	0.66	2.11	Yes
SOU222-001	2010-51277 [a]	0.5	KYRAD	2.57	0.59	0.76		Yes	11.10	1.30	0.71		Yes	19.62	0.76	0.65		Yes
BCBOKYRAD02	2010-50536 [a]		KYRAD	2.51	0.71	0.33		Yes	7.18	1.17	0.56		Yes	10.26	0.87	0.46		Yes
F12,20,22	301004	1.5	LOCK	2.46	0.00			Yes					No	0.90		0.08		Yes
H04,06,09	301023	0.8	LOCK	2.45	0.00			Yes					No	0.84		0.09		Yes
JP-0019	DOJ1-99-0017		PGDP	2.44	16.16	4.87	10.54	No	1.06	0.29	2.11	2.11	No	2270.00	9.14	16.30	609.00	Yes
C12,18,19	301011 [d]	0.8	LOCK	2.40	0.00			Yes					No	1.06		0.10		Yes
196-03,04	301038	6.67	LOCK	2.40	0.00			Yes					No	0.80		0.12		Yes
C01,10,24	301017 [d]	0.7	LOCK	2.30	0.00			Yes					No	0.95		0.10		Yes
F05,07,17	301008	1.6	LOCK	2.20	0.00			Yes					No	0.86		0.09		Yes
C07,08,09	301015 [d]	0.9	LOCK	2.09	0.00			Yes					No	1.00		0.10		Yes

Table E.4. Sample Results for Lead-210, Radium-226, and Uranium-238 in Soil and Sediment (Continued)

		Depth	Lab	Lead-210 (pCi/g)					Radium-226 (pCi/g)					Uranium-238 (pCi/g)				
Station	Sample ID	(ft bgs)	Code	Results	MDA	Rad Error	TPU	Detect?	Results	MDA	Rad Error	TPU	Detect?	Results	MDA	Rad Error	TPU	Detect?
JP-0046	DOJ1-99-0046		PGDP	2.07	1.91	2.03	2.00	Yes	0.70	0.13	1.40	1.40	No	13.90	1.00	1.43	4.00	Yes
A2	PLDJNSA2D-01SO	8.5	PGDP	2.00	6.00	4.10	4.10	No	0.59	0.13	1.10	1.10	No	0.77	0.24	0.39	1.37	No
H04,06,09	301022	2.6	LOCK	1.90	0.00			Yes					No	1.01		0.10		Yes
F12,20,22	301001	0.8	LOCK	1.90	0.00			Yes					No	0.90		0.08		Yes
SOU195-014A	2010-51256[a]	4	KYRAD	1.89	5.01	2.14		No	1.55	1.16	0.52		Yes	1.12	0.93	1.18		No
F04,02,29	301006	1.5	LOCK	1.85	0.00			Yes					No	0.82		0.08		Yes
JP-0160	DOJ1-99-0177		PGDP	1.84	2.62	3.68	3.68	No	0.65	0.12	1.30	1.30	No	2.01	0.91	1.08	3.57	No
K008-AIP-RP	030303	0	STLMO	1.80	1.10	1.30		Yes	0.80	0.30	0.28		Yes	2.30	0.30	1.10		Yes
C02,03,20	301019[d]	0.7	LOCK	1.80	0.00			Yes					No	1.03		0.10		Yes
BC5KYRAD02	2010-50538[a]		KYRAD	1.74	0.90	0.42		Yes	2.01	1.56	0.70		Yes	0.69	0.93	0.55		Yes
194-05,06	301039	9	LOCK	1.72	0.00			Yes					No	0.79		0.12		Yes
194-03,04	301045[e]	16	LOCK	1.68	0.00			Yes					No	1.06		0.14		Yes
A2	PLDJNSA2-02SO	11.5	PGDP	1.60	6.60	3.30	4.40	No	1.10	0.18	2.20	2.20	No	1.69	0.86	1.03	3.04	No
F01,21,23	301009	0.8	LOCK	1.60	0.00			Yes					No	0.92		0.08		Yes
C02,03,20	301020[d]	3	LOCK	1.59	0.00			Yes					No	1.00		0.09		Yes
H01,05,15	301026	2.6	LOCK	1.57	0.00			Yes					No	0.87		0.08		Yes
C07,08,09	301014[d]	2.1	LOCK	1.56	0.00			Yes					No	0.94		0.08		Yes
JP-0157	DOJ1-99-0157		PGDP	1.56	4.07	3.11	3.11	No	0.90	0.16	1.80	1.80	No	108.00	1.80	2.95	29.10	Yes
JP-0113	DOJ1-99-0115		PGDP	1.54	1.60	1.68	1.69	No	0.49	0.12	0.97	0.97	No	6.02	0.88	1.33	3.23	Yes
C07,08,09	301016[d]	2.1	LOCK	1.51	0.00			Yes					No	0.91		0.08		Yes
H04,06,09	301021	0.8	LOCK	1.50	0.00			Yes					No	0.94		0.10		Yes
F12,20,22	301003	1.5	LOCK	1.50	0.00			Yes					No	0.92		0.09		Yes
K008-AIP-RP	030302	0	STLMO	1.49	1.20	0.82		Yes					No	0.76	0.26	0.56		Yes
BC14KYRAD	2010-50539[a]		KYRAD	1.49	0.68	0.32		Yes	1.94	1.52	0.67		Yes	1.64	0.70	0.40		Yes
JP-0075	DOJ1-99-0075		PGDP	1.48	4.62	2.97	2.97	No	1.24	0.16	2.48	2.48	No	14.80	1.54	2.05	6.04	Yes
194-03,04	301036[e]	8	LOCK	1.48	0.00			Yes					No	0.80		0.12		Yes
H02,10,18	301027	0.7	LOCK	1.44	0.00			Yes					No	1.00		0.11		Yes
F12,20,22	301002	0.8	LOCK	1.40	0.00			Yes					No	0.93		0.09		Yes
SOU195-014A	2010-51257[a]	7	KYRAD	1.38	0.70	0.32		Yes	2.12	1.07	0.49		Yes	1.11	0.58	0.38		Yes
JP-0090	DOJ1-99-0090		PGDP	1.37	2.21	2.74	2.74	No	0.77	0.14	1.55	1.55	No	22.00	0.02	0.75	3.30	Yes
OUTFALL10-1	WC02-242	4	PORTS	1.36	0.67	0.68	0.68	No	0.94	0.32	0.22	0.37	No	0.67	0.05	0.12	0.21	Yes
SOU195-014C	2010-51262[a]	4	KYRAD	1.31	0.79	0.36		Yes	2.30	1.59	0.71		Yes	0.49	0.97	0.46		Yes
JP-0062	DOJ1-99-0062		PGDP	1.31	2.95	2.61	2.61	No	0.71	0.13	1.41	1.41	No	4.01	1.17	1.62	3.02	Yes
F01,21,23	301010	1.6	LOCK	1.26	0.00			Yes					No	0.82		0.08		Yes
SWMU222-4	2010-52458[a]		KYRAD	1.25	0.48	0.22		Yes					No	1.52	0.44	0.29		Yes
JP-0163	DOJ1-99-0163		PGDP	1.22	2.94	2.45	2.45	No	0.97	0.23	1.93	1.93	No	3.23	1.36	0.78	1.76	Yes
NST2S02	BJC2021SS	3	PGDP	1.20	2.87	2.41	2.41	No	0.64	0.18	1.28	1.28	No	104.00	0.31	3.50	21.00	Yes
194-01,02	301040	6.75	LOCK	1.20	0.00			Yes					No	0.79		0.12		Yes
194-05,06	301050	17.5	LOCK	1.20	0.00			Yes					No	0.71		0.11		Yes
SOU195-014	2010-51255[a]	10	KYRAD	1.20	0.88	0.36		Yes	1.89	1.50	0.67		Yes	0.74	0.97	0.51		Yes
SOU195-014B	2010-51260[a]	7	KYRAD	1.17	0.64	0.30		Yes	2.25	0.91	0.43		Yes	0.79	0.56	0.35		Yes
194-05,06	301042	11.5	LOCK	1.17	0.00			Yes					No	0.72		0.11		Yes
H03,07,13	301029	0.7	LOCK	1.10	0.00			Yes					No	1.10		0.12		Yes

Table E.4. Sample Results for Lead-210, Radium-226, and Uranium-238 in Soil and Sediment (Continued)

		Depth (ft bgs)	Lab Code	Lead-210 (pCi/g)					Radium-226 (pCi/g)					Uranium-238 (pCi/g)				
Station	Sample ID			Results	MDA	Rad Error	TPU	Detect?	Results	MDA	Rad Error	TPU	Detect?	Results	MDA	Rad Error	TPU	Detect?
H03,07,13	301029	0.7	LOCK	1.10	0.00			Yes					No	1.10				Yes
SOU195-006	2010-51265 [a]	7	KYRAD	1.09	0.73	0.33		Yes	2.13	1.16	0.53		Yes	0.86	0.57	0.34		Yes
SOU195-025	2010-51250 [a]	7	KYRAD	1.09	0.84	0.38		Yes	2.41	1.65	0.73		Yes	1.05	0.72	0.52		Yes
SOU195-014B	2010-51261 [a]	10	KYRAD	1.08	0.96	0.43		Yes	1.46	1.45	0.64		Yes	0.77	0.69	0.44		Yes
SOU200-009	2010-51275 [a]	4	KYRAD	1.08	5.15	2.23		No	1.87	1.32	0.60		Yes	1.08	0.93	0.88		Yes
H02,10,18	301028	3	LOCK	1.07	0.00			Yes					No	0.92		0.08		Yes
JP-0162	DOJ1-99-0162		PGDP	1.05	1.94	2.10	2.10	No	0.84	0.16	1.67	1.67	No	1.63	0.91	0.47	2.29	No
194-03,04	301041 [e]	12	LOCK	1.04	0.00			Yes					No	0.81		0.12		Yes
SOU200-005	2010-51271 [a]	4	KYRAD	1.04	0.89	0.40		Yes	2.15	1.57	0.70		Yes	1.64	0.99	0.64		Yes
SOU195-014C	2010-51263 [a]	7	KYRAD	1.03	1.04	0.46		No	1.73	1.32	0.59		Yes	0.90	0.75	0.45		Yes
SOU195-025	2010-51251 [a]	10	KYRAD	1.02	0.77	0.35		Yes	1.91	1.46	0.66		Yes	1.17	1.07	0.62		Yes
JP-0091	DOJ1-99-0091		PGDP	1.01	2.08	2.02	2.02	No	0.82	0.14	1.64	1.64	No	12.70	1.24	1.72	3.82	Yes
NST1S01	BJC1011SS	2.5	PGDP	1.01	3.31	2.02	2.02	No	0.65	0.19	1.29	1.29	No	65.90	1.87	2.87	18.00	Yes
SOU200-008	2010-51274 [a]	4	KYRAD	1.01	0.70	0.32		Yes	1.88	1.18	0.53		Yes	1.01	0.56	0.32		Yes
H04,06,09	301024	2.6	LOCK	1.00	0.00			Yes					No	0.94		0.09		Yes
OUTFALL10-1	WC02-242D	4	PORTS	0.99	0.63	0.64	0.65	No	0.87	0.29	0.25	0.31	No	0.68	0.07	0.13	0.46	Yes
SOU195-014B	2010-51259 [a]	4	KYRAD	0.99	0.92	0.41		Yes	1.62	1.32	0.59		Yes	0.93	0.99	0.56		Yes
JP-0018	DOJ1-99-0016		PGDP	0.96	4.68	1.92	2.81	No	0.64	0.14	1.28	1.28	No	188.00	0.05	2.30	32.00	Yes
OUTFALL10-2	WC02-243	4	PORTS	0.96	0.68	0.63	0.64	No	0.82	0.31	0.28	0.31	No	0.63	0.02	0.13	0.21	Yes
SOU200-006	2010-51272 [a]	4	KYRAD	0.95	0.66	0.30		Yes	2.67	1.09	0.51		Yes	0.94	0.57	0.38		Yes
SOU200-001	2010-51267 [a]	4	KYRAD	0.94	0.83	0.37		Yes	2.73	1.33	0.61		Yes	1.06	0.70	0.39		Yes
SOU200-010	2010-51276 [a]	4	KYRAD	0.89	0.94	0.42		No	1.75	1.47	0.65		Yes	0.76	0.69	0.36		Yes
SOU195-006	2010-51266 [a]	10	KYRAD	0.88	0.78	0.35		Yes	1.98	1.52	0.68		Yes	1.51	0.98	0.63		Yes
JP-0081	DOJ1-99-0081		PGDP	0.87	1.43	1.75	1.75	No	0.61	0.11	1.22	1.22	No	3.60	0.01	0.17	0.47	Yes
SOU200-003	2010-51269 [a]	4	KYRAD	0.86	0.92	0.41		No	2.22	1.27	0.57		Yes	0.74	0.69	0.50		Yes
JP-0015	DOJ1-99-0013		PGDP	0.81	1.66	1.62	1.62	No	0.62	0.13	1.23	1.23	No	3.16	0.82	1.25	1.99	Yes
H03,07,13	301030	3	LOCK	0.80	0.00			Yes					No	0.83		0.08		Yes
NST1S03	BJC1031SS	12	PGDP	0.79	1.55	1.59	1.59	No	0.80	0.18	1.60	1.60	No	0.66	0.04	0.11	0.13	Yes
JP-0080	DOJ1-99-0080		PGDP	0.73	1.91	1.46	1.46	No	0.82	0.15	1.64	1.64	No	2.39	0.94	0.47	3.33	No
SOU195-014	2010-51254 [a]	7	KYRAD	0.71	0.74	0.33		No	1.72	1.50	0.66		Yes	0.54	0.70	0.44		Yes
LBC2L005	LBCSOSU2S1-01	1	STLMO	0.70	2.20		1.30	No	1.40	0.15		0.30	Yes	3.12	16.80	9.24		No
SOU200-007	2010-51273 [a]	4	KYRAD	0.69	0.78	0.35		No	2.12	1.68	0.75		Yes	1.16	0.90	0.41		Yes
JP-0110	DOJ1-99-0110		PGDP	0.67	8.67	1.34	5.33	No	0.81	0.19	1.61	1.61	No	626.00	4.72	8.10	168.00	Yes
SOU200-002	2010-51268 [a]	4	KYRAD	0.65	0.62	0.28		Yes	2.10	0.94	0.44		Yes	1.08	0.56	0.33		Yes
JP-0057	DOJ1-99-0057		PGDP	0.65	1.60	1.30	1.30	No	0.28	0.09	0.56	0.56	No	7.97	0.78	1.14	4.06	Yes
JP-0097	DOJ1-99-0097		PGDP	0.62	1.70	1.25	1.25	No	0.76	0.13	1.52	1.52	No	2.58	0.77	1.04	3.71	No
JP-0066	DOJ1-99-0066		PGDP	0.60	2.87	1.21	1.85	No	0.85	0.14	1.70	1.70	No	4.81	1.22	1.63	3.47	Yes
JP-0082	DOJ1-99-0082		PGDP	0.60	2.74	1.20	1.67	No	1.29	0.18	2.58	2.58	No	20.00	0.02	0.75	3.30	Yes
194-03,04	301046 [e]	21	LOCK	0.60	0.00			Yes					No	1.18		0.16		Yes
JP-0061	DOJ1-99-0061		PGDP	0.60	2.19	1.20	1.41	No	0.33	0.08	0.66	0.66	No	6.32	0.76	1.00	0.16	Yes
JP-0013	DOJ1-99-0011		PGDP	0.55	2.26	1.11	1.36	No	0.83	0.15	1.66	1.66	No	17.30	0.97	1.38	4.86	Yes
JP-0063	DOJ1-99-0063		PGDP	0.54	2.50	1.09	1.64	No	0.65	0.12	1.29	1.29	No	1.00	0.01	0.10	0.16	Yes
JP-0087	DOJ1-99-0088		PGDP	0.47	5.67	0.94	3.46	No	0.77	0.13	1.54	1.54	No	138.00	2.54	4.19	53.00	Yes

Table E.4. Sample Results for Lead-210, Radium-226, and Uranium-238 in Soil and Sediment (Continued)

		Depth	Lab	Lead-210 (pCi/g)					Radium-226 (pCi/g)					Uranium-238 (pCi/g)				
Station	Sample ID	(ft bgs)	Code	Results	MDA	Rad Error	TPU	Detect?	Results	MDA	Rad Error	TPU	Detect?	Results	MDA	Rad Error	TPU	Detect?
A10	PLDJNSA10-02SO	8.5	PGDP	0.34	5.70	0.69	3.60	No	0.49	0.12	0.98	0.98	No	1.91	0.79	0.42	3.26	No
ISOCSOFFST	ISOCSBKGR08-01	0	PGDP	0.34	1.04	0.68	0.68	No					No	1.58	0.47	0.25	0.33	Yes
NST2S03	BJC2031SS	15	PGDP	0.31	2.30	0.61	1.39	No	0.99	0.19	1.98	1.98	No	19.80	0.08	0.79	3.00	Yes
JP-0112	DOJ1-99-0114		PGDP	0.27	1.38	0.54	0.85	No	0.67	0.11	1.34	1.34	No	7.50	0.01	0.37	1.10	Yes
JP-0060	DOJ1-99-0060		PGDP	0.22	2.13	0.44	1.40	No	0.13	0.04	0.16	0.26	No	8.24	0.85	1.26	3.40	Yes
C01,10,24	301018 [d]	2.8	LOCK	0.20	0.00			Yes					No	1.03		0.09		Yes
NST2S05	BJC2052SS	12.5	PGDP	0.17	1.28	0.35	0.78	No	0.52	0.14	1.03	1.03	No	1.21	0.20	0.32	1.70	No
JP-0100	DOJ1-99-0100		PGDP	0.09	1.44	0.18	0.89	No	0.72	0.12	1.44	1.44	No	1.48	0.67	0.39	2.08	No
NST1S02	BJC1021SS	2.5	PGDP	0.06	2.53	0.13	1.54	No	0.57	0.19	1.15	1.15	No	29.70	1.38	2.18	8.27	Yes
JP-0016	DOJ1-99-0014		PGDP	0.00	1.81	0.01	1.10	No	0.57	0.12	1.13	1.13	No	8.80	0.04	0.35	1.20	Yes
196-01,02	301037	7	LOCK	0.00 [f]	0.00			No					No	0.82		0.12		Yes
JP-0164	DOJ1-99-0164		PGDP	-0.01	1.86	0.01	1.15	No	0.69	0.15	1.38	1.38	No	1.84	0.92	0.45	2.57	No
NST2S01	BJC2011SS	2	PGDP	-0.13	1.73	0.25	1.06	No	0.57	0.16	1.14	1.14	No	8.11	0.91	1.35	2.56	Yes
JP-0045	DOJ1-99-0045		PGDP	-0.29	2.68	0.58	1.76	No	0.58	0.12	1.15	1.15	No	6.00	0.01	0.23	0.77	Yes
JP-0016	DOJ1-99-0014DUP		PGDP	-0.29	1.76	0.59	1.08	No	0.52	0.12	1.05	1.05	No	11.00	0.02	0.37	1.40	Yes
JP-0087	DOJ1-99-0087		PGDP	-0.43	5.27	0.86	3.23	No	0.65	0.12	1.30	1.30	No	126.00	2.33	3.83	48.30	Yes
JP-0071	DOJ1-99-0071		PGDP	-0.75	5.45	1.50	3.40	No	2.78	0.26	5.56	5.56	No	19.00	1.98	2.46	7.68	Yes
BGS194-04	301049	24	LOCK	-0.80	0.01			No					No	0.76		0.12		Yes
JP-0085	DOJ1-99-0085		PGDP	-0.86 [f]	6.72	1.72	4.14	No	0.80	0.15	1.60	1.60	No	160.00	3.01	5.07	61.80	Yes
F05,07,17	301007	1	LOCK	-1.10 [f]	0.00			No					No	0.93		0.08		Yes
A10	PLDJNSA10-03SO	9	PGDP	-1.20	31.00	2.50	18.00	No	0.14	0.20	0.00	0.06	No	326.00	4.61	7.56	125.00	Yes
JP-0072	DOJ1-99-0072		PGDP	-1.31	9.10	2.62	5.58	No	6.88	0.41	13.75	13.75	No	87.00	0.24	2.80	21.00	Yes
JP-0111	DOJ1-99-0112		PGDP	-1.99	6.10	3.99	3.99	No	0.84	0.17	1.69	1.69	No	317.00	0.67	11.00	68.00	Yes
JP-0076	DOJ1-99-0076		PGDP	-2.04	6.16	4.07	4.07	No	2.19	0.23	4.38	4.38	No	69.00	2.28	3.26	26.70	Yes
NST2S05	BJC2051SS	12.5	PGDP	-2.12	12.77	4.25	7.90	No	5.15	1.39	10.30	10.30	No	11.10	1.90	3.14	4.33	Yes
JP-0077	DOJ1-99-0077		PGDP	-2.71	5.02	5.42	5.42	No	1.47	0.17	2.94	2.94	No	56.00	0.21	1.80	11.00	Yes
A2	PLDJNSA2-01SO	8.5	PGDP	-2.90	6.20	5.80	5.80	No	0.65	0.14	1.30	1.30	No	1.24	0.26	0.44	2.14	No
JP-0152	DOJ1-99-DUP1		PGDP	-2.91	6.47	5.83	5.83	No	0.87	0.13	1.73	1.73	No	393.00	0.69	12.00	120.00	Yes
JP-0111	DOJ1-99-0111		PGDP	-2.99	6.03	5.98	5.98	No	0.91	0.17	1.81	1.81	No	365.00	0.13	4.50	63.00	Yes
JP-0151	DOJ1-99-0151		PGDP	-4.78	8.89	9.57	9.57	No	0.54	0.13	1.07	1.07	No	365.00	3.25	5.42	140.00	Yes
JP-0150	DOJ1-99-0150		PGDP	-10.07	12.75	20.14	20.14	No	0.79	0.18	1.58	1.58	No	599.00	4.88	8.14	230.00	Yes
JP-0153	DOJ1-99-0153		PGDP	-19.47	14.31	38.93	38.93	No	0.32	0.17	0.64	0.64	No	1921.00	3.50	50.00	617.00	Yes

Yellow shading indicates sample analysis by the Kentucky Radiation Health Branch Laboratory.

Blue shading indicates a detected lead-210 result for samples other than those analyzed by the Kentucky Radiation Health Branch.

TPU = total propagated uncertainty

Lab Codes are the following: LOCK = Lockheed Engineering & Science Co., Las Vegas, NV; KYRAD = Kentucky Radiation Health Branch; PGDP = USEC-Paducah Gaseous Diffusion Plant; PORTS = USEC-Portsmouth Plant; STLMO = Severn Trent, Earth City, Missouri

[a] The uranium-238 results was reported by the lab as thorium-234/uranium-238.

[b] The maximum uranium-238 result was used for comparison.

[c] This sample is not plotted in Figure 2, the coordinates place the sample in Illinois. The available coordinates are likely incorrect.

[d] This sample is not plotted in Figure 2, no coordinates are available.

[e] This sample is not plotted in Figure 2, the coordinates place the sample in Ballard County, which is outside the scale of the map.

[f] This results is set as a nondetect because the reported result is less than the minimum detectable activity (MDA).

Table E.5. Results of Filtering

Method	Chemical	Date Collected	MDA	Lab Code	Lab Sample ID	Media	Rad Error	Result	Lab Qualifier	Station	Units	Val Qualifier	Greater Than DL	Less Than DL	Pass cut
DNT	Lead-210	7/31/2006	152.1	KYRAD	2006-51812	SW	133.1	529.9		A-Composite	pCi/L	X	529.9		529.9
DNT	Lead-210	7/21/2004	139	KYRAD	2004-51807	SW	120.4	557.4		A-Composite	pCi/L	=	557.4		557.4
DNT	Lead-210	7/9/2003	86.13	KYRAD	2003-06373	SW	77.85	213.2		A-Composite	pCi/L	=	213.2		213.2
DNT	Lead-210	12/8/2006	141.6	KYRAD	2006-53149	SW	156.5	1469		A-Composite	pCi/L	X	1469		1469
DNT	Lead-210	7/18/2005	96.2	KYRAD	2005-51647	SW	176.1	661.4		A-Composite	pCi/L	X	661.4		661.4
DNT	Lead-210	5/26/2006	116	KYRAD	2006-51119	SW	126.8	1605		A-Composite	pCi/L	X	1605		1605
Gamma Spec	Lead-210	2/2/2007	159.2	KYRAD	2007-50161	SW	276.5	692.8	U	A-Composite	pCi/L	U	692.8		692.8
DNT	Lead-210	10/27/2005	105.5	KYRAD	2005-52609	SW	124.9	1707		A-Composite	pCi/L	X	1707		1707
Gamma Spec	Lead-210	6/4/2007	174.2	KYRAD	2007-51252	SW	107	1284		A-Composite	pCi/L	=	1284		1284
DNT	Lead-210	10/13/2004	99.77	KYRAD	2004-52643	SW	143.4	309.4		C-Composite	pCi/L	=	309.4		309.4
DNT	Lead-210	3/9/2005	173.9	KYRAD	2005-50440	SW	189.5	2593		C-Composite	pCi/L	=	2593		2593
DNT	Lead-210	5/11/2005	144.7	KYRAD	2005-51034	SW	82.96	514		A-Composite	pCi/L	X	514		514
DNT	Lead-210	6/9/2004	147.5	KYRAD	2004-51367	SW	77.57	1714		A-Composite	pCi/L	=	1714		1714
Gamma Spec	Lead-210	4/3/2007	180.9	KYRAD	2007-50606	SW	97.97	1719	U	A-Composite	pCi/L	U	1719		1719
Gamma Spec	Lead-210	11/19/2007	168	KYRAD	2007-52795	SW	123.9	274.7	J	A-Composite	pCi/L	J	274.7		274.7
DNT	Lead-210	1/10/2005	138.2	KYRAD	2005-50023	SW	147.8	1210		C-Composite	pCi/L	X	1210		1210
Gamma Spec	Lead-210	2/22/2007	275.7	KYRAD	2007-50293	SW	160.8	2222	U	C-Composite	pCi/L	U	2222		2222
DNT	Lead-210	1/3/2006	299	KYRAD	2005-53157	SW	285.5	881.4		C-Composite	pCi/L	X	881.4		881.4
DNT	Lead-210	3/9/2005	173.9	KYRAD	2005-50440	SW	189.5	2593		C-Composite	pCi/L	X	2593		2593
DNT	Lead-210	12/20/2004	173.3	KYRAD	2004-53235	SW	237	832.2		C-Composite	pCi/L	=	832.2		832.2
Gamma Spec	Lead-210	4/25/2007	128.9	KYRAD	2007-50839	SW	138.1	1185		C-Composite	pCi/L	=	1185		1185
DNT	Lead-210	12/14/2006	533.1	KYRAD	2006-53330	SW	283.4	3222	U	ATC746K	pCi/L	X	3222		3222
DNT	Lead-210	9/11/2006	149.7	KYRAD	2006-52207	SW	130.7	594		B-Composite	pCi/L	X	594		594
Gamma Spec	Lead-210	6/25/2007	154.2	KYRAD	2007-51454	SW	85.39	1936	U	B-Composite	pCi/L	U	1936		1936
DNT	Lead-210	9/22/2004	112.7	KYRAD	2004-52430	SW	121.2	368.1		B-Composite	pCi/L	=	368.1		368.1
DNT	Lead-210	10/13/2004	146.1	KYRAD	2004-52679	SW	126.1	664.9		D2-Composite2	pCi/L	=	664.9		664.9
DNT	Lead-210	12/24/2003	80.3	KYRAD	2003-08104	SW	79.66	233		D2-Composite2	pCi/L	=	233		233
DNT	Lead-210	3/2/2006	67	KYRAD	2006-50341	SW	43.39	102.5		B-Composite	pCi/L	X	102.5		102.5
Gamma Spec	Lead-210	4/3/2007	183.7	KYRAD	2007-50628	SW	95.3	2502	U	B-Composite	pCi/L	U	2502		2502
DNT	Lead-210	7/18/2005	129.3	KYRAD	2005-51670	SW	96.29	1306		B-Composite	pCi/L	X	1306		1306
DNT	Lead-210	1/10/2005	225.3	KYRAD	2005-50022	SW	113.8	3492		B-Composite	pCi/L	X	3492		3492
DNT	Lead-210	8/31/2004	106.9	KYRAD	2004-52253	SW	92.05	604.6		D-Composite	pCi/L	=	604.6		604.6
DNT	Lead-210	6/30/2004	138.7	KYRAD	2004-51697	SW	127.6	575.8		D2-Composite2	pCi/L	=	575.8		575.8
DNT	Lead-210	10/27/2005	115.4	KYRAD	2005-52720	SW	122.4	1419		F-Composite	pCi/L	X	1419		1419
Gamma Spec	Lead-210	11/29/2010	1.61	KYRAD	2010-53281	SW	0.894	974	U	C-613	pCi/L	U	974		974
DNT	Lead-210	11/17/2005	152.4	KYRAD	2005-52866	SW	106.8	1269		D-Composite	pCi/L	X	1269		1269
Gamma Spec	Lead-210	2/2/2007	126.9	KYRAD	2007-50240	SW	224.8	490.7	U	F-Composite	pCi/L	U	490.7		490.7
DNT	Lead-210	12/13/2006	532.5	KYRAD	2006-53325	SW	282.9	3226	U	BBCDG	pCi/L	X	3226		3226
DNT	Lead-210	10/27/2005	2017	KYRAD	2005-52676	SW	2740	9532		D1-Composite	pCi/L	X	9532		9532
DNT	Lead-210	9/14/2005	130.7	KYRAD	2005-52307	SW	55.96	169.4		D1-Composite	pCi/L	X	169.4		169.4
DNT	Lead-210	12/13/2006	5867	KYRAD	2006-53326	SW	3802	7905	U	BBCROSS	pCi/L	X	7905		7905
DNT	Lead-210	7/5/2006	315.2	KYRAD	2006-51734	SW	293.3	612.9	R	BBCUG	pCi/L	X	612.9		612.9
DNT	Lead-210	8/25/2005	592.4	KYRAD	2005-52201	SW	312.6	3755		BBCUG	pCi/L	X	3755		3755

Table E.5. Results of Filtering (Continued)

Method	Chemical	Date Collected	MDA	Lab Code	Lab Sample ID	Media	Rad Error	Result	Lab Qualifier	Station	Units	Val Qualifier	Greater Than DL	Less Than DL	Pass cut
DNT	Lead-210	12/8/2006	141.1	KYRAD	2006-53231	SW	155.1	1554		D1-Composite	pCi/L	X	1554		1554
Gamma Spec	Lead-210	6/4/2007	171.1	KYRAD	2007-51333	SW	99.26	406.2		D1-Composite	pCi/L	=	406.2		406.2
DNT	Lead-210	8/13/2004	135.7	KYRAD	2004-52111	SW	137.5	621.3		F-Composite	pCi/L	=	621.3		621.3
Gamma Spec	Lead-210	11/29/2010	51.1	KYRAD	2010-53280	SW	23.7	230	U	K001	pCi/L	U	230		230
DNT	Lead-210	1/26/2005	152	KYRAD	2005-50163	SW	150	482.9		F-Composite	pCi/L	X	482.9		482.9
DNT	Lead-210	1/26/2005	152	KYRAD	2005-50163	SW	150	482.9		F-Composite	pCi/L	=	482.9		482.9
DNT	Lead-210	7/16/2002	437.6	KYRAD	2002-06663	SW	256.7	27660		D2-Composite	pCi/L	=	27660		27660
DNT	Lead-210	9/14/2005	110.6	KYRAD	2005-52329	SW	55.95	146.3		D2-Composite	pCi/L	X	146.3		146.3
DNT	Lead-210	11/20/2006	267.2	KYRAD	2006-53106	SW	283.2	843		G-Composite	pCi/L	X	843		843
DNT	Lead-210	12/22/2006	230.8	KYRAD	2006-53421	SW	148.8	2500		G-Composite	pCi/L	X	2500		2500
DNT	Lead-210	8/31/2004	107.1	KYRAD	2004-52318	SW	90.23	526		G-Composite	pCi/L	=	526		526
DNT	Lead-210	7/31/2006	150.7	KYRAD	2006-51871	SW	132.9	446.9		D2-Composite	pCi/L	X	446.9		446.9
DNT	Lead-210	11/20/2006	113.4	KYRAD	2006-53074	SW	73.27	265.4		D2-Composite	pCi/L	X	265.4		265.4
DNT	Lead-210	7/21/2004	137.2	KYRAD	2004-51947	SW	144	342.6		G-Composite	pCi/L	=	342.6		342.6
DNT	Lead-210	5/26/2006	159.3	KYRAD	2006-51229	SW	79.65	2701		D2-Composite	pCi/L	X	2701		2701
DNT	Lead-210	8/25/2005	599	KYRAD	2005-52191	SW	424.1	1900		K010	pCi/L	X	1900		1900
DNT	Lead-210	6/1/2005	237.4	KYRAD	2005-51358	SW	260.6	1634		G-Composite	pCi/L	X	1634		1634
Gamma Spec	Lead-210	4/3/2007	182	KYRAD	2007-50729	SW	96.81	2054	U	G-Composite	pCi/L	U	2054		2054
DNT	Lead-210	12/14/2006	537.4	KYRAD	2006-53312	SW	285.4	3298	U	K011	pCi/L	X	3298		3298
DNT	Lead-210	6/16/2005	539.3	KYRAD	2005-51401	SW	366.8	865.9		K012	pCi/L	X	865.9		865.9
DNT	Lead-210	8/23/2005	589.5	KYRAD	2005-52186	SW	491.7	2210		L14	pCi/L	X	2210		2210
DNT	Lead-210	12/14/2006	539.1	KYRAD	2006-53316	SW	286.2	3332	U	K015	pCi/L	X	3332		3332
Gamma Spec	Lead-210	11/29/2010	685	KYRAD	2010-53280	SW	274	4070	U	L4	pCi/L	U	4070		4070
DNT	Lead-210	12/14/2006	7379	KYRAD	2006-53321	SW	4801	11210	U	LBC@McCaw	pCi/L	X	11210		11210
Gamma Spec	Lead-210	5/11/2010	0.838952	KYRAD	2010-51250	SO	0.375929	1.0877436		SOU195-025	pCi/g	=			
Gamma Spec	Lead-210	5/11/2010	0.774856	KYRAD	2010-51251	SO	0.352924	1.0153096		SOU195-025	pCi/g	=			
Gamma Spec	Lead-210	5/11/2010	0.622129	KYRAD	2010-51252	SO	0.323104	2.7034682		SOU195-120C	pCi/g	=			
Gamma Spec	Lead-210	5/11/2010	9.25275	KYRAD	2010-51253	SO	3.831	6.5693666	U	SOU195-120A	pCi/g	U			
Gamma Spec	Lead-210	5/12/2010	0.738264	KYRAD	2010-51254	SO	0.327648	0.7087367	U	SOU195-014	pCi/g	U			
Gamma Spec	Lead-210	5/12/2010	0.87614	KYRAD	2010-51255	SO	0.357205	1.1963452		SOU195-014	pCi/g	=			
Gamma Spec	Lead-210	5/12/2010	5.00644	KYRAD	2010-51256	SO	2.14186	1.8868582	U	SOU195-014A	pCi/g	U			
Gamma Spec	Lead-210	5/12/2010	0.69731	KYRAD	2010-51257	SO	0.323468	1.3837602		SOU195-014A	pCi/g	=			
Gamma Spec	Lead-210	5/12/2010	5.07442	KYRAD	2010-51258	SO	2.12668	3.5576405	U	SOU195-014A	pCi/g	U			
Gamma Spec	Lead-210	5/12/2010	0.919572	KYRAD	2010-51259	SO	0.410998	0.9908741		SOU195-014B	pCi/g	=			
Gamma Spec	Lead-210	5/12/2010	0.643217	KYRAD	2010-51260	SO	0.297765	1.1705553		SOU195-014B	pCi/g	=			
Gamma Spec	Lead-210	5/12/2010	0.963233	KYRAD	2010-51261	SO	0.42696	1.0807067		SOU195-014B	pCi/g	=			
Gamma Spec	Lead-210	5/12/2010	0.786643	KYRAD	2010-51262	SO	0.364651	1.3145335		SOU195-014C	pCi/g	=			
Gamma Spec	Lead-210	5/12/2010	1.03762	KYRAD	2010-51263	SO	0.457097	1.0294589	U	SOU195-014C	pCi/g	U			
Gamma Spec	Lead-210	5/12/2010	5.28305	KYRAD	2010-51264	SO	2.15693	6.0068083	J	SOU195-014C	pCi/g	J			
Gamma Spec	Lead-210	5/12/2010	0.727831	KYRAD	2010-51265	SO	0.330025	1.0930592		SOU195-006	pCi/g	=			
Gamma Spec	Lead-210	5/12/2010	0.779156	KYRAD	2010-51266	SO	0.351511	0.8835402		SOU195-006	pCi/g	=			
Gamma Spec	Lead-210	5/5/2010	0.832552	KYRAD	2010-51267	SO	0.370699	0.9368339		SOU200-001	pCi/g	=			
Gamma Spec	Lead-210	5/5/2010	0.616779	KYRAD	2010-51268	SO	0.276128	0.6544536		SOU200-002	pCi/g	=			

Table E.5. Results of Filtering (Continued)

Method	Chemical	Date Collected	MDA	Lab Code	Lab Sample ID	Media	Rad Error	Result	Lab Qualifier	Station	Units	Val Qualifier	Greater Than DL	Less Than DL	Pass cut
Gamma Spec	Lead-210	5/5/2010	0.918867	KYRAD	2010-51269	SO	0.405092	0.8584913	U	SOU200-003	pCi/g	U			
Gamma Spec	Lead-210	5/5/2010	0.894012	KYRAD	2010-51271	SO	0.401519	1.0366496		SOU200-005	pCi/g	=			
Gamma Spec	Lead-210	5/5/2010	0.662666	KYRAD	2010-51272	SO	0.300982	0.9515829		SOU200-006	pCi/g	=			
Gamma Spec	Lead-210	5/5/2010	0.777267	KYRAD	2010-51273	SO	0.346092	0.6884684	U	SOU200-007	pCi/g	U			
Gamma Spec	Lead-210	5/5/2010	0.695554	KYRAD	2010-51274	SO	0.31533	1.0058769		SOU200-008	pCi/g	=			
Gamma Spec	Lead-210	5/5/2010	5.14907	KYRAD	2010-51275	SO	2.22839	1.0775268	U	SOU200-009	pCi/g	U			
Gamma Spec	Lead-210	5/5/2010	0.942465	KYRAD	2010-51276	SO	0.415427	0.8905683	U	SOU200-010	pCi/g	U			
Gamma Spec	Lead-210	4/27/2010	0.590492	KYRAD	2010-51277	SO	0.763757	2.571285		SOU222-001	pCi/g	=			
Gamma Spec	Lead-210	9/2/2010	0.816	KYRAD	2010-52457	SO	0.406	4.92		SWMU222-1	pCi/g	=			
Gamma Spec	Lead-210	9/2/2010	0.475	KYRAD	2010-52458	SO	0.221	1.25		SWMU222-4	pCi/g	=			
Gamma Spec	Lead-210	11/4/2010	1.71	KYRAD	2010-53090	SO	0.869	8.44		SWMU222-1	pCi/g	=			
Gamma Spec	Lead-210	11/4/2010	1.41	KYRAD	2010-53091	SO	0.709	6.98		SWMU222-2	pCi/g	=			
Gamma Spec	Lead-210	11/4/2010	1.14	KYRAD	2010-53092	SO	0.607	6.81		SWMU222-3	pCi/g	=			
Gamma Spec	Lead-210	11/4/2010	2.05	KYRAD	2010-53093	SO	1.03	10.6		SWMU222-4	pCi/g	=			
Gamma Spec	Lead-210	11/4/2010	1.47	KYRAD	2010-53094	SO	0.757	8.6		SWMU222-5	pCi/g	=			
Gamma Spec	Lead-210	5/11/2010	0.838952	KYRAD	2010-51250	SO	0.375929	1.0877436		SOU195-025	pCi/g	=			
Gamma Spec	Lead-210	5/11/2010	0.774856	KYRAD	2010-51251	SO	0.352924	1.0153096		SOU195-025	pCi/g	=			
Gamma Spec	Lead-210	5/11/2010	0.622129	KYRAD	2010-51252	SO	0.323104	2.7034682		SOU195-120C	pCi/g	=			

DNT = Analytical methods was not transmitted.
Gamma Spec = Gamma Spec
KYRAD = Kentucky Radiation Health Branch Laboratory
SW = surface water
X = no 3rd party validation was performed
U = not detected above the MDA
R = result rejected
“=” = result accepted by 3rd party validation

Lead-210 is the daughter of polonium-214 that is a member of the uranium-238 decay chain. Lead-210 is reported at background levels of 1-2 pCi/g in at least one facility (http://www.lrb.usace.army.mil/Portals/45/docs/FUSRAP/DaytonIII/day3-si-2004-12.pdf, Table 2). Please see Tables E.4 and E.5 for the Kentucky Radiation Health Branch (RHB) lead-210 analysis. Only data with a sample specific minimum detectable concentration (MDC) of less than 1 pCi/g were included in the analysis. Based on the data provided by the RHB for lead-210, the background would be in the 1-2 pCi/g range for lead-210 at PGDP.

The no action levels [i.e., 1E-6 values calculated using Risk Assessment Information System (RAIS) and Paducah-specific parameters] are as follows:

- Resident—0.661 pCi/g,
- Industrial worker—7.62 pCi/g, and
- Outdoor worker—1.08 pCi/g.

Based on information provided by TestAmerica to LATA Environmental Services of Kentucky, LLC, the MDC obtained by liquid scintillation (LS) is approximately 5 pCi/g. TestAmerica indicates this is the target MDC by LS; however, this MDC can be lower, if necessary. TestAmerica's target MDC by gamma spectroscopy is the same, 5 pCi/g, but it could vary. TestAmerica indicates that "Lead-210 is a low energy radionuclide on the gamma spec and there could be interferences from other radionuclides and samples with sufficient activity. This could raise the MDA."

Soil analysis by the Kentucky RHB using gamma spectroscopy and a thin window high purity germanium (HPGe) detector, however, achieved an MDC of approximately 1 pCi/g for lead-210 (employing the 46 KeV line for lead-210). Using gamma spectroscopy with the appropriate thin window HPGe detector an MDC of 1 pCi/g is achievable without interference from other radionuclides. In fact, lead-210 is used in calibration standards for thin window HPGe detectors. Gamma spectroscopy, using these thin window HPGe detectors and incorporation of lead-210 into the calibration standard, provides a significant improvement in efficiency in the region less than 59 KeV. Because the analysis of lead-210 by gamma spectroscopy uses the 46 KeV line energy, thin window HPGe detectors are the preferred detectors for analysis of lead-210 by gamma spectroscopy. Achieving a 1 pCi/g MDC for soil analysis is fully supported by the Kentucky RHB data for lead-210 analysis. Because there is no requirement for sample dissolution and separation from other radionuclides, gamma spectroscopy using a thin window HPGe detector would be the preferred method for analysis of lead-210 in soil.

Because analysis of lead-210 by LS requires dissolution of the media in this case soil, it would be preferable to use gamma spectroscopy in order to eliminate concerns regarding complete dissolution of the sample.

With the equipment used by the United States Enrichment Corporation (USEC) laboratory, gamma spectroscopy analysis for lead-210 was not possible because the two primary energy lines are below the analytical laboratory normal energy calibration range. It would require the purchase of a new calibration mixture to include the Pb-210 lines at 46 KeV. The analytical laboratory only has one manual detector that can measure in the x-ray region, so output would be limited.

Lead-210 was included as part of the standard gamma scan for radiological analysis by TestAmerica during the Soils OU project. The MDC for lead-210 was approximately 30 pCi/g. This MDC is protective of a worker at a risk of 1E-5.

The ingrowth of lead-210 from uranium-238 is blocked at uranium-234. Due to the long ingrowth period from uranium-234 to lead-210, it is unlikely that, at the present time, ingrowth of lead-210 from the uranium used in the uranium enrichment processes at PGDP contributes to presence of lead-210 as a potential contaminant/risk at PGDP.

Independent analysis of lead-210 is not necessary on a routine basis. The need for the analysis of radionuclides, such as lead-210, not related to natural uranium and recycled uranium enrichment by the gaseous diffusion process at PGDP should be assessed on project by project basis.

[1] EPA 2012. *Lead-210*, accessed from http://www.epa.gov/radiation/glossary/termjklm.html in 2012.

USGS 2012. *^{210}Pb (lead 210) Dating*, accessed from http://gec.cr.usgs.gov/archive/lacs/lead.htm in 2012.

E.7. PAH CONTAMINATION AND ESTABLISHMENT OF REMEDIAL GOALS

E.7.1. IDENTIFICATION OF THE PROBLEM

Due to the nature of polycyclic aromatic hydrocarbons (PAHs), as described in the Toxicological Profile for PAHs,[1] the presence of PAHs in PGDP in some soils and sediments (e.g., along roads, including roadside ditches, and around buildings) may not be directly related to PGDP releases, but rather from other on- or off-site site activities, including airborne deposition of PAHs that result from the incomplete burning of oil, gas, wood, garbage, or other organic substances or deposition due to the use of rubber, asphalt, crude oil, coal tar, creosote, and roofing tar. The most common source of PAHs in the environment currently is deposition of automobile exhaust.[2] Thus, in evaluating risk/hazard at PGDP SWMUs/areas of concern under the FFA, there is a potential for PAHs not associated with PGDP releases to be identified as a risk driver, potentially leading to the development of disagreements on appropriate cleanup decisions.[3]

The on-site Surface Water Operable Unit (SWOU) contaminated sediment project provides an example of the aforementioned problems. As discussed in the SWOU (on-site) contaminated sediment Engineering Evaluation/Cost Analysis (EE/CA), [9] PAHs were determined not to be good candidates to verify cleanup because PAHs were detected above cleanup criteria at random locations due to their sources. To address PAH contamination in on-site sediments, other contaminants of concern (COCs) found to be co-located with PAHs [i.e., polychlorinated biphenyls (PCBs) and uranium] were used to verify cleanup.

E.7.2. DISCUSSION

Varying approaches have been used to address the presence of PAHs as risk drivers by DOE. At the Oak Ridge Reservation, an early document proposed that DOE manage PAHs as if they were wholly associated with background;[4] however, currently at the Oak Ridge Reservation, PAHs are being addressed on a case-by-case basis and anthropogenic sources are considered. At the Portsmouth Gaseous Diffusion Plant,[2] DOE proposed remediation of PAHs in areas where (1) the source has been determined to be contributed to by past plant operations or treatment, storage, and disposal activities; and (2) concentrations are sufficiently high that the acceptable risk range of 1E-4 to 1E-6 is exceeded.[5]

Commonwealth of Kentucky guidance indicates that parking lots, paved areas, areas within 3 ft of a roadway, railroad tracks, railway areas, storm drains, or ditches presently or historically receiving industrial or urban runoff should not be sampled when determining background, in part due to the potential for PAHs to be present in these areas.[3,6] Kentucky Revised Statutes exclude emissions from the engine exhaust of a motor vehicle from the definition of a release;[7] therefore, remediation of the widespread low concentrations of PAHs, when linked to such sources (e.g., automobile exhaust and asphalt), should not be considered.

As part of the baseline human health risk assessment (BHHRA) process at PGDP, the potential risks posed by PAHs are included in the quantitative BHHRA. In evaluating methods to address unacceptable risk/hazard, the nature of the PAHs and the potential non-PGDP sources will be considered as uncertainties when identifying risk drivers requiring action and when analyzing alternatives to manage site risk. This evaluation will include consideration of the following:

- PAHs are a group of chemicals formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances. PAHs are constituents of rubber, asphalt, coal, crude oil, coal tar, creosote, and roofing tar.

- PAH media concentrations in some areas (e.g., along roads and in roadside ditches) may increase over time in the absence of identifiable releases from PGDP processes.

- PAHs currently in the environment will degrade over time; however, the rate of degradation is unknown and depends upon the site conditions, including the medium in which PAHs are present and the location of the environmental medium.

Of the PAH chemicals considered to be carcinogenic, benzo(a)pyrene is believed to be the most potent. In a database search at PGDP in October 2017, there were 563 detected benzo(a)pyrene results, out of 5,224 analyzed environmental soil and sediment samples. Table E.6 summarizes these benzo(a)pyrene results and indicates that the highest concentrations of the PAH are in surface soils.

Table E.6. Maximum Benzo(a)pyrene Concentrations by Sample Depth

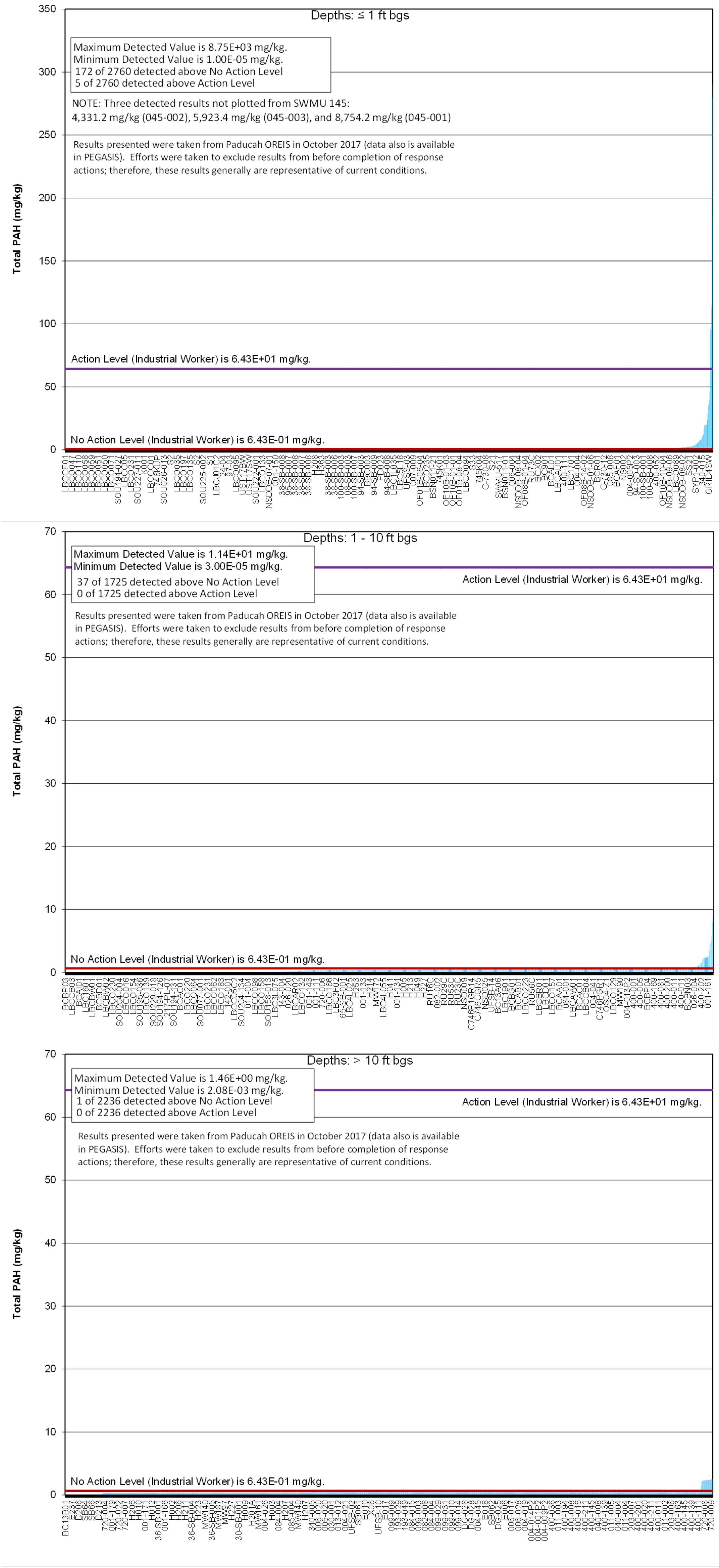
Sample Depth (ft)	Maximum Benzo(a)pyrene Concentration (mg/kg)
0-1	6,100
2-4	3.9
4-8	8.6
8-12	0.95
>12	0.98

Toxicity equivalence factors (TEFs) are used to calculate Total PAHs.[8] The method to calculate Total PAHs using TEFs is described in Section 3.3.3.2 (Step 8) of the Paducah Risk Methods Document. As described there, detected concentrations of each carcinogenic PAH in each sample are multiplied by the carcinogenic PAH's TEF. Also, for carcinogenic PAHs not detected in a sample, the minimum detection limit for the PAH is multiplied by the carcinogenic PAH's TEF. The products for detected and non-detected PAHs are then summed to derive Total PAHs. The carcinogenic PAHs considered in these calculations are benzo(a)pyrene; benz(a)anthracene; benzo(b)fluoranthene; benzo(k)fluoranthene; chrysene; dibenz(a,h)anthracene; and indeno(1,2,3-cd)pyrene.

Table E.7 summarizes the maximum concentrations of Total PAHs detected in surface (0–1 ft), subsurface (1–10 ft), and deep subsurface soils (> 10 ft) at PGDP (as defined by the Paducah Risk Methods Document).[8] Figure E.9 summarizes the range of concentrations of Total PAHs detected in soil at the PGDP as found in PEGASIS. This figure provides a comparison to the no action level (ELCR = 1E-06) and action level (ELCR = 1E-04) for the industrial worker. These values are 0.643 mg/kg and 64.3 mg/kg, respectively. Figures E.10 through E.12 illustrate the location of these Total PAHs by depth.

Table E.7. Maximum Total PAHs by Depth

Sample Depth (ft)	Maximum Total PAH Concentration (mg/kg)
Surface (0–1)	8,750
Subsurface (1–10)	11.4
Deep Subsurface (> 10)	1.46



Maximum Detected Value is 8.75E+03 mg/kg.
Minimum Detected Value is 1.00E-05 mg/kg.
172 of 2760 detected above No Action Level
5 of 2760 detected above Action Level

NOTE: Three detected results not plotted from SWMU 145:
4,331.2 mg/kg (045-002), 5,923.4 mg/kg (045-003), and 8,754.2 mg/kg (045-001)

Results presented were taken from Paducah OREIS in October 2017 (data also is available in PEGASIS). Efforts were taken to exclude results from before completion of response actions; therefore, these results generally are representative of current conditions.

Maximum Detected Value is 1.14E+01 mg/kg.
Minimum Detected Value is 3.00E-05 mg/kg.
37 of 1725 detected above No Action Level
0 of 1725 detected above Action Level

Results presented were taken from Paducah OREIS in October 2017 (data also is available in PEGASIS). Efforts were taken to exclude results from before completion of response actions; therefore, these results generally are representative of current conditions.

Maximum Detected Value is 1.46E+00 mg/kg.
Minimum Detected Value is 2.08E-03 mg/kg.
1 of 2236 detected above No Action Level
0 of 2236 detected above Action Level

Results presented were taken from Paducah OREIS in October 2017 (data also is available in PEGASIS). Efforts were taken to exclude results from before completion of response actions; therefore, these results generally are representative of current conditions.

Figure E.9. Total PAH Concentrations by Depth

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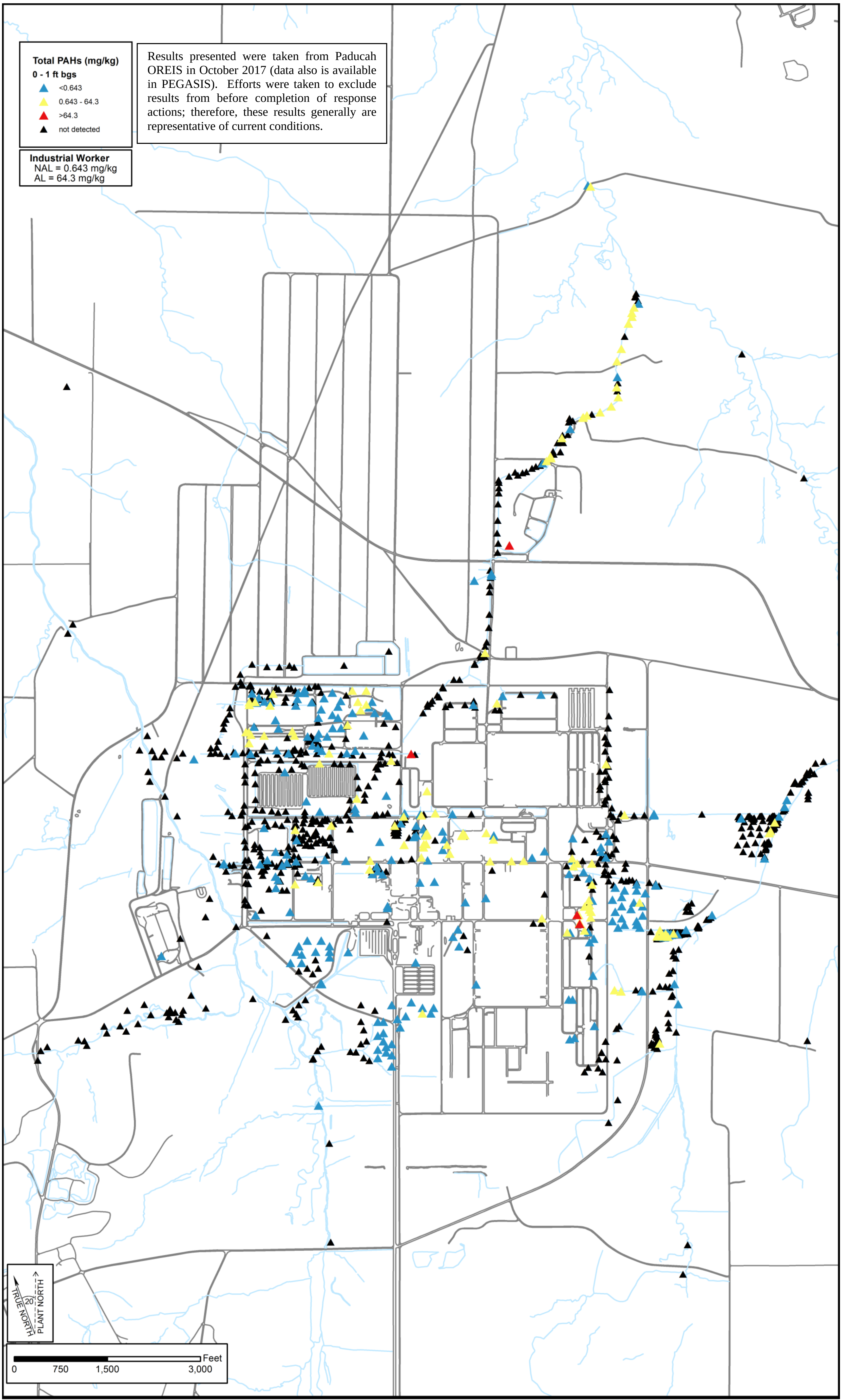
Results presented were taken from Paducah OREIS in October 2017 (data also is available in PEGASIS). Efforts were taken to exclude results from before completion of response actions; therefore, these results generally are representative of current conditions.

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10/10/2017

Figure E.10. Total PAH in Surface (0-1 ft bgs) Soil/Sediment Samples

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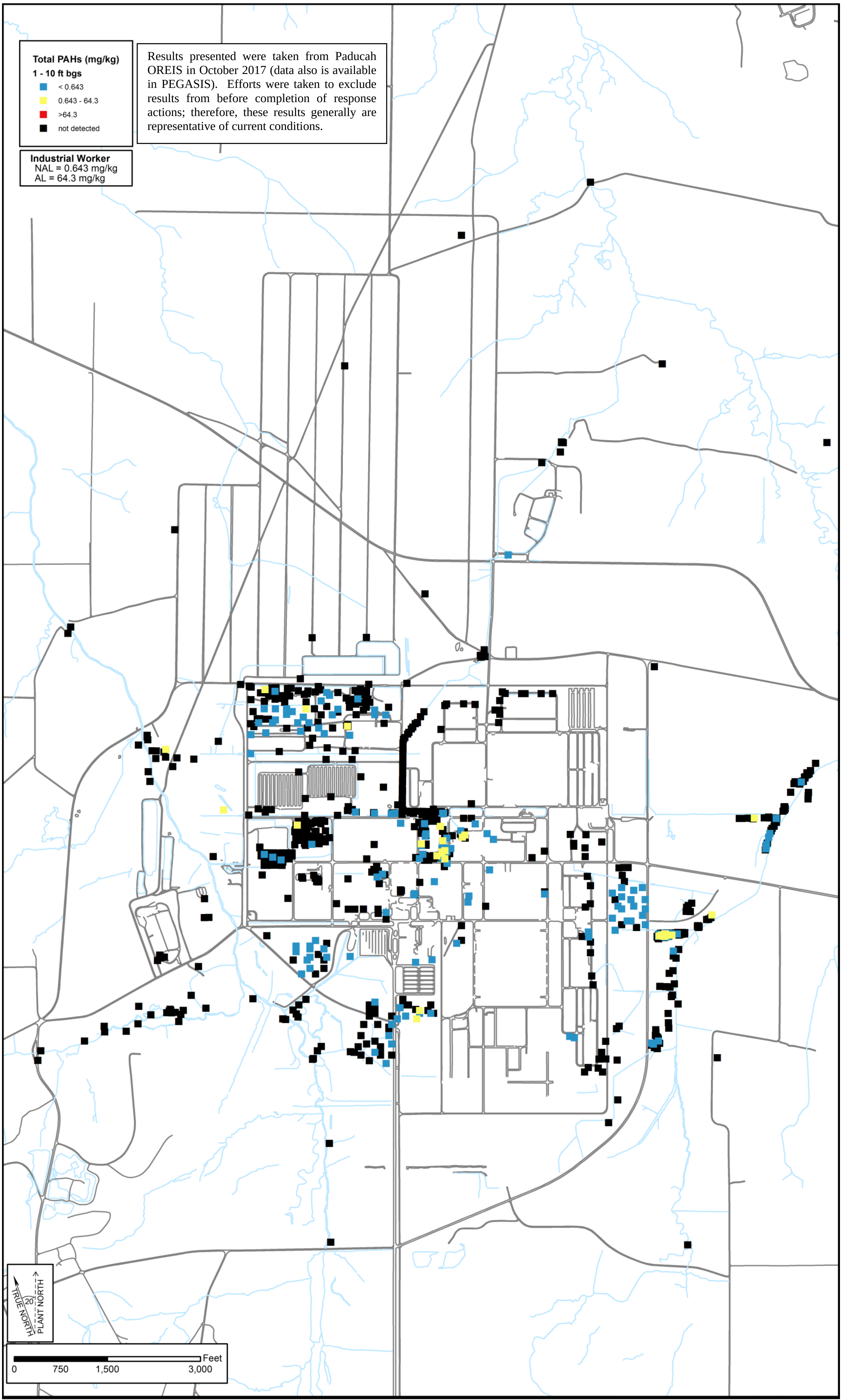

Results presented were taken from Paducah OREIS in October 2017 (data also is available in PEGASIS). Efforts were taken to exclude results from before completion of response actions; therefore, these results generally are representative of current conditions.

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10/10/2017

Figure E.11. Total PAH Subsurface (1-10 ft bgs) Soil/Sediment Samples

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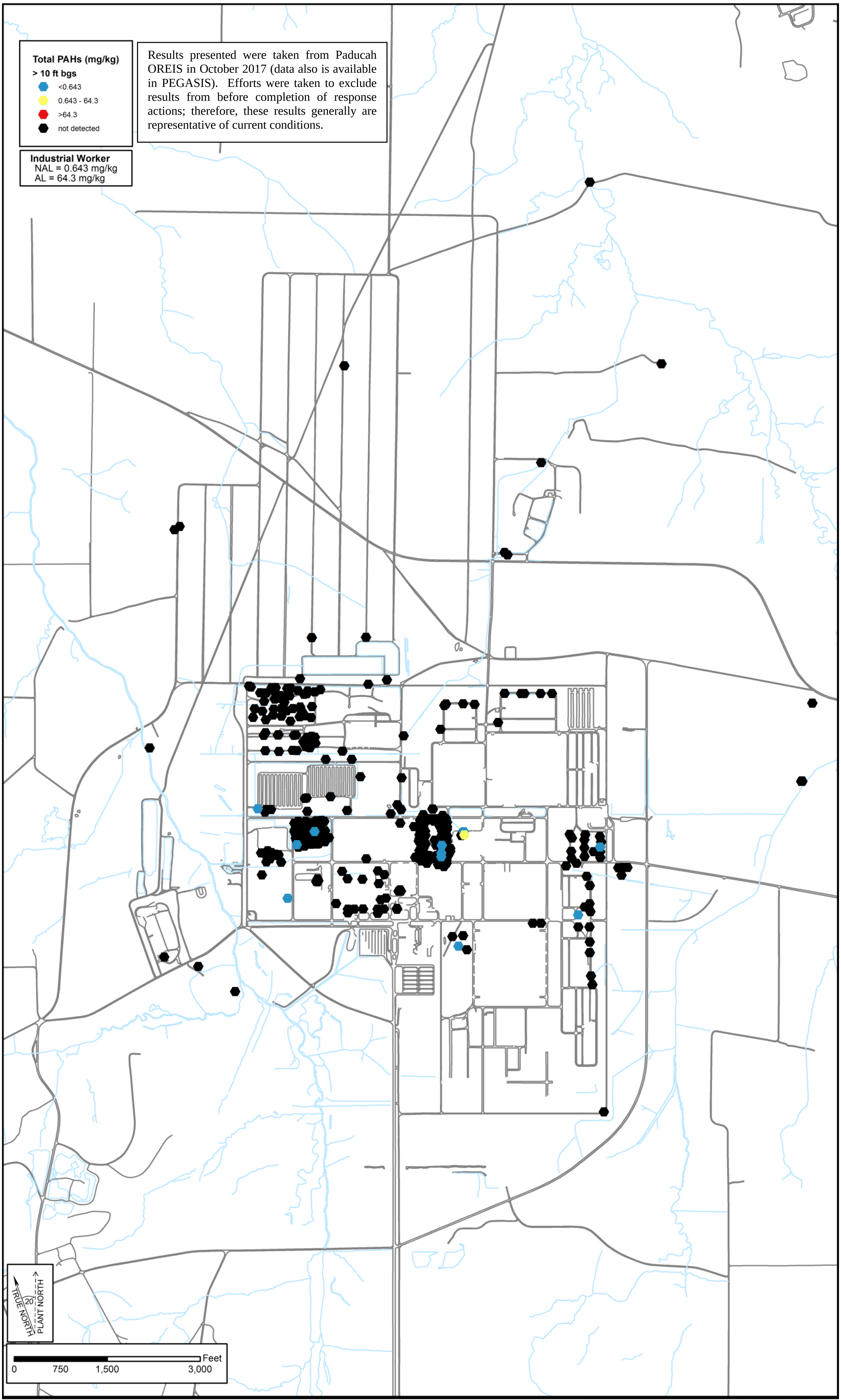

Results presented were taken from Paducah OREIS in October 2017 (data also is available in PEGASIS). Efforts were taken to exclude results from before completion of response actions; therefore, these results generally are representative of current conditions.

Figure E.12. Total PAH Deep Subsurface (>10 ft bgs) Soil/Sediment Samples

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The Observations section of BHHRAs address uncertainties associated with the presence of PAHs, and the feasibility study (FS) includes discussions ensuring that remedial actions appropriately address the uncertainties associated with the presence of residual concentrations of PAHs.

E.7.3. SUMMARY

In evaluating risk/hazard at PGDP, the need to sample for PAHs and the evaluations of PAH sampling results will be determined on a case-by-case basis to incorporate uncertainties concerning the presence of PAHs into the risk management process. This will include ***quantitative*** evaluation of the risk/hazard presented by PAHs in the BHHRA when PAHs are sampled for, consistent with the Paducah Risk Methods Document.[8] Subsequently, the BHHRA will discuss the uncertainties associated with the presence of PAHs, and these uncertainties will be combined with risk characterization in the Observations section. The FS will manage these uncertainties and incorporate regulatory requirements to ensure that potential exposure to residual PAHs in environmental media is addressed appropriately.

[1] Agency for Toxic Substances and Disease Registry [ATSDR 1995] (see http://www.atsdr.cdc.gov/toxprofiles/tp69.pdf).

[2] *Risk Management Considerations for Polycyclic Aromatic Hydrocarbon Contamination at the Portsmouth Gaseous Diffusion Plant,* POEF-ER-4616&D1, January 27, 1995.

[3] E-mail correspondence among FFA parties.

[4] *Final Report on the Background Soil Characterization Project at the Oak Ridge Reservation, Oak Ridge, Tennessee; Volume 1, Results of Field Sampling Program,* DOE/OR/01-1175/V1, October 1993.

[5] "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (OSWER Directive 9355.0-30) April 22, 1991.

[6] Kentucky Guidance for Ambient Background Assessment, January 8, 2004, Natural Resources and Environmental Protection Cabinet.

[7] Kentucky Revised Statute 224.01-400 (1) (b).

[8] Draft *Risk Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0107&D2/R9, December 2017.

[9] *Engineering Evaluation/Cost Analysis for Contaminated Sediment Associated with the Surface Water Operable Unit (On-Site) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0012&D2, August 2008.

E.8. SITE-SPECIFIC SOIL SCREENING LEVELS AND SITE-SPECIFIC DILUTION ATTENUATION FACTORS AT THE PADUCAH GASEOUS DIFFUSION PLANT

E.8.1. IDENTIFICATION OF THE PROBLEM

U.S. Environmental Protection Agency (EPA) provides guidance for calculating risk-based, site-specific, soil screening levels (SSLs) for contaminants in soil that may be used to identify areas needing further investigation at National Priorities List sites (EPA 1996a; EPA 1996b; EPA 2002). SSLs are risk-based concentrations derived from equations combining exposure information assumptions with EPA toxicity data. SSLs may be developed for the direct exposure pathways (e.g., incidental ingestion, dermal contact, particulate inhalation, and inhalation of volatiles) based on excess lifetime cancer risk for carcinogens or on hazard quotients for noncarcinogens; or. SSLs may be developed for the indirect exposure pathway of soil to groundwater migration and subsequent ingestion of contaminated groundwater. This paper looks only at these SSLs for soil to groundwater migration.

Contaminant concentrations are attenuated by adsorption and degradation as soil leachate moves through soil and groundwater. In the aquifer, dilution by groundwater further reduces concentrations before contaminants reach receptor points (i.e., drinking water wells). This reduction through dilution in concentration can be expressed as a dilution attenuation factor (DAF), defined as the ratio of soil leachate concentration to receptor point concentration. A DAF of 1 corresponds to a situation where there is no dilution or attenuation of a contaminant (i.e., when the concentration in the receptor well is equal to the soil leachate concentration). On the other hand, higher DAF values correspond to a large reduction in contaminant concentration from the contaminated soil to the receptor well (EPA 1996a).

In order to facilitate agreement with respect to use of SSLs and DAFs at Paducah Gaseous Diffusion Plant (PGDP), the Federal Facility Agreement (FFA) Managers decided that the Groundwater Modeling Working Group (MWG) would develop a white paper for inclusion in the Risk Methods Document to provide guidance on development of site-specific SSLs and site-specific DAFs to be implemented when scoping projects.

E.8.2. BACKGROUND

E.8.2.1 HYDROGEOLOGY OF THE PADUCAH SITE

PGDP is located in the Jackson Purchase region of western Kentucky, approximately 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River. Buried Pleistocene fluvial deposits of the ancestral Tennessee River unconformably overlie Cretaceous marine sediments at a depth of approximately 100 ft directly beneath and north of the Paducah Site. The bottom Pleistocene fluvial deposits consist of a gravel unit that ranges in thickness from 30 ft to 50 ft, with the top of the unit encountered at a general depth of 60 ft below ground surface (bgs) at the Site. This gravel unit is the primary member of the uppermost aquifer beneath the Paducah Site and north to the Ohio River—the Regional Gravel Aquifer (RGA). The RGA is the main conduit for groundwater flow to the north, where groundwater discharges to the Ohio River, and the main pathway for off-site contaminant plume migration. A thick sequence of silts and fine sands, comprising the Upper Continental Recharge System (UCRS), overlies the RGA.

E.8.2.2 USE OF SSLS AND DAF AT THE PADUCAH SITE

The maximum UCRS soil concentrations that are protective of RGA groundwater quality, SSLs, are determined by combining the DAF (unitless) calculations with contaminant-specific distribution coefficients (K_d) (units of volume/mass).

RGA groundwater flows are much higher relative to UCRS groundwater flows; thus, mixing the two waters will result in much lower RGA groundwater contaminant concentrations relative to the initial UCRS groundwater contaminant concentrations. The reduction in groundwater concentrations in the RGA is proportional to the ratio of the volume of RGA groundwater to contaminated UCRS groundwater. The DAF calculates the impact on the concentration from the relative rates of vertical migration of contaminated UCRS water and horizontal migration of RGA groundwater to yield a concentration of the blended water.

To complete the evaluation, the K_d of the constituent must be factored into the analysis. K_d represents the ratio of contamination adhered to soil particles (the source zone) relative to that dissolved in groundwater (as the soil leachate).

Starting with a target-acceptable RGA groundwater contaminant concentration [i.e., maximum contaminant levels (MCLs) or site-specific risk based concentrations, etc.] and assuming that the receptor point concentration is below the source area in the RGA, the maximum acceptable UCRS groundwater contaminant concentration can be calculated using a DAF value. When this result is combined with the applicable K_d for the UCRS and for the contaminant, this calculation will yield the SSL, the maximum-acceptable UCRS soil contaminant concentration that is protective of RGA groundwater quality at the target concentration.

E.8.3. HISTORICAL USE OF SSLS AT THE PADUCAH GASEOUS DIFFUSION PLANT

E.8.3.1 EARLY PROJECTS

Prior to the use of site-specific soil-to-groundwater SSLs, projects used background and risk-based screening levels from the site Risk Methods Document. The following are example projects.

- SWMU 2 Data Summary Interpretation Report (DOE 1997)
- WAG 6 Remedial Investigation (RI) (DOE 1998a)
- WAG 27 RI (DOE 1999a)

Other site RIs screened media analyses against EPA-derived SSLs using a DAF of 20. The following projects used this approach.

- WAGs 9 & 11 Site Evaluation (DOE 1999b)
- WAG 28 RI (DOE 2000a)
- WAG 3 RI (DOE 2000b)

The SWMUs 7 and 30 RI used EPA SSLs at a DAF of 1 to screen chemicals or radionuclides of potential concern (COPCs) prior to fate and transport modeling using Seasonal Soil Model (SESOIL) (DOE 1998b). The Southwest Plume Site Investigation (SI) Report provided SSLs at DAFs of 1 and 20 for volatile organic compounds (DOE 2007).

E.8.3.2 SOUTHWEST PLUME FFS

Following the Southwest Plume SI Report, the Southwest Plume Focused Feasibility Study (FFS) (DOE 2011) used deterministic modeling [SESOIL/Analytical Transient 1-, 2-, 3-Dimensional Simulation of Waste Transport in the Aquifer System (AT123D)] and site-specific values of attenuation and migration factors to evaluate remediation goals for protection of groundwater for trichloroethene (TCE) and its breakdown products for the Oil Landfarm (SWMU 1) and the C-720 area.

The Southwest Plume FFS calculated a DAF of 59. Cleanup goals of 0.073 and 0.075 mg/kg for TCE at SWMU 1 and C-720, respectively, were calculated (using an MCL of 5 μg/L as a target-acceptable RGA groundwater contaminant concentration). Site-specific values used in the calculations are shown in Tables C.9 and C.10 of the FFS (DOE 2011).

E.8.3.3 SOILS OU RI

Based on expected minimum and maximum RGA hydraulic conductivity (K) (0.03 to 1.09 cm/s), RGA gradient (i) (1.84E-04 to 2.98E-03 m/m), and UCRS infiltration (I) (0.0679 to 0.1964 m/yr) values, DAF values for the Soils Operable Unit (OU) ranged between 5 and 139 (DOE 2013). The parameter distributions, with the exception of I, were developed for probabilistic evaluation of soil cleanup remediation goals for SWMU 1 and the C-720 Building (DOE 2007; DOE 2011). For the soil remediation goal probabilistic evaluation, I was held constant. For this probabilistic evaluation, I was assumed to range linearly between 2.64 inches/yr and 7.64 inches/yr (0.067 m/yr and 0.194 m/yr) (DOE 2013).

Limiting the maximum hydraulic conductivity value to 1,500 ft/d, to reflect the expected lower hydraulic conductivity values found beneath the PGDP, the maximum DAF was calculated at 68. To develop a better understanding of the potential DAF distribution, a probabilistic evaluation was performed. The evaluation predicted mean, median, minimum, and maximum DAF values of 52, 33, 3, and 366, respectively. Evaluation of the probabilistic DAF distribution (Figure E.13) shows that lower DAF values occur more frequently than higher DAF values with the most frequently occurring DAF being between 11 and 20.

DAF values for the Soils OU ranged between 5 and 139 (DOE 2013).

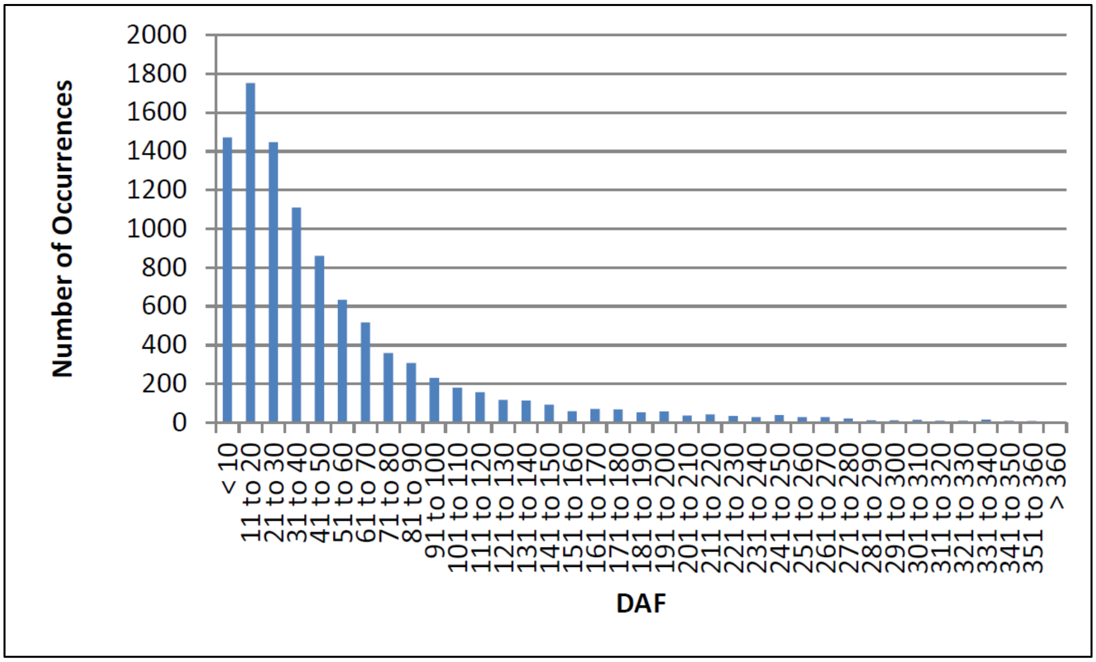

Figure E.13. Probabilistic DAF Distribution

Deterministic evaluation of typical PGDP site conditions predicted a DAF of 58 for the Soils OU RI. Minimum and maximum deterministic predicted DAF values were 5 and 139, respectively. The DAF of 58 derived with the expected values for hydraulic parameters was used to support screening of the Soils OU results to identify those SWMUs/AOCs where constituents might present an impact to groundwater.

E.8.4. DISCUSSION

E.8.4.1 RISK METHODS DOCUMENT MODELING MATRIX

Based on guidance presented in Section 3.3.4.3 "Quantification of Exposure" of the Risk Methods Document (DOE 2017a), to determine if fate and transport modeling is needed, the maximum soil concentrations (or activities for radionuclides) at the source (over all depths) for each analyte are compared to the appropriate groundwater protection preliminary remediation goal (PRG). If the maximum soil concentration exceeds the groundwater protection PRG, then future concentrations in groundwater will be modeled. Models to be used to determine future concentrations and activities at the source and in groundwater will be based on the modeling matrix presented in Table E.8 (from Table 1 DOE 2017a). Tier 1 values are existing sets of screening levels used for the initial screening of a site. Tier 2 values also are used for scoping, but account for more specific estimates of model parameters than the default Tier 1 values. Tiers 3 and 4 values are derived by models used primarily with site–specific values for site decision making.

Table E.8. Modeling Matrix for Groundwater

	Values for Soil to Protect Groundwater	Model	Point of Exposure	Notes
INVESTIGATION DOCUMENTS	Tier 1 (Used for scoping)	SSLs and/or RESidual RADioactivity (RESRAD) Vapor intrusion model	At source unit At source unit	Value to be used for initial scoping, use DAF of 1 for SSLs, unless site-specific values are available. Groundwater protection value based on residential use and targets of 1E-6, 0.1, and 1 for risk, hazard, and radiological dose, respectively. If site-specific DAF values are used, then need to justify these values. The depth of water needs to be considered in the calculation. Initial vapor intrusion model will use default values.
	Tier 2 (Used for scoping)	SESOIL and/or RESRAD	At source unit	Includes source delimitation. Recognize SESOIL limitations when modeling inorganic COPCs—refine K_ds.
DECISION DOCUMENTS	Tier 3 (Enhanced modeling used in decision documents if needed)	SESOIL and RESRAD suite of codes (including RESRAD-OFFSITE) with AT123D	At source unit and at downgradient points (Industrialized area, DOE property boundary, creek, river)	Uses source delimitation and refined K_ds from above. Use values from this effort to set initial cleanup levels. On the Terrace (southern portion of PGDP), different points of exposure will apply.
	Tier 4 (Enhanced modeling used in decision and design documents if needed)	Source modeling and three-dimensional finite-difference groundwater model (MODFLOW/MT3D/ RT3D)	At source unit and at downgradient points appropriate to the selected remedy	To be used to refine cleanup levels (if needed). May be especially important to set monitoring goals. On the Terrace (southern portion of PGDP), different points of exposure will apply.

(Table from DOE 2017a)

E.8.4.2 METHODOLOGY FOR DEVELOPMENT OF TIER 1 SSLS FOR GROUNDWATER PROTECTION

SSLs[1] will be calculated using EPA guidance (i.e., EPA 1996a; EPA 1996b; EPA 2002). EPA guidance is appropriate for calculating SSLs corresponding to target leachate contaminant concentrations in the zone of contamination. Inputs to the calculations will use project-specific data, when available, to guide selection of values for variables of the SSL and DAF calculations, as appropriate. If necessary, additional data may be collected if determined during project scoping.

For nonradionuclides, soil to groundwater SSLs in the Risk Methods Document are calculated from the equation below. This methodology follows EPA guidance in EPA 1996b.

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

Where:

Variable	Explanation	Recommended Input
C_w	Target groundwater concentration (mg/L)	MCLs or resident/child resident no action level.
DAF	dilution attenuation factor (unitless)	See equation below.
K_d	soil-water partition coefficient (L/kg)	For inorganics: Chemical-specific (RAIS default, unless project-specific value is available). For organics: $K_d = K_{oc} \times f_{oc}$
K_{oc}	soil organic carbon-water partition coefficient (L/kg) K_{oc} is the determinant for each organic chemical's effective distribution coefficient	Chemical-specific (RAIS default, unless project-specific value is available). See also equation shown for K_d.
f_{oc}	fraction organic carbon in soil (unitless)	0.002 (RAIS default), unless project-specific value is available. (NOTE: Paducah-specific values range 0.0002 to 0.005. Most projects have location-specific values available.[a])
θ_w	water-filled soil porosity (Lwater/Lsoil)	0.3 (RAIS default), unless project-specific value is available. [NOTE: Paducah-specific values of total porosity are from the WAG 6 RI data set (DOE 1998a). Water filled soil porosity ranges between 0.37 for shallow water table settings and 0.30 for deep water table settings.[b]]
θ_a	air-filled soil porosity (Lair/Lsoil)	0.13[c] (EPA 1996b,), unless project-specific value is available. (NOTE: Paducah-specific values are 0.0 for shallow water table settings and 0.07 for deep water table settings.[d])
ρ_b	dry soil bulk density (kg/L)	1.5 (RAIS default), unless project-specific value is available. (NOTE: Paducah-specific value is 1.7.[e])
H'	dimensionless Henry's law constant	Chemical-specific (RAIS default).

[a] Fraction organic carbon in soil typically can be found on the Paducah Site's Environmental Geographic Analytical Spatial Information System as Total Organic Carbon (TOC).

[b] The water-filled soil porosity 0.37 value represents 100 % water saturation and the 0.30 value represents 80% water saturation.

[c] Although the default value for air-fill soil porosity is 0.13, much lower values are representative of the near-saturated, fine-grained soils of the Paducah Site.

[d] The air-filled soil porosity 0.0 value represents 100 % water saturation and the 0.07 value represents 80% water saturation.

[e] ρ_b = [1.00-0.37 (θ_{total})] x 2.65 kg/L (soil particle specific gravity)

---

[1] These SSLs are developed as Tier 1 values. Using more sophisticated modeling (e.g., SESOIL) to develop Tier 2 values also is consistent with EPA guidance.

For radionuclides, soil to groundwater SSLs are calculated from the equation below. This methodology also follows EPA guidance in EPA 1996b, since Henry's law constant is not applicable.

$$\mathrm{SSL} = \mathrm{C_w} \times \mathrm{DAF} \times \frac{\left(\mathrm{K_d} + \left(\frac{\theta_\mathrm{w}}{\rho_\mathrm{b}}\right)\right)}{1{,}000}$$

Where:

Variable	Explanation	Recommended Input
C_w	Target groundwater concentration (pCi/L)	MCLs or resident/child resident no action level.
DAF	dilution attenuation factor (unitless)	See equation below.
K_d	soil-water partition coefficient (L/kg)	Radionuclides: values are from DOE 2003 and DOE 2012.
θ_w	water-filled soil porosity (L/L)	0.3 (RAIS default), unless project-specific value is available. (NOTE: Paducah-specific value is 0.37.)
ρ_b	dry soil bulk density (kg/L)	1.5 (RAIS default), unless project-specific value is available. (NOTE: Paducah-specific value is 1.7.)

DAF calculation utilizes EPA guidance and the following equations (EPA 1996a).

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

Where:

Variable	Explanation	Recommended Input
i	horizontal hydraulic gradient (m/m)	Project-specific value.
d	mixing zone depth (m)	See equation below.
I	infiltration rate (m/yr)	Range of values taken from DOE 2017b.
L	length of source area parallel to groundwater flow (m)	Project-specific value (maximum distance across the source area in a direction parallel to RGA groundwater flow).
K	aquifer hydraulic conductivity (m/yr)	Project-specific value taken from within range of values in DOE 2017b.

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

$$\mathrm{d} = \left(0.0112\mathrm{L}^2\right)^{0.5} + \mathrm{d_a}\left\{1 - e^{\left[\frac{(\mathrm{-LI})}{(\mathrm{Kid_a})}\right]}\right\}$$

Where:

Variable	Explanation	Recommended Input
i	horizontal hydraulic gradient (m/m)	Project-specific value.
d_a	aquifer thickness (m)	Average of values for project-specific area taken from most recent KRCEE database.
I	infiltration rate (m/yr)	Range of values taken from DOE 2017b.
L	length of source area parallel to groundwater flow (m)	Project-specific value.
K	aquifer hydraulic conductivity (m/yr)	Project-specific value taken from within range of values in DOE 2017b.

An example comparison of site-specific and default inputs for key COPCs is shown in Table E.9.

Table E.9. Example Site-Specific and Default Inputs for Key COPCs

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

[a] SSL is based on MCL for the organics and resident NAL for the radionuclides.
[b] DOE 2011, for SWMU 1 area, using site-specific foc.
[c] DOE 2013.
[d] DOE 2003.
[e] DOE 2017a.
[f] RAIS 2017. https://rais.ornl.gov/, accessed November 27, using K_{oc} × foc where foc is 0.002.

E.8.5. SUMMARY

Site-specific SSLs and site-specific DAFs will be developed collaboratively during project scoping by the FFA parties. If adequate site-specific data (of known and sufficient quality and quantity) are not available to support these calculations, SSLs developed using DAFs of 1 and 20 will be used for screening, consistent with EPA guidance (EPA 1996a). For the purposes of this paper, it is the intent of the FFA parties that "site" is a project-level term and does not refer to larger areas of consideration such as the facility, the plant, the Superfund Site or site-wide.

The method to be used in developing site-specific SSLs and site-specific DAFs is presented in the attachment to this paper and will follow Section 4.2, "Methodology for Development of Tier 1 SSLs for Groundwater Protection."

E.8.6. REFERENCES

DOE 1997. *Data Summary Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/OR/07-1549&D1, February.

DOE 1998a. *Remedial Investigation Report for Waste Area Grouping 6 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/OR/07-1727&D2, May.

DOE 1998b. *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/OR/07-1604&D2, January.

DOE 1999a. *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/OR/07-1777&D2, June.

DOE 1999b. *WAGs 9 and 11 Site Evaluation Report at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/OR/07-l 785&D2, June.

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DOE 2000b. *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/OR/07-1895&D1, September .

DOE 2003. *Risk and Performance Evaluation of the C-746-U Landfill at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/OR/07-2041&D2/R1, September.

DOE 2007. *Southwest Plume Site Investigation Report at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/OR/07-2180&D2/R1, June.

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*, U.S. Department of Energy, Paducah, KY, DOE/LX/07-0362&D2, May.

DOE 2012. *Remedial Investigation/Feasibility Study Report for the CERCLA Waste Disposal Alternatives Evaluation at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, U.S. Department of Energy, Paducah, KY, DOE/LX/07-0244&D1, May.

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

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

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

EPA (U.S. Environmental Protection Agency) 1996a. *Soil Screening Guidance: User's Guide*. OSWER 9355.4-23, Office of Solid Waste and Emergency Response, July.

EPA 1996b. *Soil Screening Guidance: Technical Background Document*. EPA/540/R95/128, Office of Solid Waste and Emergency Response, May.

EPA 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*. OSWER 9355.4-24, Office of Solid Waste and Emergency Response, December.

ATTACHMENT

METHOD TO BE USED IN DEVELOPING SITE-SPECIFIC SSLS AND SITE-SPECIFIC DAFS

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SITE-SPECIFIC SSL AND SITE-SPECIFIC DAF

OBJECTIVE

The methodology will serve as a standard for determining site-specific soil screening levels (SSLs) for soil to groundwater migration and site-specific dilution attenuation factors (DAFs). While this guidance presents a standard method for determining site-specific SSLs and DAFs, deviations from this guidance are likely, and these deviations will be discussed on a case-by-case basis.

BASIS

In order to facilitate agreement with respect to use of SSLs and DAFs at the Paducah Site, the Federal Facility Agreement Managers decided that the Groundwater Modeling Working Group would develop a white paper for inclusion in the Risk Methods Document providing guidance on development of site-specific SSLs and site-specific DAFs to be implemented when scoping projects.

SITE-SPECIFIC SSL AND SITE-SPECIFIC DAF DEVELOPMENT GUIDANCE

This guidance applies to determining maximum Upper Continental Recharge System soil concentrations that are protective of Regional Gravel Aquifer groundwater quality, SSLs, by combining the DAF (unitless) calculations with contaminant-specific distribution coefficients (K_d) (units of volume/mass).

Requirements for this determination are inputs to the equations identified in Section 4.2, “Methodology for Development of Tier 1 SSLs for Groundwater Protection.” Each variable will be documented as to its source. An assessment of each of these variables for use as project-specific inputs will be included. These parameters will be agreed to by all parties during scoping. Derivation using the equations will be clearly documented.

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E.9. HUMAN HEALTH INFORMATION FOR THE PADUCAH VAPOR INTRUSION EVALUATION

Information provided in Table E.10 is taken from several sources. It should be noted that according to the Occupational Safety & Health Administration (OSHA) website (https://www.osha.gov/dsg/annotated-pels/, accessed in January 2022), "OSHA recognizes that many of its permissible exposure limits (PELs) are outdated and inadequate for ensuring protection of worker health. Most of OSHA's PELs were issued shortly after adoption of the Occupational Safety and Health (OSH) Act in 1970, and have not been updated since that time. Since 1970, OSHA promulgated … new PELs for 16 agents, and standards without PELs for 13 carcinogens. Industrial experience, new developments in technology, and scientific data clearly indicate that in many instances these adopted limits are [also] not sufficiently protective of worker health. This has been demonstrated by the reduction in allowable exposure limits recommended by many technical, professional, industrial, and government organizations, both inside and outside the United States."

Additionally, the following information has been provided in this section:

- Information provided by EPA Region 4 for cis-1,2-DCE and trans-1,2-DCE screening levels.

- Information provided by EPA Region 4 regarding the basis of their use of the Agency for Toxic Substances and Disease Registry intermediate minimal risk levels.

- Excerpt of Agency for Toxic Substances and Disease Registry minimal risk levels updated March 2016.

- Excerpt of information from the Region 4 Scientific Support Section Vapor Intrusion Screening Tool.

- Information provided by Kentucky Risk Assessment Branch to support a project discussion on June 20, 2017.

- Archived Provisional Peer Reviewed Toxicity Values for *trans*-1,2-Dichloroethylene (withdrawn by EPA).

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Table E.10. Vapor Intrusion Screening Levels (VISLs) for Analytes of Interest for PGDP—Commercial

Chemical	Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk via VI from Soil Source?	Is Chemical Sufficiently Volatile and Toxic to Pose Inhalation Risk via VI from Groundwater Sources?	Indoor Air VISL ($\mu g/m^3$) at TCR = 1E-06 or THQ = 1[a]	Toxicity Basis	Soil Gas VISL ($\mu g/m^3$) at TCR = 1E-06 or THQ = 1[a]	Target Groundwater Concentration ($\mu g/L$) at TCR = 1E-06 or THQ = 1[a]	Occupational Exposure Limits[b]		
							OSHA PEL/TWA ($\mu g/m^3$)	NIOSH REL/TWA ($\mu g/m^3$)	ACGIH TLV/TWA ($\mu g/m^3$)
	Cvp > Cia, target?	Chc > Cia, target?	Min (Cia, c; Cia, nc)	C or NC	Csg	Chc			
Chloroform	Yes	Yes	5.33E-01	C	1.78E+01	3.55E+00[c]	No PEL/TWA[d]	No REL/TWA[e]	4.88E+01
Dichloroethane, 1,1- (1,1-DCA)	Yes	Yes	7.67E+00	C	2.56E+02	3.34E+01	4.00E+05	4.00E+05	4.00E+05
Dichloroethylene, 1-1- (1,2-DCE)	Yes	Yes	8.76E+02	NC	2.92E+04	8.21E+02	No PEL/TWA	No PEL/TWA	2.00E+04
Dichloroethylene, 1,2-cis- (cis-1,2-DCE)	No Inhalation Toxicological Information	No Inhalation Toxicological Information	NVA[f],[g], 3.50E+03	NC	N/A	N/A	7.93E+05	7.93E+05	7.93E+05
Dichloroethylene, 1,2-trans- (trans-1,2-DCE)	Yes	Yes	NVA[g], 3.50E+03	NC	N/A	N/A			
Mercury (elemental)[h]	Yes	Yes	1.31E+00	NC	4.38E+01	3.73E+00	1.00E+02	5.00E+01	2.5E+01
Trichloroethane, 1,1,1- (1,1,1-TCA)[i]	Yes	Yes	2.19E+04	NC	7.30E+05	3.11E+04	1.91E+06	No REL/TWA[j]	1.91E+06
Trichloroethylene (TCE)	Yes	Yes	2.99E+00	C	9.97E+01	7.43E+00	5.37E+05	1.34E+05[k]	5.37E+04
Vinyl Chloride (VC)	Yes	Yes	2.79E+00	C	9.29E+01	2.45E+00	2.56E+03	No REL/TWA	2.56E+03

ACGIH = American Conference of Governmental Industrial Hygienists
C = carcinogenic
Cia = concentration, indoor air
Chc = concentration, groundwater vapor
Csg = concentration, subslab and exterior soil gas concentration
Cvp = concentration, pure phase vapor
$\mu g/m^3$ = micrograms per cubic meter

Table E.10. Vapor Intrusion Screening Levels (VISLs) for Analytes of Interest for PGDP—Commercial (Continued)

N/A = no value available
NC = noncarcinogenic
NIOSH = National Institute for Occupational Safety and Health
NVA = no VISL value available
REL = recommended exposure limit
STEL = short-term exposure limit
TCR = target risk for carcinogens
THQ = target hazard quotient for noncarcinogens
TWA = time-weighted average
VI = vapor intrusion
VISL = vapor intrusion screening level

[a] The agreed upon VISLs in the Paducah Gaseous Diffusion Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report (DOE/LX/07-2471&D2) were calculated at a hazard quotient of 1 because this was a preliminary assessment and was not intended to be used for human health risk assessment. Projects should consider using reporting limits targeted to meet the hazard quotient of 0.1 to ensure usability for future risk assessment.

[b] Occupational exposure limits obtained from the OSHA Occupational Chemical Database (https://www.osha.gov/chemicaldata), accessed February 7, 2022. Values provided in units of parts per million were converted to units of µg/m^3 using the NIOSH online conversion calculator (https://wwwn.cdc.gov/niosh-oeb/resource/calculator), accessed February 7, 2022; based on 25°C and 1 atmosphere, and using molecular weight obtained from the OSHA Occupational Chemical Database.

[c] The maximum contaminant level (MCL) for total trihalomethanes in drinking water, of which, chloroform is a key component, is 80 µg/L.

[d] There is no OSHA PEL/TWA for chloroform; a ceiling peak PEL of 240,000 µg/m^3 has been established.

[e] There is no NIOSH REL/TWA for chloroform; a 60-minute STEL of 9,780 µg/m^3 has been established.

[f] The reference concentration for *trans*-1,2-DCE, was used as a surrogate to calculate the screening levels for *cis*-1,2,-DCE.

[g] Provisional value provided by EPA, as documented in Section E.9, because VISL value is not available.

[h] For an analyte to be considered a contaminant of potential concern for VI, the analyte must be toxic and sufficiently volatile to migrate from a subsurface source into a building at a concentration greater than its indoor air screening level. Elemental mercury is toxic and can be sufficiently volatile to exist in vapors at levels potentially harmful to human receptors; therefore, mercury must be present in subsurface media in elemental form to pose a VI risk. The majority of mercury, which is a common industrial contaminant and by-product of coal combustion, detected in groundwater or soils at PGDP is expected to be in the form of salts—not elemental mercury. Mercury has not been detected in site monitoring wells at concentrations greater than its groundwater VISL; therefore, mercury is not expected to be present in vapor form above trace concentrations. Indoor air in each building identified for VI sampling, however, was screened for mercury using a field meter as a protective measure based on its widespread detection in site soil.

[i] 1,1,1-TCA was included to be considered only when there is documented use within a facility.

[j] There is no NIOSH REL/TWA for 1,1,1-TCA; a 15-minute STEL of 1.90E+06 µg/m^3 has been established.

[k] Recommendation listed in *NIOSH Pocket Guide to Chemical Hazards*, Appendix C, Supplementary Exposure Limits, (https://www.cdc.gov/niosh/npg/nengapdxc.html), accessed February 2022.

Note:

The VISL values are taken from the VISL calculator (results generated, April 5, 2022, https://epa-visl.ornl.gov/cgi-bin/visl_search) derived for a commercial exposure scenario at a target excess cancer risk of 1.0E-06 and a target hazard quotient of 1.0. Per the VISL calculator, the commercial exposure scenario has a 70-year averaging time for carcinogens, a 25-year averaging time for noncarcinogens, an exposure duration of 25 years, an exposure frequency of 250 days/year, and an exposure time of 8 hours/day.

-----Original Message-----
From: Koporec, Kevin
Sent: Thursday, June 15, 2017 10:04 AM
To: Bentkowski, Ben <Bentkowski.Ben@epa.gov>
Subject: VI/air screening levels

Here is the table of screening values Ben.
In case you want the DCE values handy before you can open the table, here's the SLs (ug/m3).

1,2-Dichloroethylene (both isomers):
residential indoor air SL = 800; subsurface soil vapor SL = 27,000.
Industrial indoor air SL = 3500; subsurface soil vapor SL = 120,000.

From: Koporec, Kevin <Koporec.Kevin@epa.gov>
Sent: Tuesday, June 20, 2017 1:46 PM
To: White, Jana; Bentkowski, Ben; Duncan, Tracey; Rich Bonczek; Corkran, Julie; 'Begley, Brian (EEC)'; Brewer, Gaye (EEC); Jeri.Higginbotham@ky.gov; Towarnicky, Joseph M; Overby, Teresa; Nourse, Bobette (PPPO/CONTR); Jung, Christopher H (EEC); Kim Knerr; Frederick, Tim
Subject: RE: C-400 VI Work Plan - Follow-up Technical Discussion
Attachments: 12DCE May2016.pdf

Re: DCE inhalation tox value.
Here is the basis for region 4's use of the ATSDR Intermediate MRL as an interim value for assessment of inhalation to 1,2-DCE. ATSDR is on the list of sources of Toxicity values on our (EPA Superfund risk assessment) hierarchy. I would note that we have recently requested an expedited assessment of this chemical by the EPA IRIS program.

Kevin Koporec
Toxicologist
USEPA Region 4

-----Original Appointment-----
From: White, Jana [mailto:Jana.White@FFSPaducah.Com]
Sent: Tuesday, June 20, 2017 1:23 PM
To: White, Jana; Koporec, Kevin; Bentkowski, Ben; Duncan, Tracey; Rich Bonczek; Corkran, Julie; 'Begley, Brian (EEC)'; Brewer, Gaye (EEC); Jeri.Higginbotham@ky.gov; Towarnicky, Joseph M; Overby, Teresa; Nourse, Bobette (PPPO/CONTR); Jung, Christopher H (EEC); Kim Knerr; Frederick, Tim
Subject: FW: C-400 VI Work Plan - Follow-up Technical Discussion
When: Tuesday, June 20, 2017 2:00 PM-3:00 PM (UTC-06:00) Central Time (US & Canada).
Where: DOE Large Conference Room Conference Call 1-800-454-9043 Participant Code: 4415861

-----Original Appointment-----
From: White, Jana [mailto:Jana.White@FFSPaducah.Com]
Sent: Friday, June 16, 2017 9:37 AM
To: White, Jana; Duncan, Tracey; Rich Bonczek; Corkran, Julie; Bentkowski, Ben; 'Begley, Brian (EEC)'; Brewer, Gaye (EEC); Jeri.Higginbotham@ky.gov; Towarnicky, Joseph M; Overby, Teresa; Nourse, Bobette (PPPO/CONTR); Jung, Christopher H (EEC); Kim Knerr; Frederick, Tim
Subject: C-400 VI Work Plan - Follow-up Technical Discussion
When: Tuesday, June 20, 2017 2:00 PM-3:00 PM (UTC-06:00) Central Time (US & Canada).
Where: DOE Large Conference Room Conference Call 1-800-454-9043 Participant Code: 4415861

The purpose of the meeting is to continue discussions on language for Condition 4; review remaining actions associated with Worksheet #15 of QAPP; and to discuss the schedule associated with C-400 VI.
The current deadline for the informal dispute is July 1st and the parties have agreed to meet prior to July 1st to continue resolution of the remaining technical issues.

If you have any questions, please let me know.
Thanks,
Jana

Superfund Technical Support Center
National Center for Environmental Assessment
U.S. Environmental Protection Agency
26 West Martin Luther King Drive, MS-AG41
Cincinnati, Ohio 45268

Phillip Kaiser/Hotline Director, Teresa Shannon/Administrator
Hotline 513-569-7300, FAX 513-569-7159, E-Mail: Superfund_STSC@epa.gov

May 25, 2016

Kevin Koporec
EPA Region 4

ASSISTANCE REQUESTED: Inhalation toxicity value (RfC) for 1,2-dichloroethylene and its cis- and trans- isomers.

ENCLOSED INFORMATION: Attachment 1: 1,2-DCE Frederick, Tim Response_Final.pdf

If you have any questions regarding this transmission, please contact the STSC at (513) 569-7300.

Attachments (1)

cc: STSC files

RESPONSE MESSAGE:

The STSC understands your urgent need for PPRTV assessments for 1,2-dichloroethylene and its cis- and trans- isomers. Our PTV document development queue is currently set through FY18, however NCEA/STSC representatives are currently working collaboratively on a standard operating procedure with OLEM to outline a formal chemical nomination process that might facilitate 'fast-tracking' specific PTV development requests for Regions. This process, while not currently enacted, may serve as the conduit for requests such as for 1,2-dichloroethylene and its cis- and trans- isomers. In the interim, the STSC suggests that you contact Michele Burgess (Burgess.Michele@epa.gov or 703-603-9003) of OLEM directly to discuss a path forward for PTV development for the chemicals of interest. Furthermore, please note that the ATSDR derived a Minimal Risk Level of 0.2 ppm in 1996 for acute-duration inhalation exposure and intermediate-duration inhalation exposure to trans-1,2-dichloroethylene that could be referred to when assessing the health risks associated with the inhalation of this chemical.

Supported by Highlight Technologies, LLC, under
U.S. Environmental Protection Agency Contract No. EP-C-13-007

Agency for Toxic Substances and Disease Registry
MINIMAL RISK LEVELS (MRLs)
March 2016

Name	Route	Duration	MRL	Uncertainty Factors	Endpoint	Status	Cover Date	CAS Number
1,2-DICHLOROETHENE, CIS-	Oral	Acute	1 mg/kg/day	100	Hemato.	Final	08/96	156-59-2
		Int.	0.3 mg/kg/day	100	Hemato.			
1,2-DICHLOROETHENE, TRANS-	Inh.	Acute	0.2 ppm	1000	Hepatic	Final	08/96	156-60-5
		Int.	0.2 ppm	1000	Hepatic			
	Oral	Int.	0.2 mg/kg/day	100	Hepatic			

For Duration, Acute = 1 to 14 days, Intermediate = 15 to 364 days, and Chronic = 1 year or longer.

For general information on ATSDR Minimal Risk Levels, see www.atsdr.cdc.gov/MRLs.

For more information on a specific MRL, please refer to our Toxicological Profiles, particularly Appendix A of Profiles released after 1995. The Toxicological Profiles can be found online at www.atsdr.cdc.gov/ToxProfiles, where you can also find a contact form. Or call 1-800-CDC-INFO.

Region 4 Scientific Support Section
Vapor Intrusion Screening Tool

Last updated 06/26/2017

Internal Use Only: Air Screening Table for Industrial Sites					**RSL**	**RSL**
	RSL(3)	**RSL(3)**	**RML(2)**	**RML(2)**	**Sub-slab(1)**	**Sub-slab(1)**
	ug/m^3	**ppbv**	**ug/m^3**	**ppbv**	**ug/m^3 [c]**	**ppbv [c]**
Acetone	14,000 n	5,900 n	420,000 n	180,000 n	4,500,000 n	1,900,000 n
Benzene	1.6 c	0.5 c	160 c	500 c	52 c	16 c
Carbon Tetrachloride	2 c	0.32 c	200 c	32 c	68 c	11 c
Chloroethane	4,400 n	1,700 n	130,000 n	50,000 n	1,500,000 n	57,000 n
Chloroform[a]	43 n	8.8 n	430 n	88 n	1400 n	300 n
1,1-Dichloroethane	7.7 c	1.9 c	770 c	190 c	260 c	64 c
1,2-Dichloroethane	0.47 c	0.12 c	47 c	12 c	16 c	4 c
1,1-Dichloroethylene	88 n	22 n	2600 n	670 n	29,000 n	7300 n
***cis* -1,2-Dichloroethylene**[b]	3500 n	880 n	10,000 n	2600 n	120,000 n	300,000 n
***trans* -1,2-Dichloroethylene**[b]	3500 n	880 n	10,000 n	2600 n	120,000 n	300,000 n
Ethylbenzene	4.9 c	1.1 c	490 c	110 c	160 c	37 c
Methylene Chloride	260 n	75 n	7800 n	2200 n	41,000 n	12,000 n
Naphthalene	0.36 c	0.07 c	36 c	7 c	12 c	2.3 c
1,1,1,2-Tetrachloroethane	1.7 c	0.25 c	170 c	25 c	55 c	8 c
1,1,2,2-Tetrachloroethane	0.21 c	0.03 c	21 c	3 c	7 c	1 c
Tetrachloroethylene (PCE)	18 n	2.7 n	540 n	80 n	1600 n	240 n
Toluene	2,200 n	580 n	66,000 n	17,500 n	730,000 n	190,000 n
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon)	2,200 n	290 n	390,000 n	51,000 n	4,400,000 n	57,000 n
1,1,1-Trichloroethane	2,200 n	400 n	66,000 n	12,000 n	730,000 n	130,000 n
1,1,2-Trichloroethane	0.088 n	0.016 n	SSV		26 n	5 n
Trichloroethylene (TCE)	0.88 n	0.16 n	8.8[d]/26[e] n	1.6[d]/4.8[e] n	100 n	19 n
1,2,3-Trimethylbenzene	26 n	5.3 n	66 n	13 n	730 n	150 n
1,2,4-Trimethylbenzene	26 n	5.3 n	93 n	19 n	1000 n	200 n
Vinyl Chloride	2.8 c	1.1 c	280 c	110 c	93 c	36 c
Xylene	44 n	10 n	1300 n	300 n	15,000 n	3500 n

(1) based on lower of HI=1 or 1x10e-6, except 1,2-Dichloroethylene & chloroform

(2) based on lower of HI=3 or 1x10e-4, except 1,2-Dichloroethylene & chloroform

(3) based on lower of HI=0.1 or 1x10e-6, except 1,2-Dichloroethylene, chloroform, & TCE

(a) RSL based on HI=0.1 & RML based on HI=1 because of chloroform being a threshold carcinogen (USEPA IRIS file)

(b) based on ATSDR MRL for trans-1,2-Dichloroethylene: http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls.pdf

(c) Values were calculated using the default sub-slab attenuation factor of 0.03

(d) based on HI=1 to be protective of sensitive sub-populations

(e) based on HI=3 to be protective of non-sensitive populations

SSV - Site Specific Value should be calculated

n = non carcinogen; c = carcinogen

*This table is not for rule making or specific guidance. It is a Region 4 screening tool only.

Region 4 Scientific Support Section
Vapor Intrusion Screening Tool

Last updated 06/24/2017

Internal Use Only: Air Screening Table for Residential Sites					**RSL**	**RSL**
	RSL(3)	**RSL(3)**	**RML(2)**	**RML(2)**	**Sub-slab(1)**	**Sub-slab(1)**
	ug/m^3	**ppbv**	**ug/m^3**	**ppbv**	**ug/m$^{3\ c}$**	**ppbv ^{c}**
Acetone	3,200 n	1,350 n	96,000 n	40,400 n	1,100,000 n	463,000 n
Benzene	0.36 c	0.11 c	36 c	11 c	12 c	3.8 c
Carbon Tetrachloride	0.47 c	0.08 c	47 c	7.5 c	16 c	2.5 c
Chloroethane	1,000 n	380 n	30,000 n	11,000 n	350,000 n	133,000 n
Chloroform[a]	10 n	2 n	100 n	20 n	330 n	68 n
1,1-Dichloroethane	1.8 c	0.44 c	180 c	45 c	58 c	14 c
1,2-Dichloroethane	0.11 c	0.03 c	11 c	2.7 c	3.6 c	0.9 c
1,1-Dichloroethene	21 c	5.3 n	630 n	160 n	7000 c	1800 c
***cis*-1,2-Dichloroethylene**[b]	800 n	200 n	2400 n	600 n	27,000 n	6,800 n
***trans*-1,2-Dichloroethylene**[b]	800 n	200 n	2400 n	600 n	27,000 n	6,800 n
Ethylbenzene	1.1 c	0.25 c	110 c	25 c	37 c	8.5 c
Methylene Chloride	63 n	18 n	1,900 n	540 n	3400 n	980 n
Naphthalene	0.083 c	0.02 c	8.3 c	1.6 c	2.8 c	0.53 c
1,1,1,2-Tetrachloroethane	0.38 c	0.06 c	38 c	5.5 c	13 c	1.9 c
1,1,2,2-Tetrachloroethane	0.048 c	0.007 c	4.8 c	0.7 c	1.6 c	0.23 c
Tetrachloroethylene (PCE)	4.2 n	0.6 n	130 n	19 n	360 n	53 n
Toluene	520 n	140 n	16,000 n	4100 n	170,000 n	45,000 n
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon)	520 n	70 n	93,000 n	12,000 n	1,000,000 n	131,000 n
1,1,1-Trichloroethane	520 n	95 n	16,000 n	3000 n	170,000 n	31,000 n
1,1,2-Trichloroethane	0.021 n	0.004 n	SSV	0	6 n	1 n
Trichloroethylene (TCE)	0.21 n	0.04 n	2.1^d/6.3^e n	0.4^d/1.2^e n	16 n	3 n
1,2,3-Trimethylbenzene	6.3 n	1.3 n	16 n	100 n	170 n	35 n
1,2,4-Trimethylbenzene	6.3 n	1.3 n	22 n	150 n	240 n	49 n
Vinyl Chloride	0.17 c	0.07 c	17 c	6.7 c	6 c	2 c
Xylene	10 n	2.3 n	300 n	69 n	3500 n	800 n

(1) based on lower of HI=1 or 1x10e-6, except 1,2-Dichloroethylene, chloroform, & TCE

(2) based on lower of HI=3 or 1x10e-4, except 1,2-Dichloroethylene, chloroform, & TCE

(3) based on lower of HI=0.1 or 1x10e-6, except 1,2-Dichloroethylene, chloroform, & TCE

(a) RSL based on HI=0.1 & RML based on HI=1 because of chloroform being a threshold carcinogen (USEPA IRIS file)

(b) based on ATSDR MRL for trans-1,2-Dichloroethylene: http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls.pdf

(c) Values were calculated using the default sub-slab attenuation factor of 0.03

(d) based on HI=1 to be protective of sensitive sub-populations

(e) based on HI=3 to be protective of non-sensitive populations

SSV - Site Specific Value should be calculated

n = non carcinogen; c = carcinogen

*This table is not for rule making or specific guidance. It is a Region 4 screening tool only.

MEMORANDUM

DATE: June 17, 2014

SUBJECT: Removal of the *trans*-1,2-Dichloroethylene (CASRN 156-60-5) Provisional Peer-Reviewed Toxicity Value (PPRTV) assessment from the Electronic Library

FROM: Scott Wesselkamper
Director, Superfund Health Risk Technical Support Center (STSC)
EPA/ORD/NCEA

TO: Michele Burgess (OSWER/OSRTI)
Lynn Flowers (NCEA)
Teresa Shannon (NCEA)
The File

It was brought to the attention of the STSC that there is an inconsistency in the conclusions regarding the derivation of a reference concentration (RfC) for *trans*-1,2-Dichloroethylene (DCE) between the 2006 PPRTV assessment and the 2010 IRIS assessment (http://www.epa.gov/iris/toxreviews/0418tr.pdf) for this chemical. The 2006 PPRTV assessment derived a chronic p-RfC of 0.06 mg/m^3 based on pulmonary and liver effects observed in the principal study by Freundt et al. (1977). No subchronic p-RfC was derived. The 2010 IRIS assessment found Freundt et al. (1977), a study by the National Toxicology Program (NTP, 2002), and an unpublished study by DuPont (1998) to be insufficient to support derivation of an RfC value for *trans*-1,2-DCE. Thus, there appears to be a fundamental difference in how the principal study and critical effect(s) used to derive the chronic p-RfC in the 2006 PPRTV assessment were evaluated compared to what was more recently done by IRIS. It is important to note that there are some differences in the respective decision-making processes for developing PPRTV and IRIS assessments, specifically with the IRIS Program having a more extensive review process (e.g., agency and interagency review steps, a public comment period, etc.) than that utilized for developing PPRTV assessments.

Pertinent information from the 2010 IRIS Toxicological Review on *trans*-1,2-DCE that outlines why the Freundt et al. (1977) study was discounted and no RfC value was derived is excerpted and italicized below:

"The finding of lung effects in the Freundt et al. (1977) study is difficult to interpret as this study is the only report of lung pathology in animals exposed to trans-1,2-DCE, a small number of animals were examined, several of the controls also developed this effect, and the upper respiratory tract was not examined for pathology."

"For each of the exposure durations, there was no statistically significant difference between the controls and the exposed groups with respect to the incidence of liver effects (fat accumulation). In general, however, the incidence and severity of fat accumulation increased with increasing exposure duration. Although Freundt et al. (1977) reported histopathologic changes in the liver of rats, the DuPont (1998) study did not corroborate the Freundt et al. (1977) study findings. DuPont (1998) reported relatively small increases in relative and absolute liver weight (1–8%) and no gross or microscopic changes of the liver attributable to trans-1,2-DCE at an exposure concentration 20-fold higher than that

used in the Freundt et al. (1977) study. NTP (2002a) similarly found no histopathologic changes in the liver when trans-1,2-DCE was administered for 90 days by the oral route at dietary concentrations as high as 50,000 ppm. In light of the results of DuPont (1998) and NTP (2002a), it is difficult to explain the liver findings in the single-exposure concentration study by Freundt et al. (1977). Given the limitations of the Freundt et al. (1977) study (i.e., small sample size, use of only one exposure concentration, and observation of fatty accumulation in the liver lobules and Kupffer cells in control animals at some exposure durations) and lack of corroboration from other studies, the Freundt et al. (1977) study was not used as the basis for deriving an RfC for trans-1,2-DCE."

"In summary, the available inhalation data from DuPont (1998) and Freundt et al. (1977) were considered insufficient to support reference value derivation and, therefore, an RfC for trans-1,2-DCE was not derived."

Current practice by the PPRTV Program states that once an IRIS assessment becomes available for any given chemical, the PPRTV assessment for that chemical is removed from the PPRTV electronic library. Thus, based on this practice and the rationale outlined above, it is recommended that the conclusions presented in the IRIS assessment for *trans*-1,2-DCE be presently adhered to, and the *trans*-1,2-DCE PPRTV assessment has been removed from the electronic library. Any additional questions regarding *trans*-1,2-DCE should be directed to the IRIS Hotline at (202) 566-1676 or http://www.epa.gov/iris/contact_hotline.htm.

References:

Freundt, K.J., G.P. Liebaldt and E. Lieberwirth. 1977. Toxicity studies on trans-1,2-dichloroethylene. Toxicology. 7: 141-153.

NTP (2002). NTP technical report on the toxicity studies of trans-1,2-dichloroethylene (CAS No. 156-60-5) administered in microcapsules in feed to F344/N rats and B6C3F1 mice. Public Health Service, U.S. Department of Health and Human Services; NTP TR 55. Available from the National Institute of Environmental Health Sciences, Research Triangle Park, NC and online at http://ntp.niehs.nih.gov/ntp/htdocs/ST_rpts/tox055.pdf

10-31-2002

Provisional Peer Reviewed Toxicity Values for

trans-1,2-Dichloroethylene
(CASRN 156-60-5)

Derivation of a Chronic Inhalation RfC

Superfund Health Risk Technical Support Center
National Center for Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

Acronyms and Abbreviations

bw	body weight
cc	cubic centimeters
CD	Caesarean Delivered
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CNS	central nervous system
cu.m	cubic meter
DWEL	Drinking Water Equivalent Level
FEL	frank-effect level
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
g	grams
GI	gastrointestinal
HEC	human equivalent concentration
Hgb	hemoglobin
i.m.	intramuscular
i.p.	intraperitoneal
i.v.	intravenous
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
kg	kilogram
L	liter
LEL	lowest-effect level
LOAEL	lowest-observed-adverse-effect level
LOAEL(ADJ)	LOAEL adjusted to continuous exposure duration
LOAEL(HEC)	LOAEL adjusted for dosimetric differences across species to a human
m	meter
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MF	modifying factor
mg	milligram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MRL	minimal risk level
MTD	maximum tolerated dose
MTL	median threshold limit

NAAQS	National Ambient Air Quality Standards
NOAEL	no-observed-adverse-effect level
NOAEL(ADJ)	NOAEL adjusted to continuous exposure duration
NOAEL(HEC)	NOAEL adjusted for dosimetric differences across species to a human
NOEL	no-observed-effect level
OSF	oral slope factor
p-IUR	**provisional inhalation unit risk**
p-OSF	**provisional oral slope factor**
p-RfC	**provisional inhalation reference concentration**
p-RfD	**provisional oral reference dose**
PBPK	physiologically based pharmacokinetic
ppb	parts per billion
ppm	parts per million
PPRTV	**Provisional Peer Reviewed Toxicity Value**
RBC	red blood cell(s)
RCRA	Resource Conservation and Recovery Act
RDDR	Regional deposited dose ratio (for the indicated lung region)
REL	relative exposure level
RfC	inhalation reference concentration
RfD	oral reference dose
RGDR	Regional gas dose ratio (for the indicated lung region)
s.c.	subcutaneous
SCE	sister chromatid exchange
SDWA	Safe Drinking Water Act
sq.cm.	square centimeters
TSCA	Toxic Substances Control Act
UF	uncertainty factor
µg	microgram
µmol	micromoles
VOC	volatile organic compound

PROVISIONAL PEER REVIEWED TOXICITY VALUES FOR *trans*-1,2-DICHLOROETHYLENE
Derivation of a Chronic Inhalation RfC

Background

On December 5, 2003, the U.S. Environmental Protection Agency's (EPA's) Office of Superfund Remediation and Technology Innovation (OSRTI) revised its hierarchy of human health toxicity values for Superfund risk assessments, establishing the following three tiers as the new hierarchy:

1. EPA's Integrated Risk Information System (IRIS).

2. Provisional Peer-Reviewed Toxicity Values (PPRTV) used in EPA's Superfund Program.

3. Other (peer-reviewed) toxicity values, including:

    - Minimal Risk Levels produced by the Agency for Toxic Substances and Disease Registry (ATSDR),
    - California Environmental Protection Agency (CalEPA) values, and
    - EPA Health Effects Assessment Summary Table (HEAST) values.

A PPRTV is defined as a toxicity value derived for use in the Superfund Program when such a value is not available in EPA's Integrated Risk Information System (IRIS). PPRTVs are developed according to a Standard Operating Procedure (SOP) and are derived after a review of the relevant scientific literature using the same methods, sources of data, and Agency guidance for value derivation generally used by the EPA IRIS Program. All provisional toxicity values receive internal review by two EPA scientists and external peer review by three independently selected scientific experts. PPRTVs differ from IRIS values in that PPRTVs do not receive the multi-program consensus review provided for IRIS values. This is because IRIS values are generally intended to be used in all EPA programs, while PPRTVs are developed specifically for the Superfund Program.

Because science and available information evolve, PPRTVs are initially derived with a three-year life-cycle. However, EPA Regions or the EPA Headquarters Superfund Program sometimes request that a frequently used PPRTV be reassessed. Once an IRIS value for a specific chemical becomes available for Agency review, the analogous PPRTV for that same chemical is retired. It should also be noted that some PPRTV manuscripts conclude that a PPRTV cannot be derived based on inadequate data.

Disclaimers

Users of this document should first check to see if any IRIS values exist for the chemical of concern before proceeding to use a PPRTV. If no IRIS value is available, staff in the regional Superfund and RCRA program offices are advised to carefully review the information provided in this document to ensure that the PPRTVs used are appropriate for the types of exposures and circumstances at the Superfund site or RCRA facility in question. PPRTVs are periodically updated; therefore, users should ensure that the values contained in the PPRTV are current at the time of use.

It is important to remember that a provisional value alone tells very little about the adverse effects of a chemical or the quality of evidence on which the value is based. Therefore, users are strongly encouraged to read the entire PPRTV manuscript and understand the strengths and limitations of the derived provisional values. PPRTVs are developed by the EPA Office of Research and Development's National Center for Environmental Assessment, Superfund Health Risk Technical Support Center for OSRTI. Other EPA programs or external parties who may choose of their own initiative to use these PPRTVs are advised that Superfund resources will not generally be used to respond to challenges of PPRTVs used in a context outside of the Superfund Program.

Questions Regarding PPRTVs

Questions regarding the contents of the PPRTVs and their appropriate use (e.g., on chemicals not covered, or whether chemicals have pending IRIS toxicity values) may be directed to the EPA Office of Research and Development's National Center for Environmental Assessment, Superfund Health Risk Technical Support Center (513-569-7300), or OSRTI.

INTRODUCTION

An RfC for *trans*-1,2-dichloroethylene is not available on IRIS (U.S. EPA, 2002) or in the HEAST (U.S. EPA, 1997). The CARA list (U.S. EPA, 1991, 1994a) includes a Health Effects Assessment (HEA) for *trans*-1,2-dichloroethylene (U.S. EPA, 1984) and a Health and Environmental Effects Profile (HEEP) on dichloroethylenes (U.S. EPA, 1986) that reported no data regarding inhalation toxicity in humans and inconsistent results in two subchronic inhalation assays in animals. ATSDR (1996) established an intermediate inhalation MRL of 0.2 ppm (0.8 mg/m^3) based on a LOAEL of 200 ppm (790 mg/m^3) in a 16-week subchronic inhalation study in rats by Freundt et al. (1977) to protect against hepatic effects. ACGIH (1991, 2001) assigned a TLV-TWA of 200 ppm (790 mg/m^3) for all isomers of 1,2-dichloroethylene based on a no-effect level of 1000 ppm following exposure to mixed isomers in a study by Torkelson (ACGIH, 1991). However, the value was under review, since liver effects had been reported in rats repeatedly exposed to 200 ppm of the *trans* isomer (Freundt et al., 1977). The NIOSH (1981, 2001) REL-TWA and OSHA (1999, 2000) PEL for isomers of 1,2-dichloroethylene were both established at

200 ppm (790 mg/m^3) to protect against irritation of the eyes and respiratory system and depression of the central nervous system. Neither IARC (2001) nor the WHO (2001) have written a toxicological review document on *trans*-1,2-dichloroethylene. A toxicity review on unsaturated halogenated hydrocarbons (Lemen, 2001) and the NTP (2001a,b) management status report and health and safety report for *trans*-1,2-dichloroethylene were consulted for relevant information. Literature searches were conducted from 1994 to June 2001 for studies relevant to the derivation of a provisional RfC for *trans*-1,2-dichloroethylene. The databases searched were: TOXLINE, MEDLINE, CANCERLIT, TOXLIT/BIOSIS, RTECS, HSDB, GENETOX, CCRIS, TSCATS, EMIC/EMICBACK, and DART/ETICBACK.

REVIEW OF THE PERTINENT LITERATURE

Human Studies

Acute exposures to high concentrations (>1000 ppm) of *trans*-1,2-dichloroethylene have been reported to cause eye irritation, nausea, vertigo, and narcosis in humans (ACGIH, 1991; OSHA, 1999). Due to its narcotic effects, *trans*-1,2-dichloroethylene has been used as an anesthetic in humans (ACGIH, 1991). One human fatality, presumably from depression of the central nervous system, was reported following exposure to an unknown quantity of 1,2-dichloroethylene vapor (isomer composition unreported) in an enclosed area (ATSDR, 1996). No data regarding chronic or subchronic inhalation toxicity of *trans*-1,2-dichloroethylene in humans were found in the available review documents (U.S. EPA, 1984, 1986; Lemen, 2001) or in the literature search.

Animal Studies

1,2-Dichloroethylene has been used as an anesthetic in animals (ACGIH, 1991; Lemen, 2001). Inhalation toxicity studies of *trans*-1,2-dichloroethylene in animals include a subchronic rat study by Freundt et al. (1977) and a developmental rat study by Hurtt et al. (1993). No chronic duration animal study was located in the literature search.

Other Studies

Freundt et al. (1977) exposed groups of six female Wistar rats by inhalation to 0 or 200 ppm (0 or 794 mg/m^3) of *trans*-1,2-dichloroethylene for 8 hours/day for 1 day only and for 8 hours/day, 5 days/week for prolonged durations of 1, 2, 8 and 16 weeks. Additional studies were done at higher concentrations (1000 and 3000 ppm) for 8 hours/day for a single day. All concentrations were given as mean values with a variability of ±3% (S.E.M.) based on monitoring the chambers using gas chromatography.

Subsequent to single and repeated exposures at 200 ppm, the rats were examined for gross pathology and histological pathology of selected organs (brain, sciatic nerve, lung, heart, liver, kidney, spleen, brain, and muscle). No signs of narcosis were observed during exposure, and no mortality was reported. Histopathological effects were observed only in the liver(fatty accumulation in liver lobule and Kupffer cells) and lungs (capillary hyperemia and alveolar septum distension).

Repeated exposures of 200 ppm for 1 and 2 weeks produced only slight histopathological changes for liver and lungs in contrast to the studies of 8 and 16 weeks where slight to severe changes were noted. Therefore, these latter studies of longer duration will only be addressed in this report.

In the group exposed for 8 weeks, fatty degeneration was observed in the liver lobule of 3/6 treated rats (versus 0/6 controls) and in the Kupffer cells of 3/6 treated rats (versus 1/6 controls). In the group exposed for 16 weeks, fatty degeneration both in the liver lobule and in Kupffer cells was observed in 5/6 treated rats and 2/6 controls. The observed liver lesions were graded as slight changes, except for Kupffer cell fat accumulation in the 8-week exposure group (all 3 treated and 1 control rats showing the lesion) and liver lobule fat accumulation in the 16-week exposure group (3 of the 5 treated rats with the lesion), which were graded as severe changes. Lung lesions were all graded as slight changes. In the 8-week exposure group, pulmonary capillary hyperemia and distension of the alveolar septum were observed in 6/6 treated rats (3 with severe pneumonic infiltration) and 0/6 controls. Identical findings were reported in the16-week exposure group. This study identified a free standing LOAEL of 200 ppm (794 mg/m^3) for hepatic and pulmonary lesions in rats subchronically exposed to *trans*-1,2-dichloroethylene.

These findings are supported by shorter-term experiments described in the same paper. Freundt et al. (1977) observed the same hepatic and pulmonary effects (hepatic fatty infiltration, pulmonary capillary hyperemia, and alveolar septal distension) in rats exposed to 200 ppm for as short as 8 hours. With the exception of one rat in a single exposure for 8 hours only), the incidence and/or severity was lower . Eight-hour exposure to higher concentrations produced no additional effects, except that histopathology of the cardiac muscle was observed in rats given a single 8-hour exposure to 3000 ppm. Additional studies showed that pulmonary lesions similar to those observed by inhalation exposure were also produced by intraperitoneal exposure. Based on this finding and the absence of histological evidence (transudates or exudates) for irritation of the bronchial epithelium, the investigators suggested that irritation can be discounted as the causal agent for the observed lesions and that the pulmonary lesions may be, at least in part, systemic in origin.

An overview of all the brief and prolonged studies demonstrates that both dose (200, 1000 and 3000 ppm for 8 hours) and time (200 ppm for 8 hours, 1, 2, 8 and 16 weeks) do appear to make a difference in the severity of fat accumulation in the liver lobule and of cardiotoxicity.

A developmental study by Hurtt et al. (1993) showed that the developing organism is not a sensitive target for *trans*-1,2-dichloroethylene. Hurtt et al. (1993) exposed groups of 24 presumed pregnant female CRL:CD BR rats by inhalation to concentrations of 0, 2000, 6000, or 12,000 ppm (0, 7940, 23,820, or 47,640 mg/m^3) of *trans*-1,2-dichloroethylene (99.64% purity) for 6 hours/day on gestational days (GD) 7-16. Rats were observed daily (twice daily on exposure days) for clinical signs. During exposure, the response of the dams to a sound stimulus (rapping on the side of the exposure chamber) was recorded; because of the design of the chamber, not all animals in each group could be observed. Maternal body weight was recorded on GD 1, 7-17, and 22; feed consumption was measured on alternate days from GD 1-19 and on GD 22. Dams were sacrificed on GD 22 and examined for gross pathology; the weights of liver, gravid uterus and empty uterus were recorded. Other endpoints included the number of uterine resorptions (revealed by ammonium sulfide staining in apparently ‘nonpregnant’ dams), fetal mortality, weight and sex of live fetuses, and the number of stunted live fetuses. All fetuses were examined for external malformations and variations, and subsequently analyzed for either skeletal or visceral changes. Two control females were found to be not pregnant and were excluded from most analyses.

No maternal mortality was observed (Hurtt et al., 1993). Significantly reduced body weight gain was observed at 6000 ppm on GD 11-13 and at 12,000 ppm on GD 7-17 (actual loss of weight on GD 7-9). Significantly reduced feed consumption occurred at 2000 ppm on GD 13-15, and at both higher doses during the exposure period. Body weight and food consumption reverted to normal values during the post-exposure period. Ocular irritation (lacrimation and stained periocular hair) was observed in all exposed groups. Narcotizing effects of treatment and alopecia were observed at 6000 and 12,000 ppm, and lethargy and salivation at 12,000 ppm. Of these clinical signs, only alopecia was observed in exposed rats in the post-exposure period. No other compound-related effects were observed in dams. Significant trends and increases in the mean number of total and early resorptions per litter were found in dams exposed to 6000 or 12,000 ppm. However, the researchers considered this finding to be not biologically significant, but rather an artifact of the unusually low resorption rate in the concurrent control group; rates in exposed groups were within the limits of historical control data from the same laboratory during the previous 2 years. The pregnancy rate, corpora lutea, fetuses per litter, and number of stunted fetuses were unaffected by treatment. At 12,000 ppm, mean fetal weight was significantly reduced and there was a small, statistically nonsignificant increase in the incidence of hydrocephalus. Otherwise, treatment had no significant effect on the incidence of fetal malformations or variations. In this study, fetal effects were found only at high concentrations producing overt maternal toxicity, indicating that the developing organism is not a sensitive target of *trans*-1,2-dichloroethylene toxicity.

In a briefly-described range-finding experiment for the developmental study, Hurtt et al. (1993) exposed groups of pregnant female Crl:CD BR rats by inhalation to 0, 6000, 9000, or 12,000 ppm (0, 23,820, 35,730, or 47,640 mg/m^3) of *trans*-1,2-dichloroethylene for 6 hours/day on gestational days 7-16. Narcosis [central nervous system (CNS) depression] was observed in all test groups during exposure and was evident as incoordination immediately following exposure. Maternal body weight gain and food consumption were decreased at the two highest exposure levels, and fetal body weight was decreased at the highest level.

DERIVATION OF A PROVISIONAL RfC FOR *trans*-1,2-DICHLOROETHYLENE

No pertinent data were located regarding the chronic or subchronic inhalation toxicity of *trans*-1,2-dichloroethylene in humans. No chronic inhalation toxicity study in animals was located in the literature search. The 16-week subchronic rat inhalation toxicity study by Freundt et al. (1977) was cited on IRIS (U.S. EPA, 2002) in support of the oral RfD, but was not used to derive a p-RfC. The U.S. EPA (1986) concluded that there was an unresolvable conflict between the adverse level of 200 ppm for the *trans* isomer in the Freundt study and results of an unpublished study on the mixed isomers by Torkelson that was submitted in 1965 to the ACGIH (1991). As reported in secondary sources (Torkelson and Rowe, 1981; ACGIH, 1991), no adverse effects were observed in rats, guinea pigs, rabbits, or dogs exposed by inhalation to the equivalent of 200 or 400 ppm of *trans*-1,2-dichloroethylene (500 or 1000 ppm of 1,2-dichloroethylene containing 40% *trans* isomer) for 7 hours/day, 5 days/week for 6 months. However, as indicated in a report of this study submitted to the EPA in 1994 (Dow, 1962), statistically significant increases in organ weights relative to body weight were observed in the liver of female rats and the kidney of male rats at both exposure levels, and in kidney of female rats at the high exposure level; in addition, average relative liver weight was also increased in a small group of male and female rabbits. The reported organ weight changes observed for the mixed isomers in the Dow (1962) study would appear to provide support for the *trans*-isomer-related hepatic toxicity reported by Freundt et al. (1977). However, absolute organ weights and histopathology results were not reported for the Dow (1962) study.

The critical study of Freundt et al. (1977) reported adverse effects in the liver (fatty degeneration) and lung (pulmonary capillary hyperemia and distension of the alveolar septum) in female Wistar rats exposed to atmospheres containing 200 ppm (794 mg/m^3) of *trans*-1,2-dichloroethylene 8 hours/day, 5 days/week for 16 weeks. As mentioned above, the pulmonary effects were considered to be not only local, but systemic, since they occurred in rats exposed by other routes and were not accompanied by signs of irritation in the lungs (Freundt et al., 1977). Although these same lesions were also observed in rats exposed to the same free standing LOAEL of 200 ppm for only 8 hours, a p-RfC based on this LOAEL is expected to be protective for systemic effects from chronic exposure. The minimal nature of the effects in the 8-hour study suggests that the LOAEL of 200 ppm is very close to the threshold for acute effects. Exposure to 200 ppm for longer durations (up to 16 weeks) or higher concentrations (up to 3000 ppm) for acute durations produced increases in incidence and/or severity of the lesions, but no differences in the types of lesions observed or target organs (with the exception of cardiac histopathology after 3000 ppm for 8 hours). This suggests that the concentration- and duration-response curves for *trans*-1,2-dichloroethylene are shallow, and therefore, that the LOAEL of 200 ppm is a reasonable basis for a chronic p-RfC (i.e., uncertainty factors applied during derivation of the p-RfC are likely to encompass the chronic NOAEL).

The developmental study of Hurtt et al. (1993) was conducted at much higher concentrations (2000-12000 ppm) than the Freundt et al. (1977) study. At these levels, *trans*-1,2-dichloroethylene produced overt clinical signs of toxicity in the dams. Fetal effects were observed, but only at levels that also produced overt maternal toxicity. Therefore, a p-RfC based on the LOAEL of 200 ppm (794 mg/m^3) is expected to provide adequate protection of the fetus in case of maternal exposure.

To calculate the provisional RfC, the LOAEL of 200 ppm (794 mg/m^3) in rats (Freundt et al., 1977) is first adjusted for intermittent exposure, as follows (U.S. EPA, 1994b):

$$\begin{aligned} \text{LOAEL}_{\text{ADJ}} &= (\text{LOAEL}_{\text{RAT}})\ (\text{hours/24 hours})\ (\text{days/7 days}) \\ &= (794\ \text{mg/m}^3)\ (8/24)\ (5/7) \\ &= 189\ \text{mg/m}^3 \end{aligned}$$

For purposes of calculating the p-RfC, *trans*-1,2-dichloroethylene was treated as a category 3 gas. Lesions in the lung, as well as the liver, were considered extrarespiratory effects for this derivation, because the evidence (discussed above) suggests that the lung lesions were, at least partly, systemic in origin. The human equivalent concentration (HEC) for extrarespiratory effects produced by a category 3 gas is calculated by multiplying the duration-adjusted LOAEL by the ratio of blood:gas partition coefficients ($H_{b/g}$) in animals and humans (U.S. EPA, 1994b). Since the value of $H_{b/g}$ for *trans*-1,2-dichloroethylene in rats (9.58; Gargas et al., 1989) is larger than $H_{b/g}$ in humans (6.04), a default value of 1 is used for the ratio of partition coefficients, and the $\text{LOAEL}_{\text{HEC}}$ becomes 189 mg/m^3:

$$\text{LOAEL}_{\text{HEC}} = (\text{LOAEL}_{\text{ADJ}}) \times [(H_{b/g})_{\text{RAT}} / (H_{b/g})_{\text{HUMAN}}],$$

$$\text{If} \quad (H_{b/g})_{\text{RAT}} > (H_{b/g})_{\text{HUMAN}}, \text{ then } (H_{b/g})_{\text{RAT}} / (H_{b/g})_{\text{HUMAN}} = 1$$

$$\text{Since} \quad 9.58 > 6.04,$$

$$= 189\ \text{mg/m}^3 \times [1] = 189\ \text{mg/m}^3$$

A composite uncertainty factor of 3000 was used, reflecting the following areas of uncertainty: use of a LOAEL, use of a less than chronic study, extrapolation from rats to humans using the dosimetric adjustments, protection of sensitive individuals, and database deficiencies (including lack of a multigeneration reproduction study). The modifying factor was set to 1. The provisional RfC for *trans*-1,2-dichloroethylene was derived as follows:

$$\begin{aligned} \text{p-RfC} &= \text{LOAEL}_{\text{HEC}} \div (\text{UF} \times \text{MF}) \\ &= 189\ \text{mg/m}^3 \div (3000 \times 1) \\ &= 0.06 \text{ or } 6\text{E-}2\ \text{mg/m}^3 \end{aligned}$$

Although based on the same critical study, the provisional RfC for *trans*-1,2-dichloroethylene (6E-2 mg/m^3) is 13-fold lower than the intermediate inhalation MRL (8E-1 mg/m^3) calculated by ATSDR (1996). This difference stems from lack of duration adjustment and an alternative application of uncertainty factors in the ATSDR (1996) assessment.

STATEMENT OF CONFIDENCE

Confidence in the critical study is low because, although methods and results were adequately designed, conducted and reported, certain inadequacies remain, namely, small sample size, use of a single sex, the use of a single exposure level, the relatively short exposure duration, and the lack of analysis of body and organs weights, nasal histology, clinical chemistry, and hematology. Confidence in the database is low because of the lack of data for exposures longer than 16 weeks, or for species other than rat, and the lack of a multigeneration reproduction study. Low confidence in the p-RfC results.

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E.10. PERTINENT TOXICITY VALUES AND INFORMATION

The "BAF_{fish}" is the bioaccumulation factor for fish. EPA's "Waste and Cleanup Risk Assessment Glossary" defines it as the ratio of the concentration of a contaminant in an organism to the concentration in the ambient environment at steady state, where the organism can take in the contaminant through ingestion with its food as well as through direct contact. BAF_{fish} is not used in PRG derivation, but is presented in this table for reference only. The BAF_{fish} is in units of L/kg. Bioaccumulation factors for other organisms are available on the RAIS Web site and in *Risk Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0107&D2/R1, February 2011.

Chemical Abstract Number	Analyte	BAF_{fish}	BAF_{fish} Ref.
7429-90-5	Aluminum	5.00E+02	NCRP
7440-36-0	Antimony (metallic)	1.00E+02	NCRP
7440-38-2	Arsenic, Inorganic	3.00E+02	Wang
7440-39-3	Barium	4.00E+00	IAEA
7440-41-7	Beryllium and compounds	1.00E+02	NCRP
7440-42-8	Boron And Borates Only		
7440-43-9	Cadmium (Diet)	2.00E+02	NCRP
7440-43-9	Cadmium (Water)	2.00E+02	NCRP
7440-47-3	Chromium (Total)		
16065-83-1	Chromium(III), Insoluble Salts	2.00E+02	IAEA
18540-29-9	Chromium(VI)	2.00E+02	IAEA
7440-48-4	Cobalt	3.00E+02	IAEA
7440-50-8	Copper	2.00E+02	NCRP
16984-48-8	Fluoride		
7439-89-6	Iron	2.00E+02	NCRP
7439-92-1	Lead	3.00E+02	IAEA
7439-96-5	Manganese (Diet)	4.00E+02	IAEA
7439-96-5	Manganese (Non-diet)	4.00E+02	IAEA
7439-97-6	Mercury, Inorganic Salts	1.00E+03	NCRP
7439-98-7	Molybdenum	1.00E+01	NCRP
7440-02-0	Nickel Soluble Salts	1.00E+02	IAEA
7782-49-2	Selenium	2.00E+02	NCRP
7440-22-4	Silver	5.00E+00	IAEA94
7440-28-0	Thallium (Soluble Salts)	1.00E+04	NCRP
N/A	Uranium (Soluble Salts)	1.00E+01	IAEA
N/A	Vanadium and Compounds		
7440-66-6	Zinc and Compounds	1.00E+03	IAEA
83-32-9	Acenaphthene	7.55E+02	EPI
208-96-8	Acenaphthylene[a]	2.71E+02	EPI
107-13-1	Acrylonitrile	3.16E+00	EPI
120-12-7	Anthracene	1.80E+03	EPI
71-43-2	Benzene	4.27E+00	EPI
117-81-7	Bis(2-ethylhexyl)phthalate[b]	5.88E+02	EPI
75-27-4	Bromodichloromethane	9.70E+00	EPI
86-74-8	Carbazole	1.70E+02	EPI
56-23-5	Carbon Tetrachloride	7.40E+00	EPI
67-66-3	Chloroform	1.30E+01	EPI
75-71-8	Dichlorodifluoromethane (Freon-12)[b]	6.15E+00	EPI

Chemical Abstract Number	Analyte	BAF_{fish}	BAF_{fish} Ref.
75-34-3	Dichloroethane, 1,1- [b]	7.05E+00	EPI
107-06-2	Dichloroethane, 1,2-	4.40E+00	EPI
75-35-4	Dichloroethylene, 1,1-	1.30E+01	EPI
540-59-0	Dichloroethylene, 1,2- (Mixed Isomers)	1.11E+01	EPI
156-59-2	Dichloroethylene, 1,2-*cis*-	1.11E+01	EPI
156-60-5	Dichloroethylene, 1,2-*trans*-	1.11E+01	EPI
60-57-1	Dieldrin	7.48E+03	EPI
1746-01-6	Dioxins/Furans, Total		
37871-00-4	~HpCDD		
38998-75-3	~HpCDF, 2,3,7,8-		
34465-46-8	~HxCDD, 2,3,7,8-		
55684-94-1	~HxCDF, 2,3,7,8-		
3268-87-9	~OCDD	1.31E+03	EPI
39001-02-0	~OCDF		
36088-22-9	~PeCDD, 2,3,7,8-		
57117-41-6	~PeCDF, 1,2,3,7,8-		
57117-31-4	~PeCDF, 2,3,4,7,8-		
1746-01-6	~TCDD, 2,3,7,8-	9.70E+04	EPI
51207-31-9	~TCDF, 2,3,7,8-	4.06E+03	EPI
100-41-4	Ethylbenzene	5.56E+01	EPI
206-44-0	Fluoranthene	3.63E+03	EPI
86-73-7	Fluorene	5.25E+02	EPI
118-74-1	Hexachlorobenzene	2.14E+04	EPI
91-20-3	Naphthalene	8.45E+01	EPI
88-74-4	Nitroaniline, 2-	1.00E+01	EPI
621-64-7	Nitroso-di-N-propylamine, N-	3.67E+00	EPI
87-86-5	Pentachlorophenol	5.96E+02	EPI
85-01-8	Phenanthrene[a]	2.51E+03	EPI
1336-36-3	Polychlorinated Biphenyls (high risk)	2.53E+04	EPI
1336-36-3	Polychlorinated Biphenyls (low risk)	2.53E+04	EPI
12674-11-2	~Aroclor 1016	9.14E+03	EPI
11104-28-2	~Aroclor 1221		
11141-16-5	~Aroclor 1232		
53469-21-9	~Aroclor 1242		
12672-29-6	~Aroclor 1248		
11097-69-1	~Aroclor 1254		
11096-82-5	~Aroclor 1260		
50-32-8	Polycyclic aromatic hydrocarbons (cPAH), Total Carcinogenic		
56-55-3	~Benz[a]anthracene	2.60E+02	EPI
50-32-8	~Benzo[a]pyrene	5.15E+03	EPI
205-99-2	~Benzo[b]fluoranthene	3.02E+03	EPI
207-08-9	~Benzo[k]fluoranthene	4.99E+03	EPI
218-01-9	~Chrysene	3.17E+03	EPI
53-70-3	~Dibenz[a,h]anthracene	9.60E+03	EPI
193-39-5	~Indeno[1,2,3-cd]pyrene	1.22E+04	EPI
129-00-0	Pyrene	1.51E+03	EPI
127-18-4	Tetrachloroethylene	5.20E+01	EPI
108-88-3	Toluene[b]	8.32E+00	EPI
71-55-6	Trichloroethane, 1,1,1-	5.00E+00	EPI
79-00-5	Trichloroethane, 1,1,2-	5.00E+00	EPI
79-01-6	Trichloroethylene	1.60E+01	EPI
76-13-1	Trichloro-1,2,2-trifluoroethane, 1,1,2- (Freon-113)[b]	4.96E+01	EPI
75-01-4	Vinyl Chloride	5.47E+00	EPI
1330-20-7	Xylene, Mixture		
108-38-3	Xylene, m-	1.48E+01	EPI
95-47-6	Xylene, o-	1.41E+01	EPI
106-42-3	Xylene, P-	1.48E+01	EPI

Chemical Abstract Number	**Analyte**	**BAF$_{fish}$**	**BAF$_{fish}$ Ref.**
14596-10-2	Americium-241	3.00E+01	IAEA
10045-97-3	Cesium-137	2.00E+03	IAEA
13994-20-2	Neptunium-237	1.00E+01	IAEA
13981-16-3	Plutonium-238	4.00E+00	IAEA
15117-48-3	Plutonium-239	4.00E+00	IAEA
14119-33-6	Plutonium-240	4.00E+00	IAEA
14133-76-7	Tcchnetium-99	2.00E+01	IAEA
14269-63-7	Thorium-230	3.00E+01	IAEA
13966-29-5	Uranium-234	1.00E+01	IAEA
15117-96-1	Uranium-235	1.00E+01	IAEA
7440-61-1	Uranium-238	1.00E+01	IAEA

Information compiled from RAIS October 2016.

[a] Values for Acenaphthylene and Phenanthrene, if not available use toxicity factors for Acenaphthene.

[b] Analytes are not PGDP significant COPCs (Table 2.1), but are provided for project support.

Reference Codes:

EPI	EPA's Estimation Programs Interface Suite.
IAEA	International Atomic Energy Agency (IAEA) 1982, *Generic Models and Parameters for Assessing the Environmental Transfer of Radionuclides from Routine Releases. Exposures of Critical Groups*, Safety Series No. 57.
IAEA94	IAEA 1994, *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments*, Technical Reports Series No. 364.
NCRP	National Council on Radiation Protection and Measurements, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground.* Report No. 123, 1996.
Wang	Wang, Y. Y., et al. 1993, *A Compilation of Radionuclide Transfer Factors for the Plant, Meat, Milk, and Aquatic Food Pathways and Suggested Default Values for the RESRAD Code*, ANL/EAIS/TM-103, Argonne National Laboratory, Argonne, IL, August.

E.11. MEETING MINUTES FROM PADUCAH RISK ASSESSMENT WORKING GROUP

This chapter presents meeting minutes from the Paducah RAWG held in 2021. Any redline text shown in the minutes, except where the minutes show potential changes to the text 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/R12/V1 (DOE 2021), are revisions to the draft minutes made in response to RAWG review comments.

Notes from RAWG meetings held in 2000 through 2007 and minutes from RAWG quarterly meetings held from June 2012 through December 2016 are presented 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/R8/V1 (DOE 2017). Meeting summaries from RAWG quarterly meetings held in 2017 are presented 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 (DOE 2018). Meeting summaries from RAWG quarterly meetings held in 2018 are presented 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/R10/V1 (DOE 2019). Meeting summaries from RAWG quarterly meetings held in 2019 are presented 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/R11/V1 (DOE 2020). Meeting summaries from RAWG quarterly meetings held in 2020 are presented 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/R12/V1 (DOE 2021). Meeting summaries from RAWG quarterly meetings held in 2021 are presented 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/R13/V1 (DOE 2022).

The meeting summaries included here, in DOE 2017, in DOE 2018, in DOE 2019, in DOE 2020, and in DOE 2021, are provided for historical information to promote program consistency over time and facilitate succession planning. Meeting summaries may reflect document locations (e.g., table numbers) that have since been updated. The meeting summaries may not reflect information that currently is in the document.

Risk Assessment Working Group
Meeting Summary—March 3, 2021

Rich Bonczek ✓
Martin Clauberg ✓
Stefanie Fountain ✓
Bruce Ford ✓
LeAnne Garner
Chris Saranko ✓
Alexis Wiltfong ✓
Victor Weeks ✓
Tim Frederick ✓
Shanna Alexander ✓
Brett Thomas
Jana Dawson
Kristen Rapal ✓
Brian Begley ✓
Stephanie Brock ✓
Nathan Garner ✓
Brian Lainhart
Todd Mullins ✓
Tabitha Owens ✓
Chris Travis ✓

✓ Indicates member was present

Original meeting agenda items are provided followed by meeting notes; the meeting notes are provided in italics with action items noted in green.

1. Call for Issues from Risk Assessment Working Group (RAWG) Members

EPA provided questions on the RMD in December and January and is reviewing the historical context of the document and will provide additional feedback for the 2022 update discussions.

EPA provided a summary of items they will request be reviewed for update in the 2022 document; these will be discussed in more detail during the June and September RAWG meetings. Specifically, these items include revising the FY2022 document as necessary to incorporate information from recent updates to the Exposure Factors Handbook, adding information on the relevance of the Feeds and Feeding reference, and clarifying the reference for fish ingestion rates. ***The link to the 2020 Risk Methods Document and its Appendix E will be provided to the RAWG:***

- *Paducah Environmental Information Center: https://eic.pad.pppo.gov/*
- *Public (FRNP) Documents: https://pubdocs.pad.pppo.gov/*
- *2009-2020 Risk Methods Documents: https://pubdocs.pad.pppo.gov/?dir=Risk%20Methods%20Document*
- *2020 Human Health Risk Methods Document and Appendix E files: https://pubdocs.pad.pppo.gov/?dir=Risk%20Methods%20Document/RMD%202020*

2. Notes from 12/9/2020 Meeting

No comments were received on the December 9, 2020 meeting summary (emailed to the group on December 21, 2020). If there are no objections to these revisions and there are no additional comments, the meeting summary will be considered final and will appear in Appendix E of the 2022 Risk Methods Document (RMD).

No comments were received from the RAWG members on the December 9, 2020 meeting summary emailed to the group on December 21, 2020; this meeting summary is now considered final and will be included in Appendix E of the 2022 Risk Methods Document (RMD).

3. FY 2021 Schedule/Work Plan

Item/Activity	**Date**
~~Submit Work Plan (i.e., this schedule; will be included on 9/9/2020 Meeting Agenda for discussion)~~	~~9/9/2020~~
~~RAWG concurs with Work Plan (i.e., this schedule)~~	~~10/9/2020~~
~~Additional suggested revisions/corrections to Human Health (HH) Risk Methods Document (RMD) should be sent to Stefanie~~	~~10/23/2020~~
~~Submit HH Appendix A [i.e., Preliminary Remediation Goals (PRGs)] to RAWG for review~~	~~11/20/2020~~
~~Quarterly Meeting (December)~~	~~12/9/2020~~
~~Submit revised HH Main Text and HH Appendix B, D, and E to RAWG for review~~	~~12/17/2020~~
~~Comments due for HH Appendix A~~	~~1/11/2021~~
~~RAWG concurs with HH Appendix A~~	~~2/16/2021~~
~~Comments due for HH Main Text and HH Appendix B, D, and E~~	~~2/16/2021~~
Quarterly Meeting (March)	3/3/2021
RAWG concurs with HH Main Text and HH Appendix B, D, and E	4/9/2021
Submit Entire Revised HH RMD to RAWG for Review	4/16/2021
Comments due for entire revised HH RMD	5/14/2021
Quarterly Meeting (June)	6/2/2021
Submit HH RMD to FFA Managers (DOE/LX/07-0107&D2/R12/V1)	7/14/2021
FFA Managers acknowledge receipt of HH RMD	8/13/2021
Quarterly Meeting (September)	9/8/2021

Quarterly meetings will be Web/teleconference 8:30 a.m.–11:00 a.m. (Central), 9:30 a.m.–12:00 p.m. (Eastern)
Items shown in strikeout text are completed.

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

4. Revisions to RMD Appendix A and Comments Received

Revisions to RAIS since May 2019 were reviewed and updates made, as appropriate:

- Updates to antimony (toxicity changes to inhalation noncancer in ATSDR database)
- Updates to naphthalene (addition of oral cancer)
- Updates to Aroclor 1016 and 1248 (molecular weights)

Comment from KDEP received January 11, 2021

> KY suggests that more clarifying text be added to Appendix A 9h as the current text states the PFAS tables are not included in this appendix (suggesting they are available in another appendix) and an EPA link is provided for more information (suggesting that the information the reader is looking for can all be found at the EPA's PFAS internet site. Here is the text currently in Appendix A 9h: "Per- and polyfluoroalkyl substances (PFAS)—Screening values for PFAS are not included in tables in this appendix. For information concerning these substances see https://www.epa.gov/pfas."

Legacy references to Figure 1.1 in footnotes in Appendix A will be deleted. Figure 1.1 was removed in the 2013 RMD.

Because the text commented on was revised in FY2020 by the Paducah DOE Site Lead, the group agreed to not implement the comment received from KDEP on January 11, 2021; PFAS-related items will be revisited for the 2022 update.

The group discussed that Action Levels (ALs) are those levels above which actions should be considered, whereas no action is generally warranted when levels are below No Action levels (NALs). ***A text box addressing this will be added to the main text of the RMD.***

5. Revisions to RMD Main Text, Appendix B and Appendix D and Comments Received

Revisions were made to update reference call outs, dates, and to crosswalk updates from Appendix A.

KDEP did not have any comments on these portions of the document (email dated 2/15/2021).

The footnote "a" to the Table B.8, Volatilization Parameters will be deleted. Historical version of the RMD and this table included Kd values with this footnote. The Kd values are no longer included in the table and the footnote no longer applies.

Uncertainty regarding consumption of homegrown vegetables will be added to Section 3.3.7.1.

The group agreed to the proposed deletion of footnote "a" in Table B.8 in this year's update to the Risk Methods Document.

The group agreed to the proposed addition of a bullet on homegrown vegetables to Section 3.3.7.1 in this year's update to the Risk Methods Document.

6. Revisions to RMD Appendix E

The only proposed edits to Appendix E are the incorporation of the 2020 meeting summaries in section E.11. Similar to the discussion on the exposure point concentrations for air, any updates to Section E.9 (VISLs) will follow the development of the Vapor Intrusion project report.

The group agreed to this approach for Appendix E for this year's update to the Risk Methods Document.

7. C-400 Data

A request for topics was sent to the Working Group two weeks prior to the meeting (February 17, 2021). No topic requests were received prior to this meeting.

Discussion was held on interaction of the RAWG and the RMD with the C-400 project. This discussion included when scoping of the C-400 risk assessment would occur. Due to delays caused by the pandemic, this scoping is now expected to occur toward the end of the first quarter of FY2022. Also, it was noted that the results of scoping the C-400 risk assessment could lead to changes to the FY2022 RMD.

8. 2022 Update Topics for Discussion during the September 8, 2021 meeting

- From the December 2020 meeting, the equations for the exposure point concentrations are within the RMD Appendix D but are not specific to direct air sampling results. These will be incorporated into the HH RMD to Appendix D following the development of the Vapor Intrusion project report.

- Uranium identification number(s) in RAIS
- 2020 Census data
- Review of Information in E.2.2, E.2.3, E.2.4, and E.2.6
- Review of KY regulatory guidance (E.3)
- VISLs (E.8) following VI project report
- Toxicity values review (E.10)
- Chemical surrogates for PAHs
- Clarification of Footnote 5 on Page 2-1 regarding lifetime adult resident and child resident cancer-based values.
- Inclusion of a reference for the f_{oc} default values in the document in a location in addition to Appendix E.
- Addition of explanation on why older references for subsistence farming are used in the document.

The above items will be discussed during the June and September RAWG meetings. ***Fish ingestion rates as well as information and references for raising laying hens under the subsistence farming scenario and any updates to be included from the revised Exposure Factors Handbook will be added to the list.***

9. Watch Topics:

- **Volatile organics definitions used in RAIS**
  This needs to be watched to see if there are any impacts (especially for PCBs and PAHs). No additional updates at this time.

  The D2/R1 VI Work Plan, submitted and approved in December 2020, has been reviewed for relevant information to be discussed for potential inclusion in the FY21 RMD revision. Based upon work completed during the development of the revised QAPP for the D2/R1 VI Work Plan, no revisions to organics definitions are necessary. Any updates to Section E.9 (VISLs) will follow the development of the Vapor Intrusion project report.

  Field sampling is in progress and the heat is still on in the buildings.

- **Derivation of Risk-based Surface Water Effluent Limits**
  On December 31, 2020, EPA issued a letter to Oak Ridge Reservation (ORR) conveying the final decision resolving the ORR dispute on discharge to surface water of wastewaters generated during a response action under CERCLA at the ORR. Although that decision is specific to ORR, this topic is relevant to several near-term projects at the site and could have schedule impacts to those projects. Those potential impacts will be managed by those projects.

  The group discussed that the ORR dispute resolution and follow-on actions do not impact the in-progress revisions to the RMD. ***DOE agreed to send to EPA and KY the rad effluent materials developed in 2014-2015 by a working group.***

- **Status of EPA's Policy for Lead in Blood**
  The December 22, 2016 EPA Memorandum "Updated Scientific Considerations for Lead in Soil

Cleanups" on lead in blood was withdrawn in anticipation of a new policy, which is still being worked on and processed through the review and revision steps. As of the December 9, 2020 meeting, EPA was planning to issue an updated toxicokinetic model and the RAWG is tracking the status of the model.

Tim is tracking the issue and will keep the team posted on any developments.

Shanna will track this item for the group going forward. There were no new updates to report during the meeting although it is anticipated that changes are pending.

- **Mercury, Inorganic Salts**
  This needs to be watched because IRIS will be including updated toxicity information. Public comment period ended November 2019 and the IRIS revisions/updates are in process for finalization. Methylmercury was added to IRIS/FR docket in May 2020.

  Shanna will track this item for the group going forward. The draft is expected to be available in 2023 with external review scheduled for 2024. ***Based on the timeline, the group agreed to take this topic off the watch list.***

- **PFAS.** EPA has issued PFAS Groundwater Guidance for Federal Cleanup Programs and companion press releases regarding testing for PFAS in drinking water. Links to the press releases for this information are below.

  https://www.epa.gov/newsreleases/epa-announces-new-method-test-additional-pfas-drinking-water

  https://www.epa.gov/newsreleases/epa-releases-pfas-groundwater-guidance-federal-cleanup-programs-fulfilling-pfas-action

  DOE has included PFAS groundwater sample results from the Fire Training Area in the 2019 ASER that is planned to be publicly available in the fall. DOE HQ is developing a list of PFAS search terms to help sites research historical PFAS uses. Several PFAS compounds have been added to IRIS/FR docket.

  PPPO responded to a survey from DOE Headquarters in December 2020. The blank survey was discussed with the Groundwater Modeling Working Group on January 13, 2021 and a copy of the blank survey is attached to this agenda.

  Of relevance to this group and any investigation that would be performed, if a project were developed: sampling methodology (e.g., specialized sampling protocols versus site standard sampling protocols), screening limits, analytical methods. Data collection protocols and analytical methods would be discussed in the P-QAPP Working Group.

  After hearing and discussing the PPPO responses to the survey from DOE Headquarters, the group discussed the status of PFAS work ongoing or planned at other sites in the DOE Complex. There is currently no regulatory value for PFAS and the science behind the numbers being used by *some regulatory bodies is controversial. Once a reliable screening value(s) is available, DOE will provide a proposed update to the RMD for the group to consider. EPA relayed that an MCL is expected in the near future along with a determination that PFAS should be added to the listing of hazardous substances. EPA also expects guidance on disposal/destruction of PFAS in the near future.*

10. Poll RAWG Members/Open Discussion

Attachment 1

Blank PFAS Survey

Emerging Contaminants: Per- and Polyfluoroalkyl Substances (PFAS)
General Assessment Survey for DOE-EM Sites

On-Site Drinking Water

- If the site provides potable drinking water, check all boxes that apply:
  ☐ Population served by public water system (PWS) is under 10,000
  ☐ Population served by PWS is over 10,000
  ☐ Site provides potable water to residential wells
  ☐ Site does not provide drinking water to workforce

- Has drinking water at the site been sampled for PFAS?
  ☐ Yes, no PFAS were detected
  ☐ Yes, PFAS were detected
  ☐ No, drinking water has not been sampled

PFAS Usage

- Does your site currently have or previously had any of the following facilities, events, and/or disposal units?
  ☐ Fire training facility
  ☐ Fire department
  ☐ Presence of AFFF-based fire suppression system
  ☐ Documented release of AFFF
  ☐ Uranium enrichment
  ☐ Metal plating processing
  ☐ Plutonium production
  ☐ Manhattan project liquid discharges
  ☐ Cold War era liquid waste discharges
  ☐ Landfill
  ☐ Wastewater treatment plant

- Does your site track and maintain past and present inventories of PFAS?
  ☐ Yes, the site has more than 100 pounds of any one PFAS
  ☐ Yes, the site does not have more than 100 pounds of any one PFAS
  ☐ No

On-Site Sampling/Monitoring Equipment

- Check all environmental media that has been tested at the site with positive PFAS results:
  ☐ Drinking water
  ☐ Surface water
  ☐ Groundwater
  ☐ Soil
  ☐ Biota
  ☐ Wastewater

☐ Leachate
☐ Sediment
☐ Biosolids/sludge
☐ No positive detections
☐ The site has not sampled

- Are on site PFAS concentrations actively monitored?
  ☐ Yes, in drinking water
  ☐ Yes, in surface water
  ☐ Yes, in groundwater
  ☐ Yes, in soil
  ☐ Yes, in biota
  ☐ Yes, in wastewater
  ☐ Yes, in leachate
  ☐ Yes, in sediment
  ☐ Yes, in biosolids/sludge
  ☐ No; previous positive detections, but not actively monitoring
  ☐ No; have not detected or sampled for PFAS

- Are there analytical results available from PFAS sampling?
  ☐ Yes
  ☐ No

- Have PFAS been measured beyond the DOE site boundary?
  ☐ Yes
  ☐ No

- If your site has not yet sampled for PFAS, do you currently use monitoring equipment that contains PFAS (e.g. Teflon)? Select all that apply.
  ☐ Yes, new monitoring wells would be required for PFAS sampling
  ☐ Yes, monitoring wells liners would need to be replaced for PFAS sampling
  ☐ Yes, new sampling supplies would be required for PFAS sampling
  ☐ Yes, new PPE would be required for PFAS sampling
  ☐ Other ____
  ☐ No

- If your site has sampled for PFAS, was sampling conducted with the appropriate methods to avoid inadvertent contamination (e.g. proper PPE, monitoring equipment, and sampling tools)?
  ☐ Yes
  ☐ No

Emerging Contaminants: Per- and Polyfluoroalkyl Substances (PFAS)
General Assessment Survey for DOE-EM Sites

Regulatory & Stakeholder

- Has the site been contacted by regulators/stakeholders regarding PFAS?
  ☐ Federal
  ☐ State
  ☐ Tribal Nations
  ☐ Local
  ☐ Other ____
  ☐ No

- Have regulators/stakeholders prompted any of the following responses?
  ☐ Search for historical uses of AFFF or other PFAS related materials
  ☐ Include PFAS analysis in current monitoring program
  ☐ Site sampling for PFAS
  ☐ Other ____

Risk Assessment Working Group
Meeting Summary—June 2, 2021

DOE	**EPA**	**Kentucky**	**FRNP**
Rich Bonczek ✓	Victor Weeks ✓	Brian Begley ✓	Stefanie Fountain ✓
	Tim Frederick	Stephanie Brock	Bruce Ford
ETAS	Shanna Alexander ✓	Nathan Garner ✓	LeAnne Garner
Martin Clauberg ✓	Brett Thomas	Brian Lainhart	Chris Saranko ✓
	Mac McRae ✓	Todd Mullins ✓	Alexis Wiltfong
	Kristen Rapal ✓	Tabitha Owens ✓	
		Bart Schaffer ✓	
		Chris Travis	

✓ Indicates member was present

Original meeting agenda items are provided followed by meeting notes; the meeting notes are provided in italics with action items noted in green.

1. Call for Issues from Risk Assessment Working Group (RAWG) Members

No topics were raised by the working group.

2. Notes from 3/6/2021 Meeting

No comments were received on the March 6, 2021 meeting summary (emailed to the group on March 15, 2021). If there are no additional comments, the meeting summary will be considered final and will appear in Appendix E of the 2022 Risk Methods Document (RMD).

No comments were received to the March 6, 2021 Meeting Summary. This summary is now final.

3. FY 2021 Schedule/Work Plan

Item/Activity	Date
~~Submit Work Plan (i.e., this schedule; will be included on 9/9/2020 Meeting Agenda for discussion)~~	~~9/9/2020~~
~~RAWG concurs with Work Plan (i.e., this schedule)~~	~~10/9/2020~~
~~Additional suggested revisions/corrections to Human Health (HH) Risk Methods Document (RMD) should be sent to Stefanie~~	~~10/23/2020~~
~~Submit HH Appendix A [i.e., Preliminary Remediation Goals (PRGs)] to RAWG for review~~	~~11/20/2020~~
~~Quarterly Meeting (December)~~	~~12/9/2020~~
~~Submit revised HH Main Text and HH Appendix B, D, and E to RAWG for review~~	~~12/17/2020~~
~~Comments due for HH Appendix A~~	~~1/11/2021~~
~~RAWG concurs with HH Appendix A~~	~~2/16/2021~~

Item/Activity	**Date**
~~Comments due for HH Main Text and HH Appendix B, D, and E~~	~~2/16/2021~~
~~Quarterly Meeting (March)~~	~~3/3/2021~~
~~RAWG concurs with HH Main Text and HH Appendix B, D, and E~~	~~4/9/2021~~
~~Submit Entire Revised HH RMD to RAWG for Review~~	~~4/16/2021~~
~~Comments due for entire revised HH RMD~~	~~5/14/2021~~
Quarterly Meeting (June)	6/2/2021
Submit HH RMD to FFA Managers (DOE/LX/07-0107&D2/R11/V1)	7/14/2021
FFA Managers acknowledge receipt of HH RMD	8/13/2021
Quarterly Meeting (September)	9/8/2021

Quarterly meetings will be Web/teleconference 8:30 a.m.–11:00 a.m. (Central), 9:30 a.m.–12:00 p.m. (Eastern)

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

No comments were received on the schedule.

4. Comments received on the entire 2021 HH RMD

Document was sent to the group on April 16, 2020; comments were due May 14, 2020.

- EPA has completed their review and had no additional comments.
- KY has completed their review and had no additional comments.
- DOE has completed their review and had no additional comments.

No comments were received on the 2021 HH RMD. The 2021 HH RMD will finalized for issue by July 14, 2021.

5. C-400 Data

A request for topics was sent to the Working Group two weeks prior to the meeting (May 20, 2021).

Scoping for the C-400 risk assessment is expected to occur toward the end of the first quarter of FY2022. Agreements arrived at during scoping the C-400 risk assessment could lead to changes to the FY2022 RMD.

No comments were received on this topic during the meeting.

6. 2022 Update Topics for Discussion during the September 8, 2021 meeting

- From the December 2020 meeting, the equations for the exposure point concentrations are within the RMD Appendix D but are not specific to direct air sampling results. These will be incorporated into the HH RMD to Appendix D following the development of the Vapor Intrusion project report.
- Uranium identification number(s) in RAIS

- 2020 Census data
- Review of Information in E.2.2, E.2.3, E.2.4, and E.2.6
- Review of KY regulatory guidance (E.3)
- VISLs (E.8) following VI project report
- Toxicity values review (E.10)
- Chemical surrogates for PAHs
- Clarification of Footnote 5 on Page 2-1 regarding lifetime adult resident and child resident cancer-based values.
- Inclusion of a reference for the f_{oc} default values in the document in a location in addition to Appendix E.
- Addition of explanation on why older references for livestock production and dairy are used in the document.
- Fish ingestion rates as well as information and references for raising laying hens under the farming scenario and any updates to be included from the revised Exposure Factors Handbook.

No comments were received on this topic during the meeting.

7. Watch Topics:

- **Volatile organics definitions used in RAIS**
  This needs to be watched to see if there are any impacts (especially for PCBs and PAHs). No additional updates at this time.

  The D2/R1 VI Work Plan, submitted and approved in December 2020, was been reviewed for relevant information to be discussed for potential inclusion in the FY21 RMD revision. Based upon work completed during the development of the revised QAPP for the D2/R1 VI Work Plan, no revisions to organics definitions were necessary. Any updates to Section E.9 (VISLs) will follow the development of the Vapor Intrusion project report. Field sampling was completed in March 2021 and a scoping meeting for the report was held on April 27, 2021. The report is being developed and the D1 is due to be submitted on September 30, 2021.

  No comments were received on this topic during the meeting.

- **Derivation of Risk-based Surface Water Effluent Limits**
  On December 31, 2020, EPA issued a letter to Oak Ridge Reservation (ORR) conveying the final decision resolving the ORR dispute on discharge to surface water of wastewaters generated during a response action under CERCLA at the ORR. Although that decision is specific to ORR, this topic is relevant to several near-term projects at the site and could have schedule impacts to those projects. Those potential impacts will be managed by those projects.

  On March 8, 2021, DOE provided to EPA and KY the rad effluent materials developed in 2014-2015 by a working group.

  There is interest among the FFA parties in resuming the working group activities on this topic. DOE discussed that the Oak Ridge project anticipates having draft screening values by August and *that these may be available for discussion by the RAWG during the September meeting. The RAWG discussed that the Oak Ridge project is using 10^{-5} risk for screening whereas Kentucky typically uses 10^{-6} risk.*

- **Status of EPA's Policy for Lead in Blood**
    - The December 22, 2016 EPA Memorandum "Updated Scientific Considerations for Lead in Soil Cleanups" on lead in blood was withdrawn in anticipation of a new policy, which is still being worked on and processed through the review and revision steps. As of the December 9, 2020 meeting, EPA was planning to issue an updated toxicokinetic model and the RAWG is tracking the status of the model.

      Shanna is tracking the issue and will keep the team posted on any developments.

    - Victor provided the May 4, 2021 EPA Memorandum "Release of Integrated Exposure Uptake Biokinetic Model for Lead in Children Version 2.0 and Revisions to the Default Parameters for the IEUBK Model for Lead in U.S. Children" (Attachment 1).

      This update will be crosswalked to the HH RMD and any proposed revisions to the FY2022 HH RMD will be provided during the August meeting for discussion with the working group.

  The IEUBK memorandum did not include an indication of any changes to PRGs or RSLs. EPA understands that new screening levels are in review and anticipated by the end of the year and likely to be lower than the current value of 400 mg/kg, perhaps around 200 mg/kg. The HH RMD approach is to compare individual results against the screening value and if all results are below the screening value, the model is not employed. DOE discussed that prior lead cleanup activities (i.e., the firing range) used a screening value of 80 mg/kg to account for the use of composite samples (so that no single sample could exceed the screening value at the time of the cleanup). DOE does not anticipate that a revised, lower screening value as discussed during the meeting would have an impact on any prior work.

- **PFAS**
  EPA has issued PFAS Groundwater Guidance for Federal Cleanup Programs and companion press releases regarding testing for PFAS in drinking water. Links to the press releases for this information are below.

  https://www.epa.gov/newsreleases/epa-announces-new-method-test-additional-pfas-drinking-water

  https://www.epa.gov/newsreleases/epa-releases-pfas-groundwater-guidance-federal-cleanup-programs-fulfilling-pfas-action

  DOE included PFAS groundwater sample results from the Fire Training Area in the 2019 ASER (https://pubdocs.pad.pppo.gov/?dir=Annual%20Site%20Environmental%20Report%20%28ASER%29). DOE HQ developed a list of PFAS search terms to help sites research historical PFAS uses. Several PFAS compounds have been added to IRIS/FR docket.

PPPO responded to a survey from DOE Headquarters in December 2020. The blank survey was discussed with the Groundwater Modeling Working Group on January 13, 2021.

Of relevance to this group and any investigation that would be performed, if a project were developed: sampling methodology (e.g., specialized sampling protocols versus site standard sampling protocols), screening limits, analytical methods. Data collection protocols and analytical methods would be discussed in the P-QAPP Working Group.

There is currently no regulatory value for PFAS and the science behind the numbers being used by some regulatory bodies is controversial. Once a reliable screening value(s) is available, DOE will provide a proposed update to the RMD for the group to consider. EPA relayed that an MCL is expected in the near future along with a determination that PFAS should be added to the listing of hazardous substances. EPA also expects guidance on disposal/destruction of PFAS in the near future.

Victor provided the March 11, 2021 Brookhaven National Laboratory presentation: "Update: Emerging Contaminants of Concern in Groundwater at Brookhaven National Laboratory" (Attachment 2).

EPA has drafted a letter to the PGDP DOE Site Lead on a recommendation for a site-wide evaluation of PFAS and anticipates sending the letter in June.

The RAWG discussed a potential approach to such an evaluation could be to perform sampling using traditional or slightly modified sampling techniques as a screening step followed by sampling at elevated concentration locations using PFAS-specific sampling techniques. The site sewage treatment plant would be an area of interest for this type of evaluation.

KY reported that they did not find any information or evidence that KY is developing screening values for drinking water or wastewater.

Rich will provide contact information for the Brookhaven National Laboratory presentation. *An update on Brookhaven is planned for the July DOE PFAS Working Group Meeting.*

8. Poll RAWG Members/Open Discussion

No discussion topics were raised by the RAWG during the meeting.

Attachment 1

May 11, 2021 EPA Memorandum: Release of Integrated Exposure Uptake Biokinetic Model for Lead in Children Version 2.0 and Revisions to the Default Parameters for the IEUBK Model for Lead in U.S. Children

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

May 4, 2021

OFFICE OF
LAND AND EMERGENCY
MANAGEMENT

MEMORANDUM

SUBJECT: Release of Integrated Exposure Uptake Biokinetic Model for Lead in Children Version 2.0 and Revisions to the Default Parameters for the IEUBK Model for Lead in U.S. Children

FROM: Larry E. Douchand, Director
Office of Superfund Remediation and Technology Innovation

TO: Superfund National Policy Managers, Regions 1-10

PURPOSE

The purpose of this memorandum is to transmit the Integrated Exposure, Uptake, Biokinetic Model for Lead in Children (IEUBK) Version 2.0 and the supporting documentation for the model update and evaluation. This documentation includes the user's guide, memorandum reviewing values for six IEUBK default parameters and peer-reviewed reports documenting the technical basis for updating the default parameters.

BACKGROUND

Since 1994, the Office of Land and Emergency Management (OLEM; formerly known as the Office of Solid Waste and Emergency Response), has recommended the IEUBK as a risk assessment tool to support environmental remediation decisions at current and future anticipated residential sites. The IEUBK model uses empirical data from numerous studies of lead uptake and biokinetics, children's contact and intake rates with contaminated media and data on the presence and behavior of environmental lead to predict a plausible distribution centered on the geometric mean of blood lead levels (PbB) for a hypothetical child or population of children.

The IEUBK model predicts PbB in young children (age less than 84 months) exposed to lead from several sources and routes. It uses more than 100 parameters that are initially set to default values. Of these, there are 46 parameters that the user may modify based on site-specific data. The remainder are internal parameters that are unavailable for modification. Default parameters are intended to provide a scientifically based, nationally representative values for lead exposure and corresponding lead intake in children in the United States. The parameters in the IEUBK Model (Version 1.1, build 11) are based on data ranging from the 1970s to the 1990s.

To stay scientifically relevant, the Technical Review Workgroup - Lead Committee (TRW-Lead) reviewed the basis for default values and evaluated the model. The default values for the following five key exposure parameters were revised based on the most recent available data:

- Soil and Dust Ingestion Rate,
- Water Consumption,
- Water Lead Concentration,
- Inhalation Rate and
- Dietary Lead.

Subsequently, these five parameters were externally peer reviewed, and EPA's Office of Research and Development led a second validation of the soil and dust ingestion rate; the lead bioavailability default value was peer reviewed and unchanged.

IMPLEMENTATION

The IEUBK version 2.0 and updated default parameters should be used in risk assessments of children's residential lead exposures and as the starting point for site-specific risk management decisions. The model can be downloaded at https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals. Supporting documents and other information related to addressing lead in soil can be found on the Internet at https://www.epa.gov/superfund/lead-superfund-sites-technical-assistance. Please contact Michele Burgess at Burgess.Michele@epa.gov or (703) 603-9003 if you have questions or concerns.

cc: Barry Breen, OLEM
Carlton Waterhouse, OLEM
Dawn Banks, OLEM/PARMS
Kathleen Salyer, OLEM/OEM
Carolyn Hoskinson, OLEM/ORCR
David Lloyd, OLEM/OBLR
Greg Gervais, OLEM/FFRRO
Mark Barolo, OLEM/OUST
Cyndy Mackey, OECA/OSRE
Karin Leff, OECA/FFEO
Lorie Schmidt, OGC/SEWRLO
OSRTI Managers
NARPM Co-Chairs
TRW-lead Committee Members

Attachment 2

March 11, 2021 Brookhaven National Laboratory Presentation

Update: Emerging Contaminants of Concern in Groundwater at Brookhaven National Laboratory

Community Advisory Council Meeting

March 11, 2021

Doug Paquette, Environmental Protection Division

Agenda

- Update on potable water supply well monitoring and treatment systems
- Current understanding of extent of Per- and Polyfluoroalkyl Substances (PFAS) and 1,4-dioxane in groundwater
- Planned installation of two PFAS treatment systems
- Integration of PFAS and 1,4-dioxane remedial actions into the ongoing CERCLA program

Emerging Contaminants of Concern

PFAS

- From 1966-2008, BNL used firefighting foam that contained PFAS for training and fire suppression systems
  - PFAS can persist in soils and groundwater for long periods of time
  - PFAS contaminated water can be effectively treated by using standard granular activated carbon filters or ion exchange resins

1,4-Dioxane

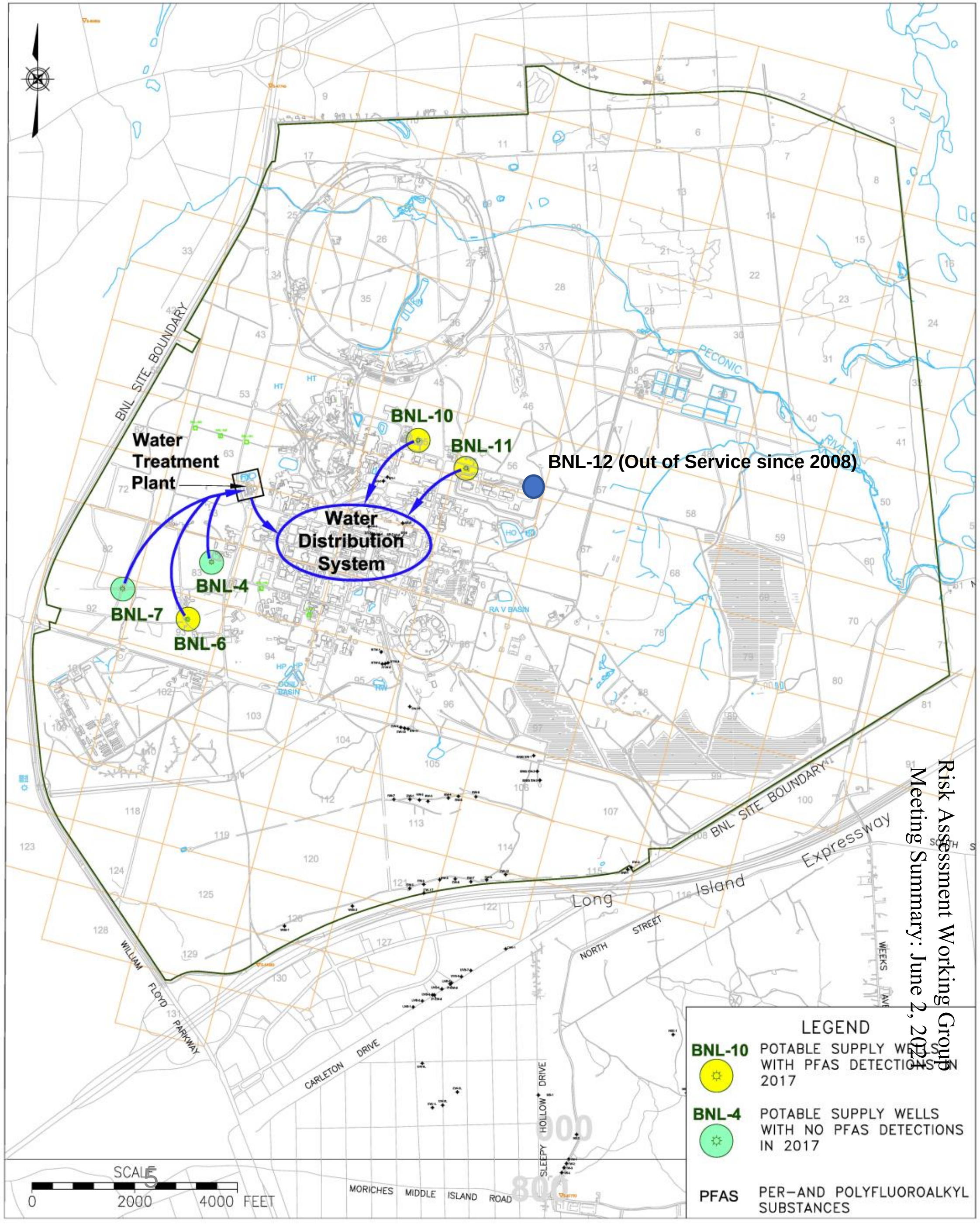
- 1,4-Dioxane was used as a stabilizing chemical for the solvent 1,1,1-Trichloroethane (TCA)
  - TCA has impacted groundwater quality at BNL and is being actively remediated
  - 1,4-Dioxane contaminated groundwater is difficult and expensive to treat
  - BNL's existing treatment systems are not effective for 1,4-dioxane

NYS Drinking Water Standards for PFAS and 1,4-Dioxane

- In August 2020, NYS established drinking water standards for:
  - PFOS (perfluorooctane sulfonate) at **10 ng/L** (nanograms per liter or parts per trillion)
  - PFOA (perfluorooctanoic acid) at **10 ng/L**
  - 1,4-Dioxane at **1 µg/L** (micrograms per liter or parts per billion)

BNL Water Supply Wells

- In March 2017, Suffolk County tested water samples from BNL's five operating potable water wells for PFAS
- PFAS were detected in three wells (BNL-6, BNL-10 and BNL-11)
  - PFOS detected at concentrations up to 23 ng/L



Status of BNL Water Supply Wells

- BNL is now testing the supply wells for PFAS and 1,4-dioxane on a quarterly basis
  - PFOS concentrations are above 10 ng/L in supply wells BNL-6, BNL-10 and BNL-11
  - In June 2018, BNL placed restrictions on use of BNL-6 because the combined PFOS and PFOA concentrations were almost 70 ng/L*
  - BNL-4 will no longer be used due to its proximity to current firehouse PFAS source area and plume
  - 1,4-Dioxane is not impacting the wells
- 2019 – BNL started work to return to service granular activated carbon filters to remove PFOS and PFOA
  - Filters at BNL-11 were back in service in late 2020
  - Filters at BNL-10 will be back in service June 2021
    - NYSDOH granted a temporary “deferral” from the new standards while the work on the carbon filters continues. BNL must follow public notification and reporting requirements
  - BNL-12 will be back in service by October 2021

Carbon Filters at BNL-11

In the 1980’s, carbon filters were installed on three supply wells to remove VOCs. They were taken out of service ~10 years ago

*EPA Health Advisory Level is 70 ng/L for combined concentrations of PFOS and PFOA

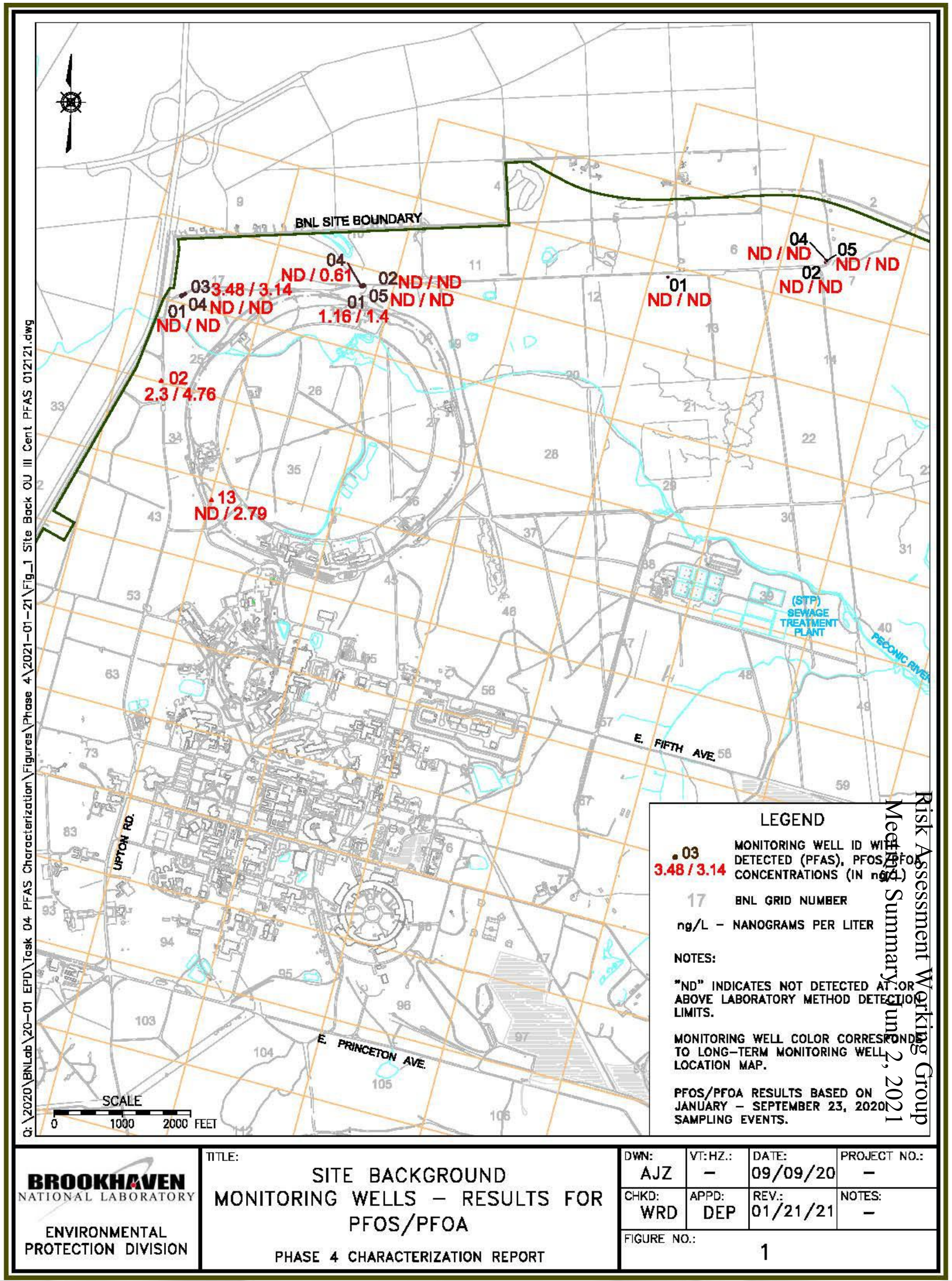
Understanding the Extent of PFAS and 1,4-Dioxane Contamination in Groundwater

- Phase 4 Project:
  - During 2020, BNL completed a comprehensive testing program for PFAS and 1,4-dioxane:
    - Sampled 360 on-site and off-site monitoring wells
      - Selected from a network of approximately 1,200 wells
    - Sampled on-site and off-site groundwater extraction wells and treatment system influent and effluent
    - Sampled Sewage Treatment Plant influent and effluent
- Phase 5/Time Critical Removal Action (TCRA) Project:
  - From July 2020-January 2021, BNL completed a detailed characterization of areas downgradient of the current and former firehouse facilities where high levels of PFAS are present
  - Results are being used to design two groundwater treatment systems

PFOS/PFOA and 1,4-Dioxane

(Northern/Background Area)

- Several low-level detections of PFOS and PFOA (<5 ng/L)
  - Data gap in north-central area
- No detections of 1,4-dioxane



LEGEND

03 3.48 / 3.14 — MONITORING WELL ID WITH DETECTED (PFAS), PFOS/PFOA CONCENTRATIONS (IN ng/L)

17 — BNL GRID NUMBER

ng/L – NANOGRAMS PER LITER

NOTES:

"ND" INDICATES NOT DETECTED AT OR ABOVE LABORATORY METHOD DETECTION LIMITS.

MONITORING WELL COLOR CORRESPONDS TO LONG–TERM MONITORING WELL LOCATION MAP.

PFOS/PFOA RESULTS BASED ON JANUARY – SEPTEMBER 23, 2020 SAMPLING EVENTS.

BROOKHAVEN NATIONAL LABORATORY
ENVIRONMENTAL PROTECTION DIVISION

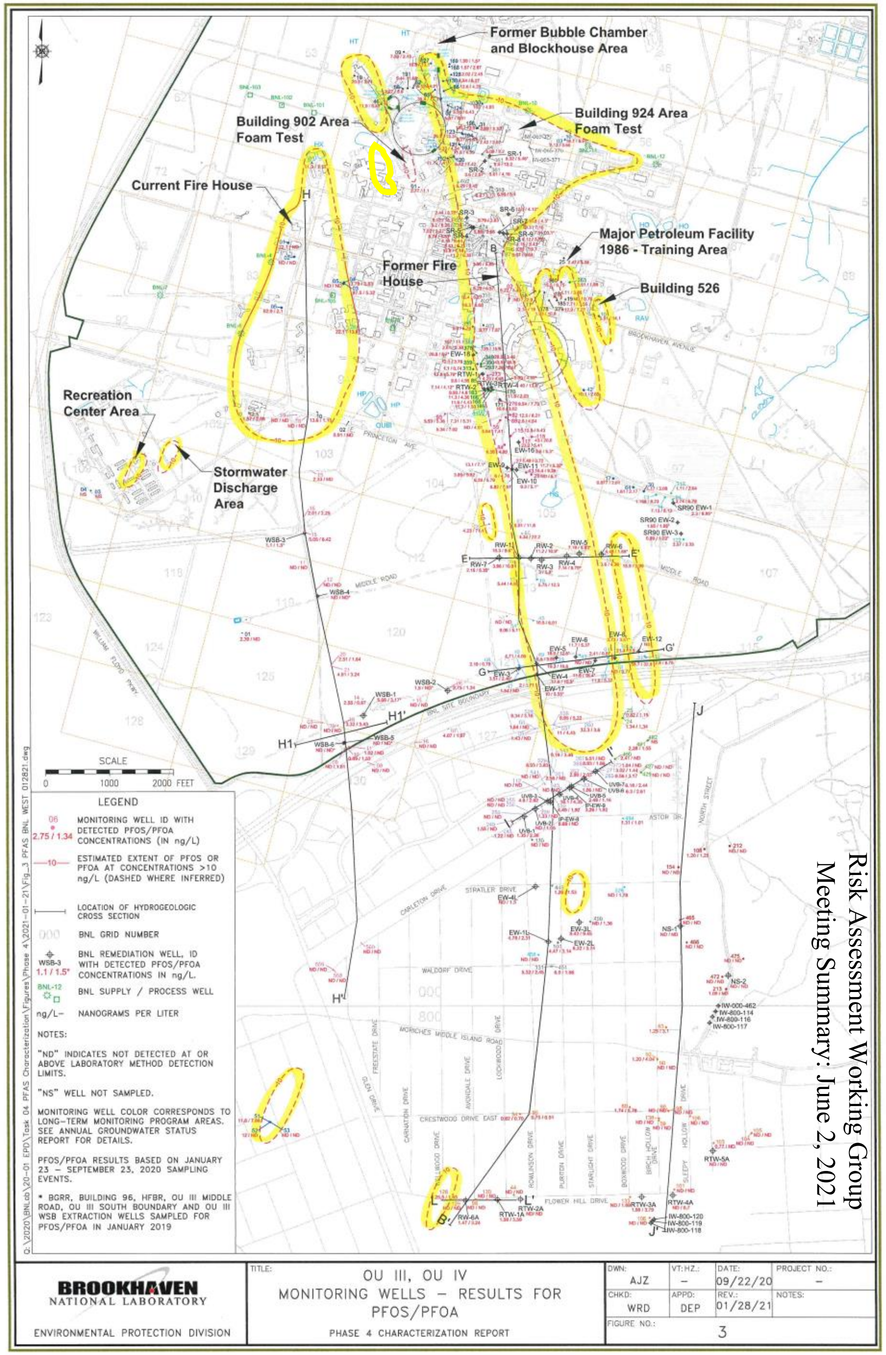
TITLE: SITE BACKGROUND MONITORING WELLS – RESULTS FOR PFOS/PFOA
PHASE 4 CHARACTERIZATION REPORT

DWN:	VT:HZ.:	DATE:	PROJECT NO.:
AJZ	–	09/09/20	–
CHKD:	APPD:	REV.:	NOTES:
WRD	DEP	01/21/21	–

FIGURE NO.: 1

PFOS/PFOA
(West-Central Area)

- Numerous detections of PFOS or PFOA >10 ng/L
  - Associated with firefighting foam training areas and foam releases from fire suppression systems
  - Yellow outlines represent estimated extent of PFOS or PFOA >10 ng/L
  - Additional characterization is required in several areas
- High concentration areas downgradient of the current and former firehouse facilities were characterized in more detail during the Phase 5/TCRA project
- Several off-site detections may be due to other sources



NOTES:

"ND" INDICATES NOT DETECTED AT OR ABOVE LABORATORY METHOD DETECTION LIMITS.

"NS" WELL NOT SAMPLED.

MONITORING WELL COLOR CORRESPONDS TO LONG-TERM MONITORING PROGRAM AREAS. SEE ANNUAL GROUNDWATER STATUS REPORT FOR DETAILS.

PFOS/PFOA RESULTS BASED ON JANUARY 23 - SEPTEMBER 23, 2020 SAMPLING EVENTS.

* BGRR, BUILDING 96, HFBR, OU III MIDDLE ROAD, OU III SOUTH BOUNDARY AND OU III WSB EXTRACTION WELLS SAMPLED FOR PFOS/PFOA IN JANUARY 2019

BROOKHAVEN NATIONAL LABORATORY
ENVIRONMENTAL PROTECTION DIVISION

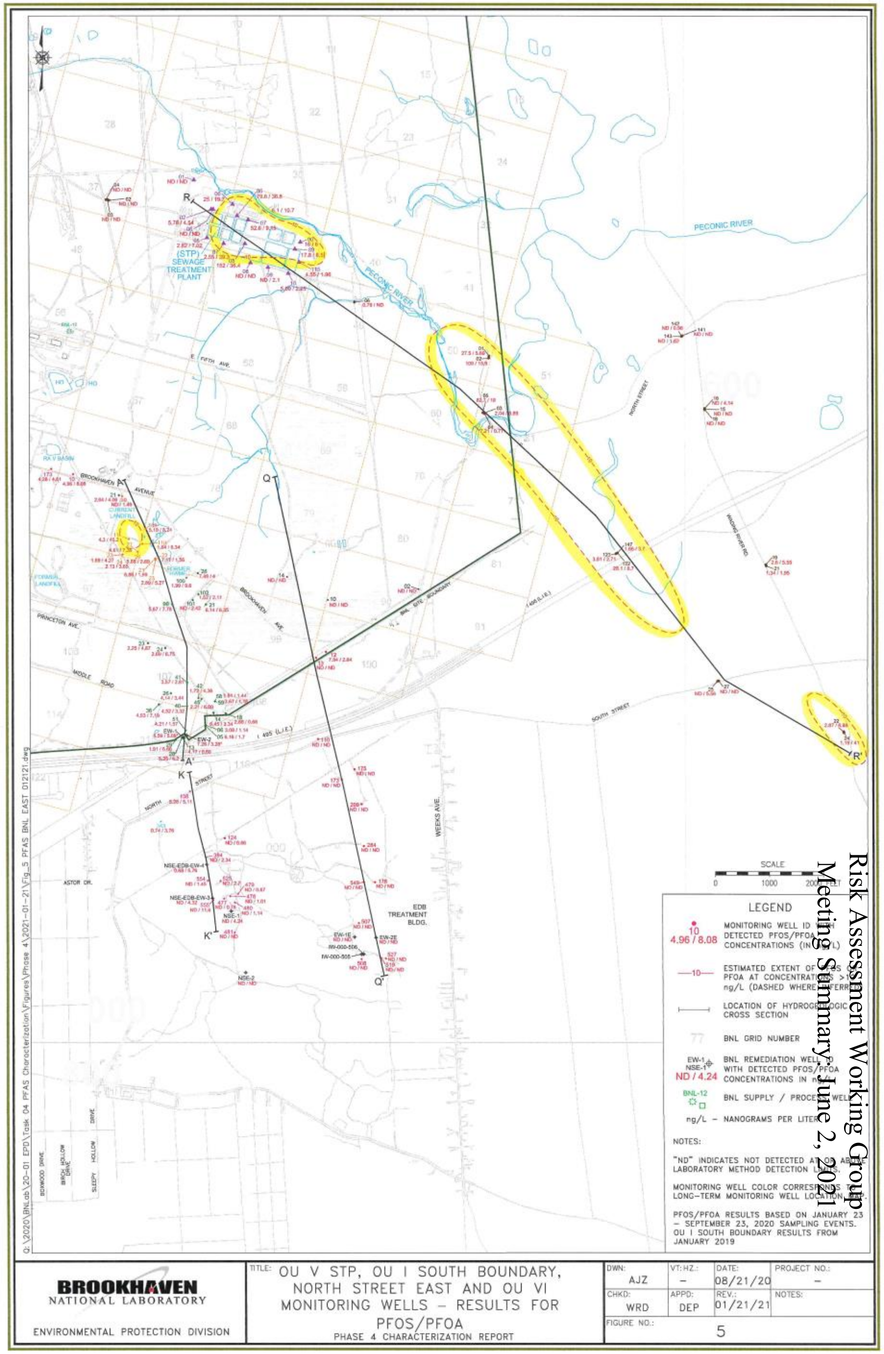
TITLE: OU III, OU IV MONITORING WELLS - RESULTS FOR PFOS/PFOA
PHASE 4 CHARACTERIZATION REPORT

DWN:	VT:HZ.:	DATE:	PROJECT NO.:
AJZ	–	09/22/20	–
CHKD:	APPD:	REV.:	NOTES:
WRD	DEP	01/28/21	
FIGURE NO.: 3			

PFOS/PFOA

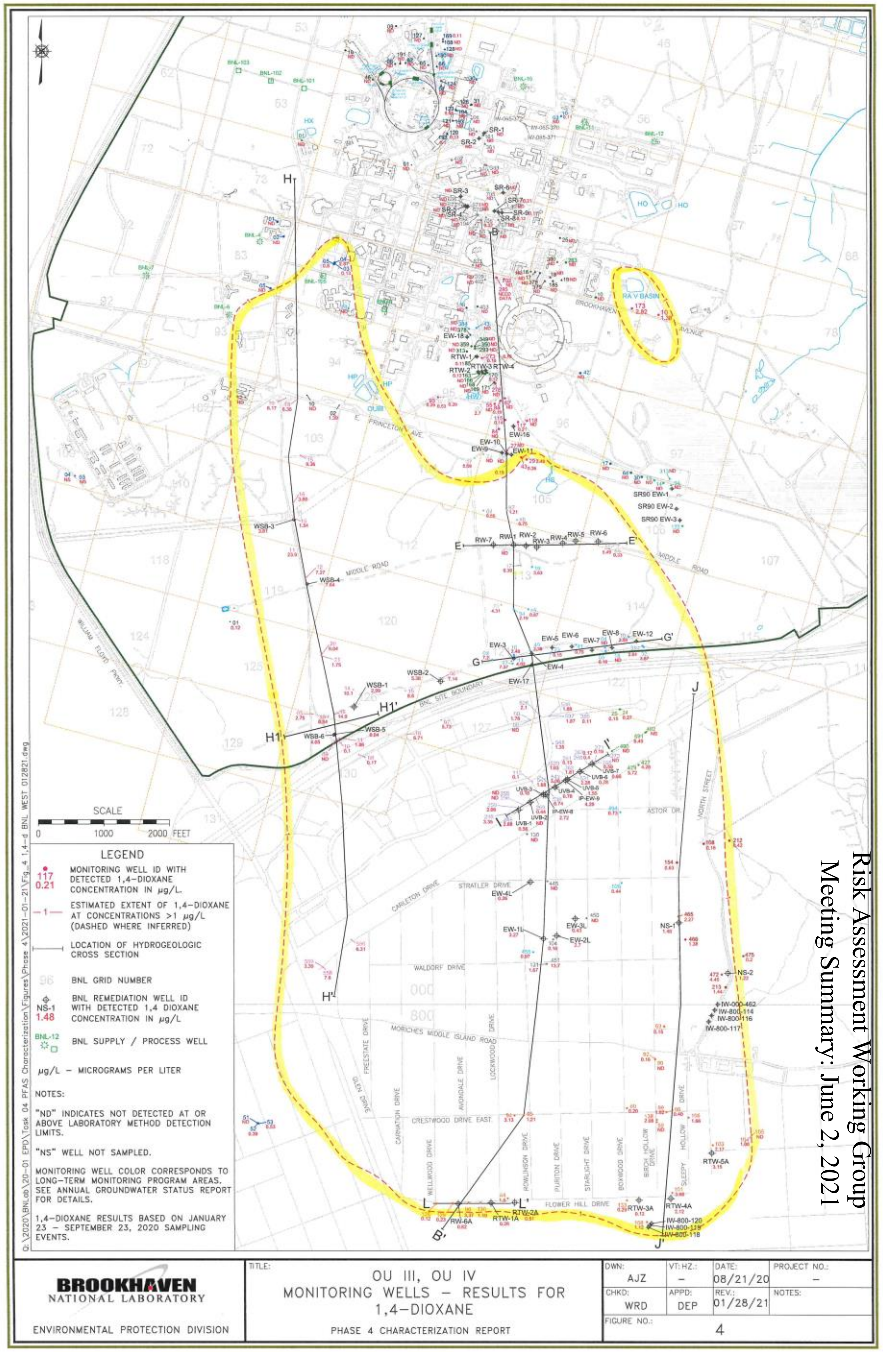
(Eastern Area)

- PFAS were detected in several areas not used for firefighter training
  - Current Landfill
    - PFOA up to 45 ng/L
  - Former STP filter bed area
    - PFOS up to 154 ng/L
  - Former OU V VOC monitoring area
    - Site boundary - PFOS up to 109 ng/L
    - Off-site – PFOS up to 28 ng/L. PFOA up to 41 ng/L
- PFAS discharged to the sanitary system impacted groundwater at the STP and downgradient areas
  - Potable water that contained PFAS was used for sanitation.
  - Possible foam discharges to floor drains at the current firehouse
  - PFOS and PFOA in STP effluent is currently <10 ng/L



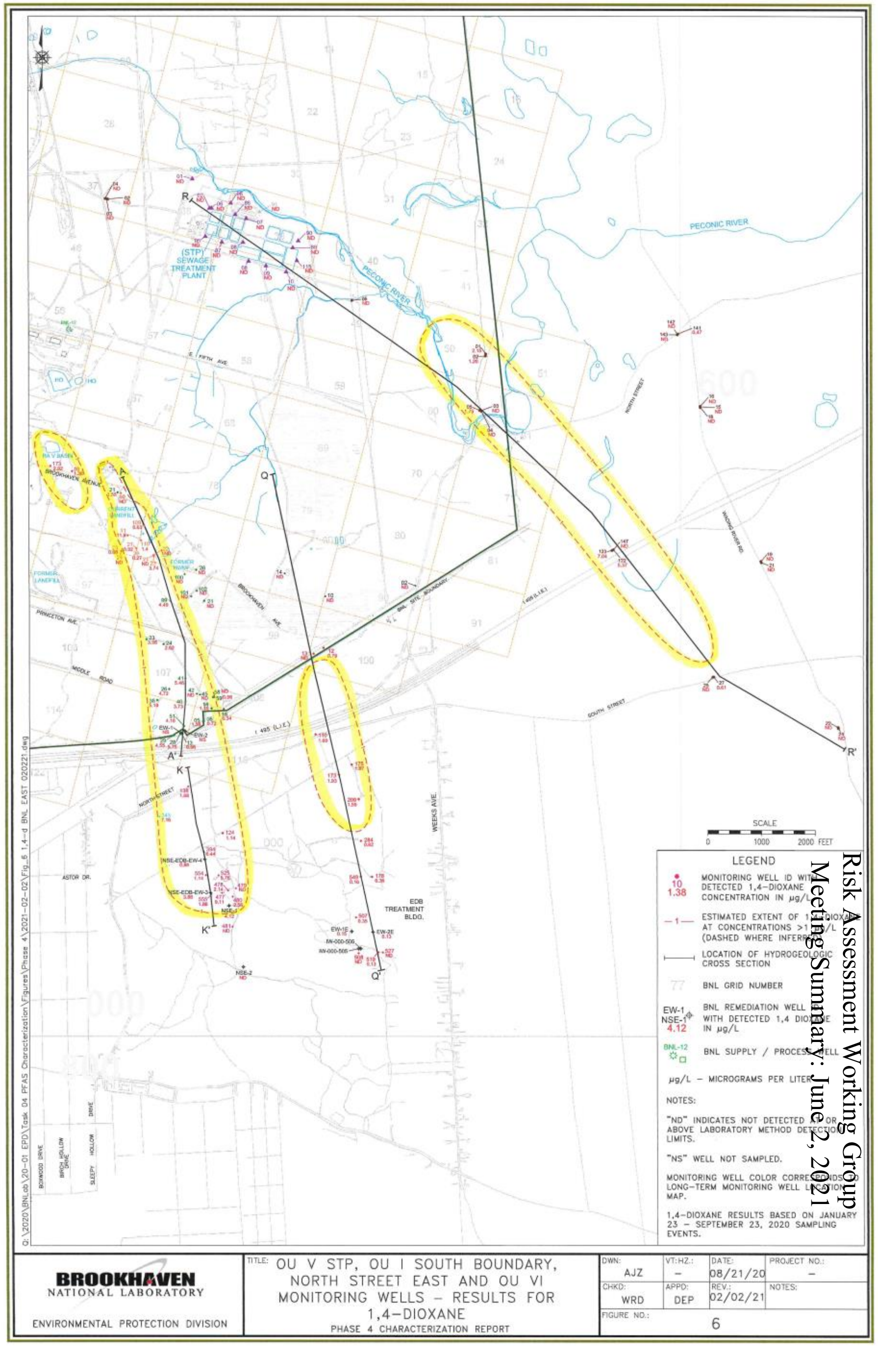
1,4-Dioxane
(West-Central Area)

- 1,4-Dioxane detected >1.0 µg/L in many wells, from the south-central area of the site to the Airport treatment system
    - Yellow outlines represent estimated extent of 1,4-dioxane >1.0 µg/L
    - There are data gaps that need to be filled during future work
- Concentrations generally <10 µg/L. Highest was ~25 µg/L in a Western South Boundary monitoring well
- Concentrations >1 µg/L in on-site and off-site groundwater extraction wells and treatment system effluent
    - Effluent is discharged to basins or injection wells
    - Possible impacts from these discharges detected at several basins



1,4-Dioxane
(Eastern Area)

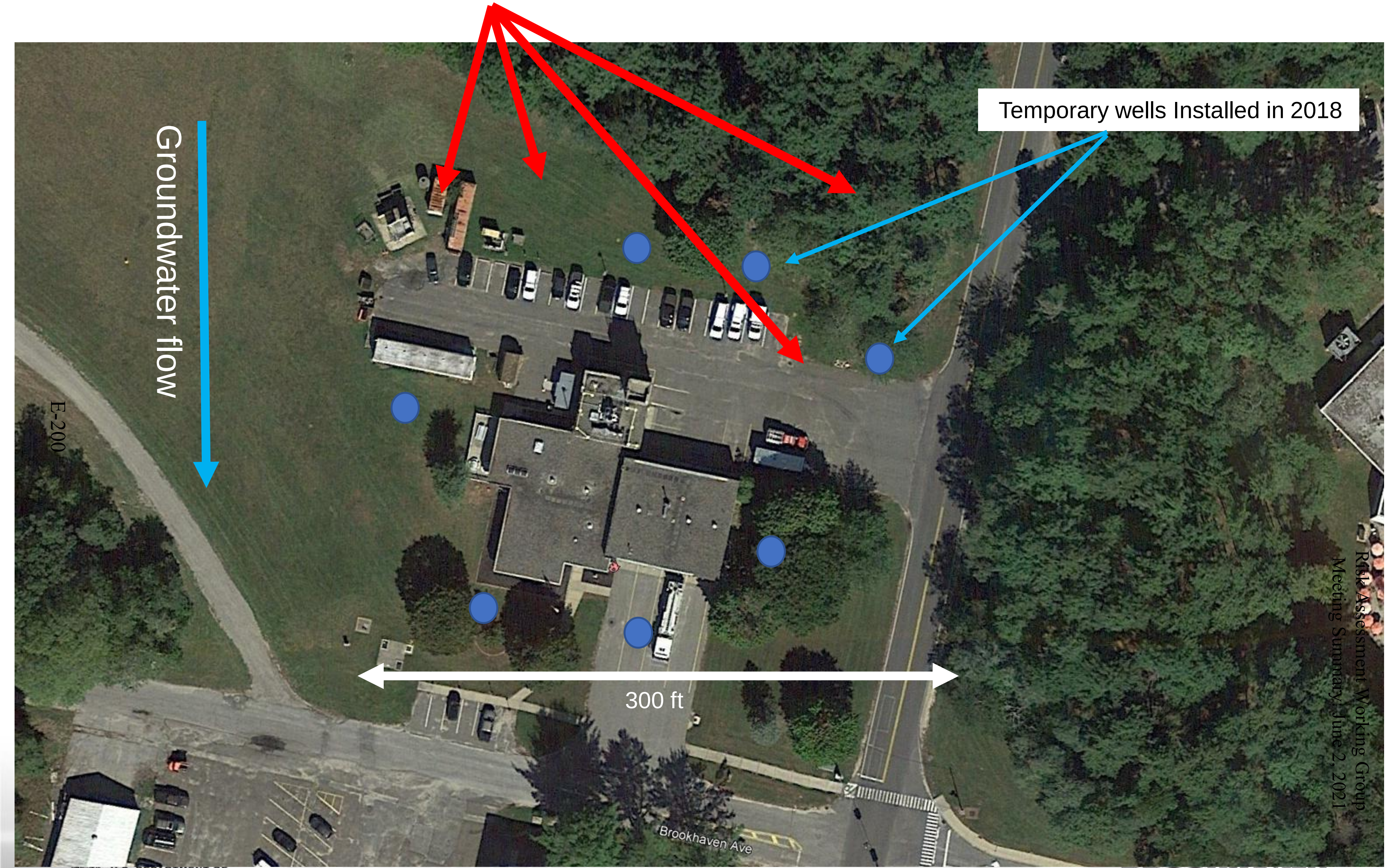
- 1,4-Dioxane detected in areas previously impacted by TCA releases:
  - Current Landfill and former Waste Management Facility, downgradient to North Street East area
    - Detected up to ~12 µg/L
    - Detected in extraction wells and system effluent up to ~3 µg/L
  - Detected in groundwater downgradient of former research agricultural fields up to ~2 µg/L
  - STP and downgradient areas
    - Not detected in groundwater near the STP
    - Site boundary and off-site detected up to ~7 µg/L



Current and Former Firehouse PFAS Plumes

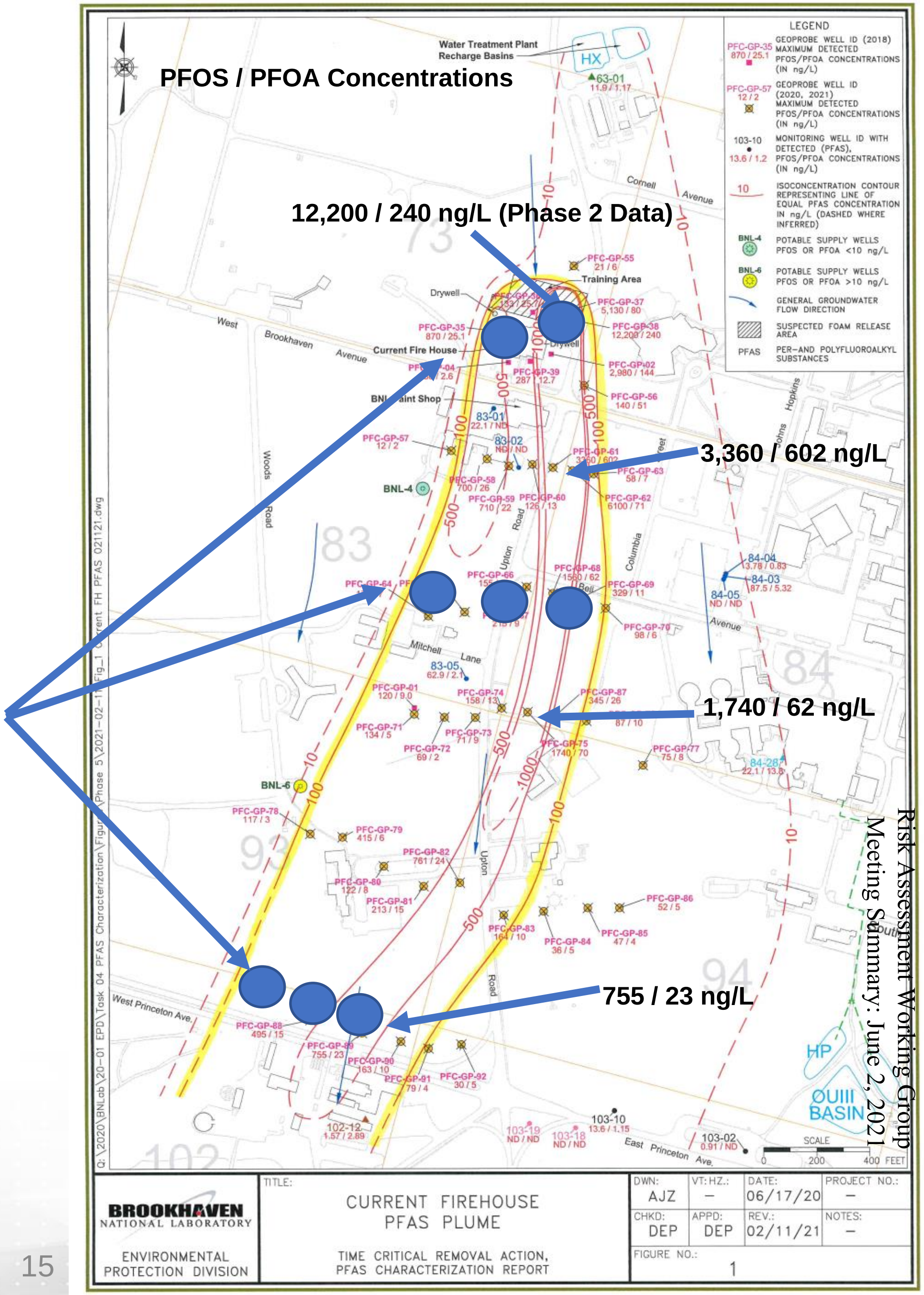
- DOE has provided $10.9M in funding to install remediation systems for the high concentration plume segments associated with the two source areas
    - BNL conducted detailed characterization of high concentration portions of the plumes (July 2020 – January 2021)
    - Currently preparing design documents for the treatment systems
        - Contaminated groundwater will be pumped out of the ground using a series of new extraction wells
        - Water will be treated using granular activated carbon filters
            - BNL will reuse infrastructure for several inactive groundwater treatment systems. Will result in significant time and cost savings
        - Treated water will be discharged into two existing recharge basin areas

Current Firehouse Foam Release Areas (1986-2008)



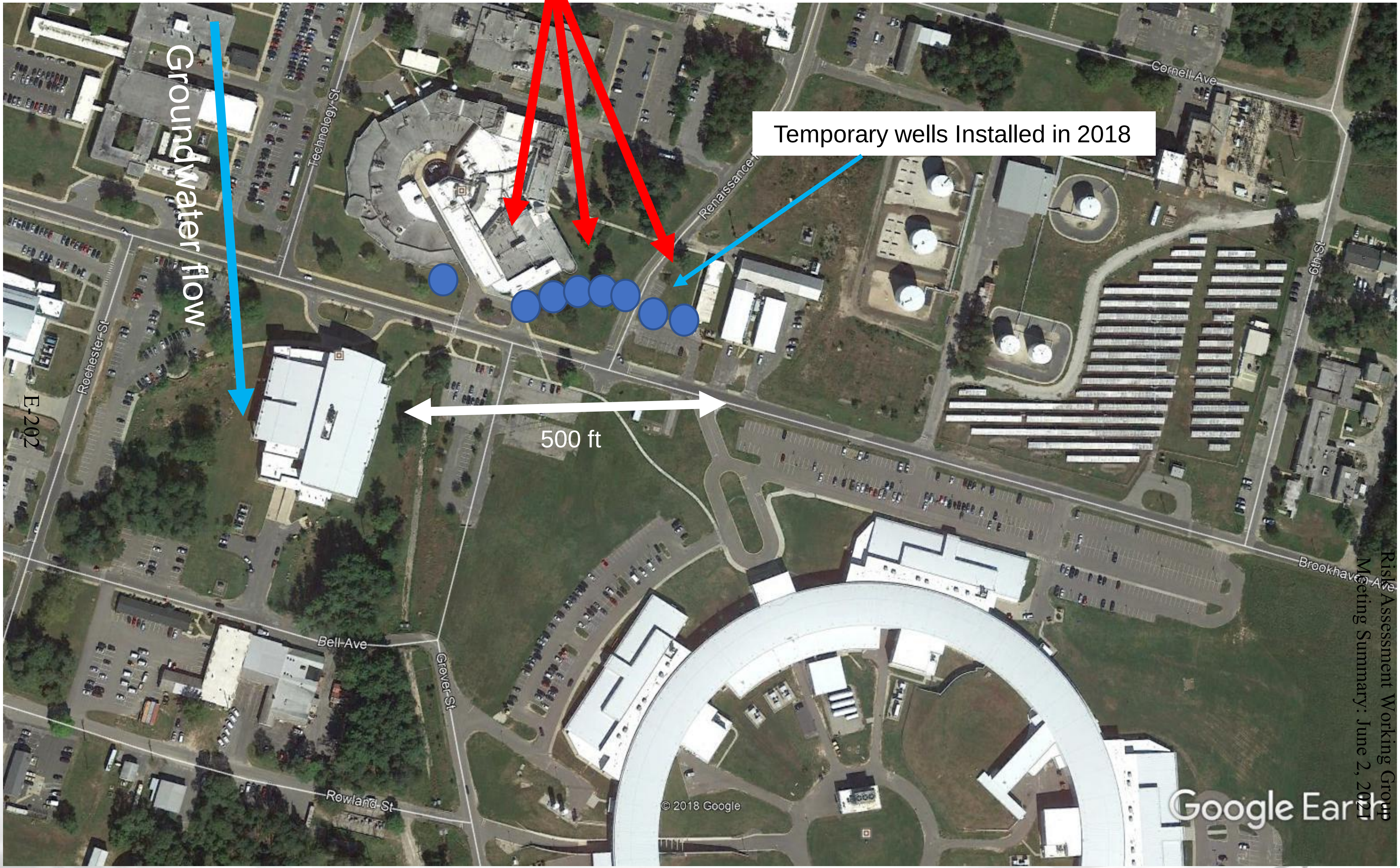
Current Firehouse Plume Characterization and Treatment System Design

- Installed 38 temporary wells to characterize the high concentration areas of the PFAS plume
  - 360 sample intervals
- Treatment system design
  - Establish a capture goal of 100 ng/L for PFOS or PFOA
  - Planning to install up to eight extraction wells
  - Groundwater modeling will be used to determine final extraction well locations, depths and pumping rates
    - Complicated area of the site due to operations of water supply wells and water recharge basins



U.S. DEPARTMENT OF ENERGY

Former Firehouse Foam Release Areas (1966-1985)



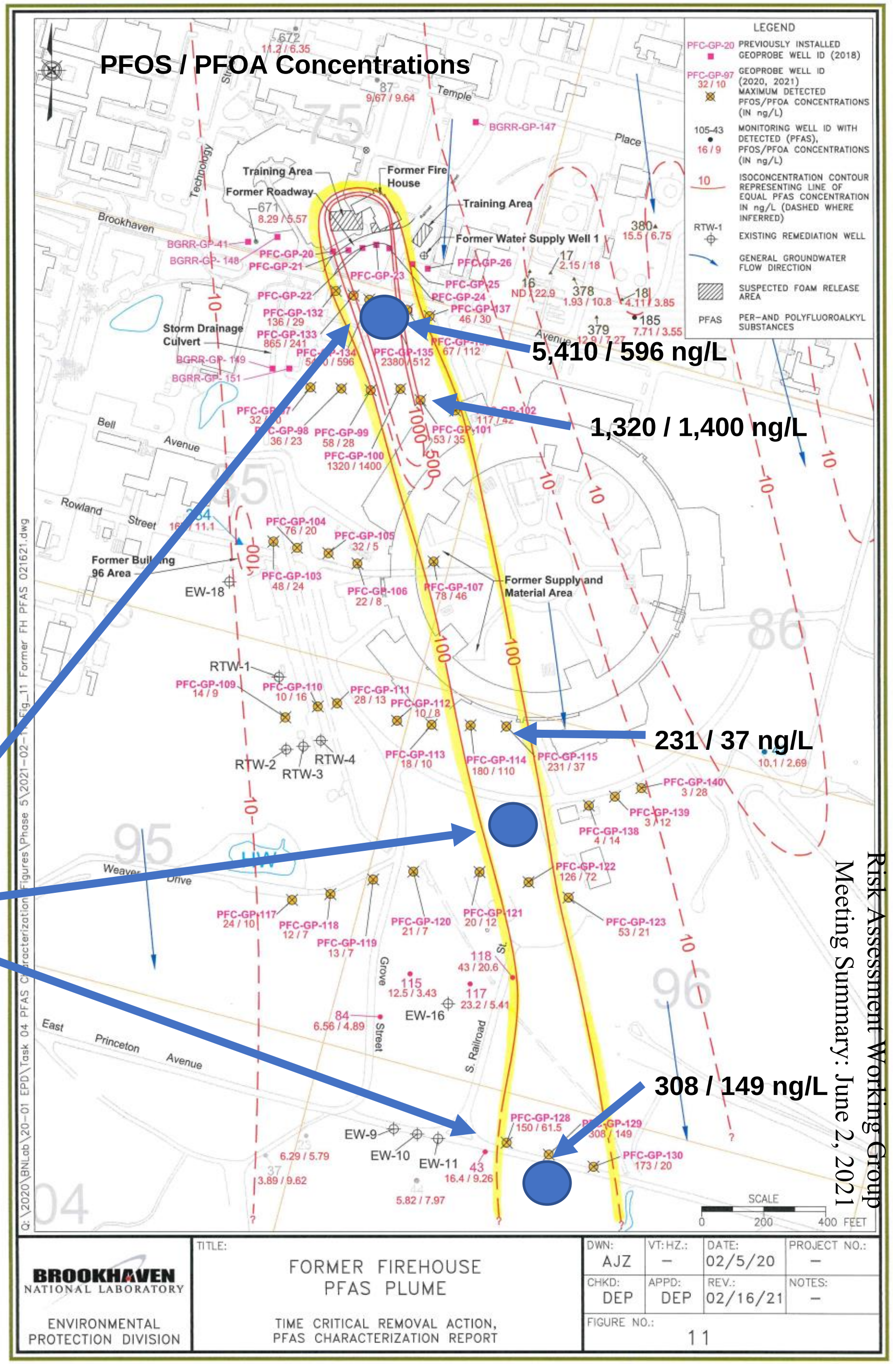
Temporary wells Installed in 2018

Groundwater flow

500 ft

Former Firehouse Plume Characterization and Treatment System Design

- Installed 37 temporary wells to characterize the high concentration portions of the PFAS plume
  - 390 sample intervals
- Treatment System Design
  - Establish a capture goal of 100 ng/L for PFOS or PFOA
  - Planning to install three extraction wells
  - Groundwater modeling will be used to determine final extraction well locations, depths and pumping rates



E-203

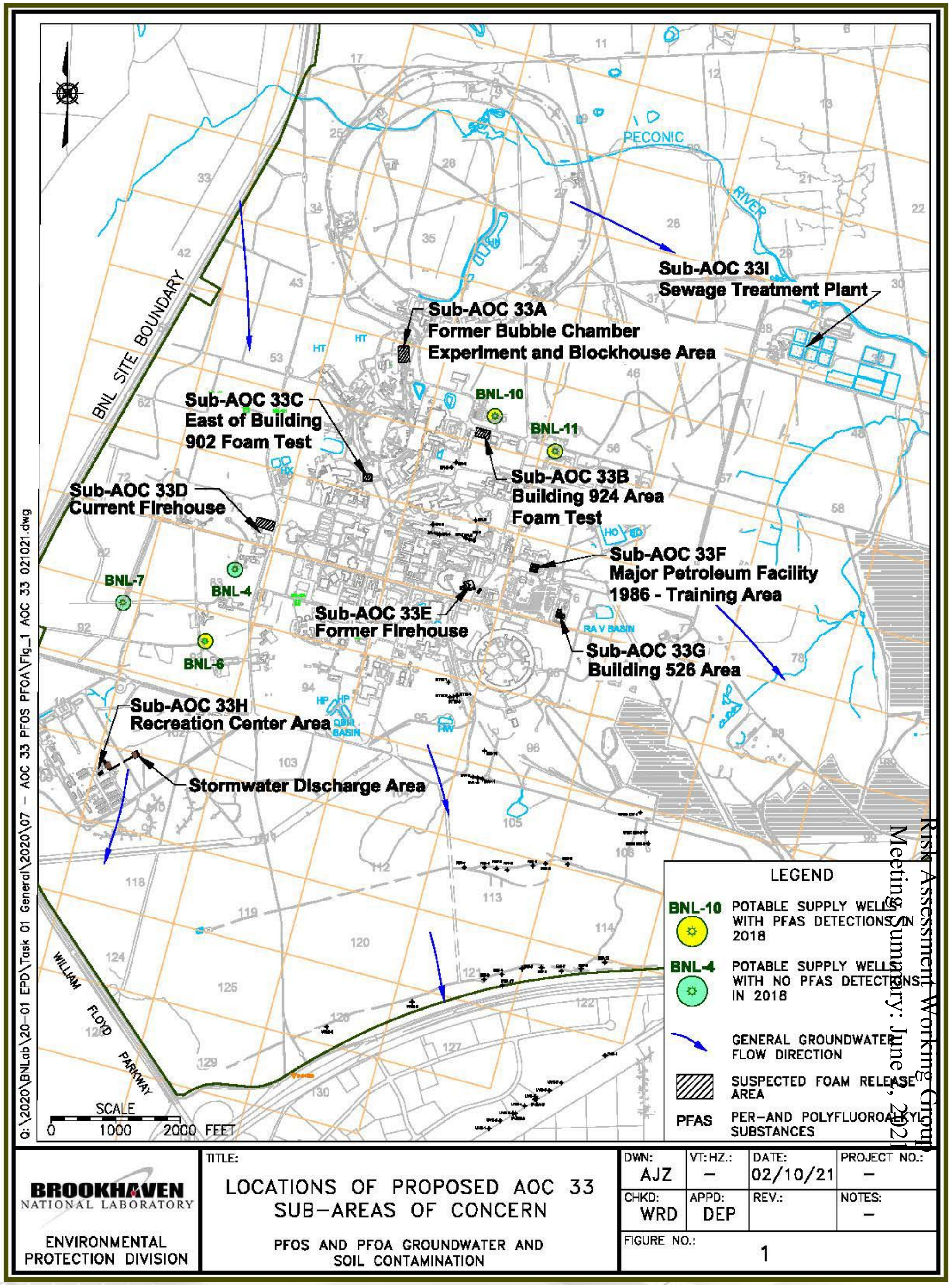
Risk Assessment Working Group Meeting Summary: June 2, 2021

Integrate response to PFAS and 1,4-Dioxane into CERCLA program

- Under the Federal Facilities Agreement, DOE is under a continuing obligation to notify EPA and NYSDEC of any additional potential Areas of Concern which DOE becomes aware
- DOE and BSA are working with EPA and NYSDEC to integrate future investigations and remedial responses into the CERCLA program
  - Including the planned remediation of the current firehouse and former firehouse PFAS plumes as a Time Critical Removal Action

BSA/DOE Recommendations

- Establish Operable Unit (OU VIII) that covers PFOS, PFOA and 1,4-dioxane remedial investigation and remedial actions
- Establish new Areas of Concern 33 and 34
  - AOC 33 – PFOS and PFOA with 9 sub-areas (33a through 33i)
  - AOC 34 – 1,4-Dioxane



Next Steps

- DOE recently submitted the recommendations to the regulatory agencies to incorporate the new OU and AOCs
  - Also provide target dates for submittal of the TCRA documents for the current firehouse and former firehouse plumes
    - Characterization report
    - Treatment system design plans
- New carbon filters for the current firehouse plume remediation system were delivered to BNL and will be installed in March
- Expect to start construction work on the treatment systems by early summer (e.g., install extraction wells and piping)

Risk Assessment Working Group
Meeting Summary—September 8, 2021

DOE
Rich Bonczek ✓

ETAS
Martin Clauberg ✓

EPA
Shanna Alexander ✓
Mac McRae ✓
Ann Schnitz ✓
Brett Thomas
Victor Weeks ✓

Kentucky
Brian Begley ✓
Stephanie Brock
Nathan Garner ✓
Brian Lainhart ✓
Todd Mullins ✓
Tabitha Owens ✓
Bart Schaffer ✓
Chris Travis

FRNP
Stefanie Fountain ✓
Bruce Ford ✓
LeAnne Garner
Chris Saranko ✓
Alexis Wiltfong ✓

✓ Indicates member was present

The group discussed that Tim Frederick (EPA), Jana Dawson(TechLaw), and Kristen Rapal (TechLaw) would no longer be participating in the Risk Assessment Working Group. Ann Schnitz (TechLaw), Mac McRae (TechLaw), and Bart Schaffer (KDEP) should be added to the member listing.

Original meeting agenda items are provided followed by meeting notes; the meeting notes are provided in *italics* with action items noted in *green*.

1. Call for Issues from Risk Assessment Working Group (RAWG) Members

Item received from Shanna Alexander on June 28, 2021: "I just had one suggestion to provide the actual basis or source of the 80 mg/kg screening value for lead in soil that was adopted to account for the use of composite samples. I believe we discussed that this cutoff value may have been the maximum result of all the 5-point composite results from the XRF analyses and that in the early 90's KDEP's soil screening criterion for lead was as low as 50 mg/kg […]. Therefore, the decision to use the 80 mg/kg as the screening value lowered the probability of a single sample result exceeding the screening value at that time (i.e., 50 mg/kg)."

The 80 mg/kg field screening value for prior lead cleanup activities at the PGDP (i.e., the firing range) was documented in:

> DOE 2009. *Removal Action Work Plan for Soils Operable Unit Inactive Facilities SWMU 19 and SWMU 181 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-0220&D2, August. (https://eic.pad.pppo.gov/Search.aspx?accession=I-04916-0019)

> **F.3.1 DECISION RULES (SWMU 181)**
> **F.3.1.1 Removal Action Support Survey—Activity I**
> …
> - If the lead concentration of any composite sample collected from an SU is greater than one-fifth of 400 mg/kg (i.e., 80 mg/kg), then excavate up to an additional 1 ft of soil from the SU until 400 mg/kg is achieved over an RU.

The above was discussed with the group and was agreed upon as acceptable. There were no additional comments made by the group.

2. Notes from 6/2/2021 Meeting

No comments were received on the June 2, 2021 meeting summary (emailed to the group on June 28, 2021). If there are no additional comments, the meeting summary will be considered final and will appear in Appendix E of the 2022 Risk Methods Document (RMD).

No comments were made by the group. The meeting summary is now finalized.

3. FY 2021 Schedule/Work Plan

Item/Activity	**Date**
~~Submit Work Plan (i.e., this schedule; will be included on 9/9/2020 Meeting Agenda for discussion)~~	~~9/9/2020~~
~~RAWG concurs with Work Plan (i.e., this schedule)~~	~~10/9/2020~~
~~Additional suggested revisions/corrections to Human Health (HH) Risk Methods Document (RMD) should be sent to Stefanie~~	~~10/23/2020~~
~~Submit HH Appendix A [i.e., Preliminary Remediation Goals (PRGs)] to RAWG for review~~	~~11/20/2020~~
~~Quarterly Meeting (December)~~	~~12/9/2020~~
~~Submit revised HH Main Text and HH Appendix B, D, and E to RAWG for review~~	~~12/17/2020~~
~~Comments due for HH Appendix A~~	~~1/11/2021~~
~~RAWG concurs with HH Appendix A~~	~~2/16/2021~~
~~Comments due for HH Main Text and HH Appendix B, D, and E~~	~~2/16/2021~~
~~Quarterly Meeting (March)~~	~~3/3/2021~~
~~RAWG concurs with HH Main Text and HH Appendix B, D, and E~~	~~4/9/2021~~
~~Submit Entire Revised HH RMD to RAWG for Review~~	~~4/16/2021~~
~~Comments due for entire revised HH RMD~~	~~5/14/2021~~
~~Quarterly Meeting (June)~~	~~6/2/2021~~
~~Submit HH RMD to FFA Managers (DOE/LX/07-0107&D2/R11/V1)~~	~~7/14/2021~~
~~FFA Managers acknowledge receipt of HH RMD~~	~~8/13/2021~~
~~Submit Work Plan (FY2022) to RAWG~~	~~9/1/2021~~
~~Quarterly Meeting (September)~~	~~9/8/2021~~

Quarterly meetings will be Web/teleconference 8:30 a.m.–11:00 a.m. (Central), 9:30 a.m.–12:00 p.m. (Eastern)

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

No comments were made by the group pertaining to the schedule.

4. FY 2022 DRAFT Schedule/Work Plan

Item/Activity	Date
RAWG Concurs with FY2022 Work Plan	10/15/2021
RAWG Provide Additional Suggested Revisions/Corrections to Human Health (HH) Risk Methods Document (RMD) for FY21	10/22/2021
Submit Draft FY2022 HH RMD Appendix A [i.e., Preliminary Remediation Goals (PRGs)] to RAWG for Review	12/2/2021
Quarterly Meeting (December/FY22Q1)	12/8/2021
Provide Draft FY2022 HH RMD Main Text and Appendix B and D to RAWG for Review	12/16/2021
RAWG Comments Due for Draft FY2022 HH RMD Appendix A	1/14/2022
Provide Draft FY2022 HH RMD Appendix E to RAWG for Review	2/10/2022
RAWG concurs with Draft FY2022 HH RMD Appendix A	2/11/2022
RAWG Comments Due for Draft FY2022 HH RMD Main Text and HH Appendix B and D	2/11/2022
Quarterly Meeting (March/FY22Q2)	3/2/2022
RAWG Comments Due for Draft FY2022 HH RMD Appendix E	3/11/2022
RAWG Concurs with Draft FY2022 HH RMD Main Text and HH Appendix B and D	3/11/2022
RAWG Concurs with Draft FY2022 HH RMD Appendix E	3/25/2022
Provide Complete Draft FY2022 HH RMD to RAWG for Review	4/7/2022
RAWG Comments Due for Entire Revised HH RMD	5/6/2022
Quarterly Meeting (June/FY22Q3)	6/1/2022
Submit FY2022 HH RMD to FFA Managers (DOE/LX/07-0107&D2/R13/V1)	7/1/2022
FFA Managers Acknowledge Receipt of FY2022 HH RMD	7/31/2022
Submit Work Plan (FY2023) to RAWG (with September meeting agenda)	8/31/2022
Quarterly Meeting (September/FY22Q4)	9/7/2022

Quarterly meetings will be Web/teleconference 8:30 a.m.–11:00 a.m. (Central), 9:30 a.m.–12:00 p.m. (Eastern)

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

No comments were made by the group pertaining to the schedule. ***Concurrence on the schedule was requested from EPA & KY by the end of October.***

5. C-400 Data

A request for topics was sent to the Working Group two weeks prior to the meeting (August 19, 2021).

Scoping for the C-400 risk assessment is expected to occur toward the end of the first quarter of FY2022. Agreements arrived at during scoping the C-400 risk assessment could lead to changes to the FY2022 RMD.

The group discussed timing for scoping the C-400 Risk Assessment as likely to occur around December as most data should be collected by then. As part of scoping, the group will discuss prior risk assessment *performed for WAG 6. Consistent with the Work Plan, the C-400 risk assessment is planned to be a human health screening-level risk assessment.*

6. FY 2022 Update Topics for Discussion

- Administrative and editorial updates (e.g., formatting of equations, addition of -6 to cancer-based values for ELCR in footnote 5, etc.)

  No comments were provided by the group.

- From the December 2020 meeting, the equations for the exposure point concentrations are within the RMD Appendix D but are not specific to direct air sampling results. These will be incorporated into the HH RMD to Appendix D following the development of the Vapor Intrusion project report. Because the Vapor Intrusion Project did not contain risk calculations, the methods presented in Section D.4.1 and Table D.4 of the C-400 Vapor Intrusion Project, completed as part of the 2013 Five-Year Review, will serve as the starting point for information added to Appendix D of the HH RMD.

  No comments were provided by the group.

- Crosswalk of IEUBK to RMD (e.g., Page A-4, Table A.4 footnote, Table B.6, etc.)

  See Section 7, Watch Topics, Status of EPA's Policy for Lead in Blood for discussion of this item.

- Updates to RAIS, including RSL updates and calculations for peak risk screening values

  The RAIS added updates are relevant to radionuclides and does not appear to pertain to the Paducah Site. No additional comments were provided by the group.

- Uranium identification number(s) in RAIS

  The disconnect in RAIS regarding the identification numbers for uranium salt and uranium metal has been resolved. No additional comments were provided by the group.

- 2020 Census data

  The 2020 Census provides information on site usage and exposure scenarios. No significant changes to the site usage or relevant exposure scenarios included in the RMD are anticipated when compared to 2020 Census data.

- Review of Information in Sections E.2.2 (Summary of Agricultural Practices in Ballard County), E.2.3 (Summary of Agricultural Practices in McCracken County), E.2.4 (Area of Crop Land in Ballard and McCracken County, Kentucky), and E.2.6 (Annual Harvests of Turkeys and Deer in McCracken and Ballard Counties, Kentucky, and Waterfowl in Ballard County, Kentucky)

The information included in these Sections is used to estimate input factors to the exposure equations in Appendix D. These inputs are not as important for the C-400 projects as they likely will be for other, future projects (e.g., the Surface Water Operable Unit – outside the fence). The group discussed that home gardening had been on the decline and has increased during the past year. A crosswalk will be performed between the sections above and the Exposure Factors Handbook and any differences will be discussed with the group.

- Review of KY regulatory guidance (Section E.3)

The group was not aware of any changes; KY will crosswalk this section and any differences will be discussed with the group.

- VISLs (Section E.9) following VI project report

There are no risk calculations in the VI project report (as there is no evidence of a complete pathway at any of the project buildings), thus there are no changes planned associated with VI risk formulas in the RMD. The VISL for trans-1,2-dichloroethene has been revised and will be updated in the RMD. The VI project report is anticipated to be submitted to KY and EPA by September 30, 2021.

- Anthropogenic background

The group discussed the chloroform results from the VI project sampling and the conclusion that the chloroform is a common disinfection by-product of treating water with chlorine and in this case is not a contaminant from site-related activities. The group agreed that a brief discussion of chloroform as an example of an anthropogenic background constituent would be added to the RMD and that generally anthropogenic background will be addressed on a project-specific basis.

The white paper, PAH Contamination and Establishment of Remedial Goals*, included in Appendix E of the RMD establishes the concept of anthropogenic background not related specifically to site-related activities.*

- Toxicity values review (Section E.10)

No comments were provided by the group.

- Chemical surrogates for PAHs

The group discussed that not all PAHs have toxicity values and a list of surrogates is included in the RMD. The group discussed that EPA and KY would review the list and provide any changes to be considered for the update to the RMD. During the meeting, KY provided their *surrogate list: PAH surrogates are acenaphthene for acenaphthylene, pyrene for benzo(e)pyrene, pyrene for benzo(g,h,i)perylene, and acenaphthene for phenanthrene.*

- Clarification of Footnote 5 on Page 2-1 regarding lifetime adult resident and child resident cancer-based values.

  No comments were provided by the group.

- Inclusion of a reference for the f_{oc} default values in the document in a location in addition to Appendix E.

  No comments were provided by the group.

- Addition of explanation on why older references for livestock production and dairy are used in the document.

  The older references used in the document provide exposure scenario rates representative of a local farming scenario, including foraging and production of feed locally, and also includes higher rates of water usage than compared to new techniques of livestock production. This reference is relevant because it facilitates the calculation of concentrations of chemicals in meat that would result from local farming (as opposed to large-scale commercial farming and purchase of feed). The group is open to considering a newer reference for use in the RMD.

- Fish ingestion rates as well as information and references for raising laying hens under the farming scenario and any updates to be included from the revised Exposure Factors Handbook.

  See Section 7, Watch Topics, Derivation of Risk-based Surface Water Effluent Limits for discussion of this item.

7. Watch Topics:

- **Volatile organics definitions used in RAIS**
  This needs to be watched to see if there are any impacts (especially for PCBs and PAHs). No additional updates at this time.

  The D2/R1 VI Work Plan, submitted and approved in December 2020, was reviewed for relevant information to be discussed for potential inclusion in the FY21 RMD revision. Based upon work completed during the development of the revised QAPP for the D2/R1 VI Work Plan, no revisions to volatile organics' definitions were necessary. Any updates to Section E.9 (VISLs) will follow the development of the Vapor Intrusion project report. Field sampling was completed in March 2021 and a scoping meeting for the report was held on April 27, 2021. The report is being developed and the D1 is due to be submitted on September 30, 2021.

  At this time, there are no additional updates, and the group anticipates submittal of VI project report by September 30, 2021.

- **Derivation of Risk-based Surface Water Effluent Limits**

  On December 31, 2020, EPA issued a letter to Oak Ridge Reservation (ORR) conveying the final decision resolving the ORR dispute on discharge to surface water of wastewaters generated during a response action under CERCLA at the ORR. Although that decision is specific to ORR, this topic is relevant to several near-term projects at the site and could have schedule impacts to those projects. Those potential impacts will be managed by those projects.

  On March 8, 2021, DOE provided to EPA and KY the rad effluent materials developed in 2014-2015 by a working group. There is interest among the FFA parties in resuming the working group activities on this topic.

  DOE will update the status of the Oak Ridge project draft screening values. The RAWG discussed during the June 2, 2021 meeting that the Oak Ridge project was using 10^{-5} risk for screening whereas Kentucky typically uses 10^{-6} risk.

  The Oak Ridge project is in the process of developing draft screening values, with some questions remaining regarding the origin of the fish and concentration references. EPA and KY noted that they would take the Oak Ridge project screening values into consideration but that any derived screening values would not be directly applicable as the Oak Ridge project is using 10^{-5} *risk for screening whereas Kentucky typically uses* 10^{-6} *risk. The group is discussing the possibility of forming a group to assess this topic.*

  DOE noted that for Paducah, the radionuclide effluent group came to an understanding of most key points. The main exception were the Tc-99 biotransfer factors, which assume whole fish consumption. This assumption is not representative of local fish consumption. The group discussed that there is no work currently being conducted on biotransfer of Tc-99, there is not much Tc-99 in surface water at or near the Paducah Site, and best available technologies exist for treating water for projects where Tc-99 is elevated, such that obtaining funding for a study of this nature would be challenging. DOE noted that the EM National Laboratory lab may be interested in the topic.

- **Status of EPA's Policy for Lead in Blood**
  - The December 22, 2016 EPA Memorandum "Updated Scientific Considerations for Lead in Soil Cleanups" on lead in blood was withdrawn in anticipation of a new policy, which is still being worked on and processed through the review and revision steps. As of the December 9, 2020 meeting, EPA was planning to issue an updated toxicokinetic model and the RAWG is tracking the status of the model.

    Shanna continues to track this item and will keep the group posted on any developments.

  - For the June 2, 2021 meeting, Victor provided the May 4, 2021 EPA Memorandum "Release of Integrated Exposure Uptake Biokinetic Model for Lead in Children Version 2.0 and Revisions to the Default Parameters for the IEUBK Model for Lead in U.S. Children." This update will be crosswalked to the HH RMD and any proposed revisions to the FY2022 HH RMD will be provided during the August meeting for discussion with the working group.

As discussed during the June 2, 2021 meeting, the IEUBK memorandum did not include an indication of any changes to PRGs or RSLs and new screening levels were in review and anticipated by the end of the year (likely to be lower than the current value of 400 mg/kg, perhaps around 200 mg/kg). The HH RMD approach is to compare individual results against the screening value and if all results are below the screening value, the model is not employed.

The group discussed the sections of the RMD that should be reviewed for potential update to reflect the revised IEUBK model, but that the screening value (RSL) of 400 mg/kg has not yet changed and there is no timing for a change available.

The revised IEUBK model inputs result in a screening value of approximately 200 mg/kg. The group notes that KY uses a different value for lead in blood than the updated IEUBK model (2.5 ug/dl vs 5 ug/dl, respectively).

DOE clarified for the group that projects first compare analytical results for lead in soil to the screening values. If concentrations exceed the screening values, the IEUBK model is used. The prior lead cleanup project at the site employed a project decision rule of one-fifth of 400 mg/kg (i.e., 80 mg/kg) for composite samples such that any one point in the composite could not exceed the 400 mg/kg screening value. If the screening value were to be revised to 200 mg/kg, a similar project decision rule would be one-fifth of 200 mg/kg (i.e., 40 mg/kg). This presents a challenge for the Paducah Site, where the decision rule would be of a similar concentration to background (36 mg/kg) and it may become difficult to discern between background and exceedances. It was emphasized by the group that this would not be an issue because remedial actions would not be considered based on background levels of contamination.

EPA recommends the site continue to use the 400 mg/kg screening level until the RSL is formally updated.

- **PFAS**
  EPA has issued PFAS Groundwater Guidance for Federal Cleanup Programs and companion press releases regarding testing for PFAS in drinking water. Links to the press releases for this information are below.

  https://www.epa.gov/newsreleases/epa-announces-new-method-test-additional-pfas-drinking-water

  https://www.epa.gov/newsreleases/epa-releases-pfas-groundwater-guidance-federal-cleanup-programs-fulfilling-pfas-action

  DOE included PFAS groundwater sample results from the Fire Training Area in the 2019 ASER (https://pubdocs.pad.pppo.gov/?dir=Annual%20Site%20Environmental%20Report%20%28ASER%29). DOE HQ developed a list of PFAS search terms to help sites research historical PFAS uses. Several PFAS compounds have been added to IRIS/FR docket.

PPPO responded to a survey from DOE Headquarters in December 2020. The blank survey was discussed with the Groundwater Modeling Working Group on January 13, 2021. There have been two follow-up items:

- DOE developed text to be used by DOE HQ when reporting on the status of PFAS contamination at Paducah and PORTS, completed in April 2021.
- DOE provided comments on an internal draft DOE HQ report entitled, *Assessment of Per- and Polyfluoroalkyl Substances (PFAS) at DOE-EM Sites*. This draft report includes survey information from across the DOE-EM complex and text taken from materials sent by PPPO in April.

Of relevance to this group and any investigation that would be performed, if a project were developed: sampling methodology (e.g., specialized sampling protocols versus site standard sampling protocols), screening limits, analytical methods. Data collection protocols and analytical methods would be discussed in the P-QAPP Working Group.

On July 30, 2021, EPA published SW-846 Methods 3512 and 8327 for testing of PFAS in non-potable waters by Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS):

- SW-846 Update VII Announcements: https://www.epa.gov/hw-sw846/sw-846-update-vii-announcements#PhaseII8327
- Method 3512: https://www.epa.gov/hw-sw846/sw-846-test-method-3512-solvent-dilution-non-potable-waters
- Method 8327: https://www.epa.gov/hw-sw846/sw-846-test-method-8327-and-polyfluoroalkyl-substances-pfas-liquid-chromatographytandem
- SW-846 Chapters and Methods: https://www.epa.gov/hw-sw846/sw-846-compendium
- SW-846 Methods home page: https://www.epa.gov/hw-sw846

Presented in the August 18, 2021 PFAS Analytical Methods Update at the DOE ASP Annual Training Workshop Series: Draft EPA 1633 is in development for non-potable waters.

- 40 PFAS (includes all PFAS applicable to EPA 537.1, 533, & SW-846 Method 8327 and 8 additional analytes not covered by these methods)
- Applicable to groundwater, surface water, wastewater, landfill leachates, soil, sediment, biosolids, and tissue

Once a reliable screening value(s) is available, DOE will provide a proposed update to the RMD for the group to consider. EPA relayed that an MCL is expected in the near future along with a determination that PFAS should be added to the listing of hazardous substances. EPA also expects guidance on disposal/destruction of PFAS in the near future.

The RAWG discussed a potential approach to such an evaluation could be to perform sampling using traditional or slightly modified sampling techniques as a screening step followed by sampling at elevated concentration locations using PFAS-specific sampling techniques. The site sewage treatment plant would be an area of interest for this type of evaluation.

As of the June 2, 2021 meeting, KY reported that they did not find any information or evidence that KY is developing PFAS screening values for drinking water or wastewater.

The contact information for the Brookhaven National Laboratory presentation was provided to the group on August 25, 2021. An update on the Brookhaven project was presented during the July DOE PFAS Working Group Meeting.

On June 7, 2021, EPA has sent a letter to the PGDP DOE Site Lead documenting EPA's "understanding of the dialog among the parties to the Federal Facility Agreement (FFA) and the project status for the Department of Energy's (DOE's) 2019 discovery of per- and polyfluoroalkyl (PFAS) substances having been released into the environment at the Paducah Site; and to propose a reasonable path forward on addressing such contaminants under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the FFA."

DOE has drafted a response to the EPA's June 7, 2021 letter. EPA understands that the response is to include moving forward with sampling groundwater for PFAS at areas of the Paducah Site other than the Fire Training Area (FTA).

DOE has proposed a screening approach that includes PFAS sampling of monitoring wells on DOE property and that are already planned to be sampled in the EMP. Regular sampling equipment and methods will be used and that samples distant from the FTA or upgradient from the other potential source areas may be useful in understanding the potential for false positives.

DOE updates the group that the DOE-EM PFAS report is still draft and that currently there is no DOE-EM PFAS policy.

8. Poll RAWG Members/Open Discussion

No additional discussion items were brought to the group for discussion.

Risk Assessment Working Group
Meeting Summary—December 8, 2021

DOE
Rich Bonczek ✓

ETAS
Martin Clauberg ✓

EPA
Shanna Alexander ✓
Kristen Avedikian
Mac McRae ✓
Ann Schnitz ✓
Brett Thomas
Victor Weeks ✓

Kentucky
Brian Begley ✓
Stephanie Brock
Nathan Garner ✓
Brian Lainhart
Todd Mullins ✓
Tabitha Owens ✓
Bart Shaffer ✓
Chris Travis ✓

FRNP
Stefanie Fountain ✓
Bruce Ford ✓
LeAnne Garner
Chris Saranko ✓

✓ Indicates member was present

Original meeting agenda items are provided followed by meeting notes; the meeting notes are provided in *italics* with action items noted in *green*.

1. Call for Issues from Risk Assessment Working Group (RAWG) Members

No items were brought forward for discussion by the group.

2. Notes from 9/8/2021 Meeting

Comments received on September 23, 2021 from Shanna Alexander on the September 8, 2021 meeting summary (provided to the RAWG on 9/21/2021):

- **Editorial -** On the first page (yellow highlighted text), I think you meant to say that the agenda items are provided in "**bold**" followed by meeting notes. Correct?
    - Correct; propose that the text be revised as appropriate.

This revision to the September 8, 2021 meeting summary was agreed to by consensus.

- **General Comment -** It seems the lines are blurred between "no comments" and "concurrence". To me saying "no comments were made by the group" is not the same as saying the group concurred with the response action. A lot of the comments provided in the summary are action items from EPA's review of the RMD that DOE agreed to address in prior calls. To me, "no comments" is an indication that the group did not accept or reject the action proposed when in fact the proposed response action is acceptable. I know that I concurred with the proposed response actions to those items that stemmed from EPA's risk comment letter (e.g., Item #6, bullets No. 1 and 2). I'm not suggesting changing this now, but I think moving forward, we should seek out whether anyone objects to each action item and if not, it should be recorded as concurrence on the item (unless specific comments are made or follow-up action is required).
    - Put forth for group consideration. In the future, propose to use, "No Comments" and "Agreed to by Consensus" or similar. No change to the summary proposed.

The group agreed by consensus to document discussions in the meeting summaries using "agreed by consensus," "agreed to by consensus," or similar, or "no comments," as appropriate.

- **Page 5, Anthropogenic Background** – I think what we're attempting to say here is that the presence of chloroform in indoor air originates from leaking water distribution lines and not just from chlorination of potable water. Chlorination of potable water doesn't necessarily equate to a vapor intrusion concern unless there is some release mechanism. Both of these items should probably be mentioned in the chloroform discussion along with how DOE plans to address the issue (e.g., project-specific decision to repair the leaking municipal water line if it poses a vapor risk greater than the CERCLA risk range or KY's $1x10^{-6}$ risk level).
    - From EPA OLEM Directive 9200.2-141 A (2018) : "Similarly, for anthropogenic contaminant concentrations, the CERCLA program normally does not set cleanup levels below anthropogenic background concentrations (US EPA, 1996; US EPA, 1997b; US EPA, 2000c). The reasons for this approach include cost-effectiveness, technical practicability, and the potential for recontamination of remediated areas by surrounding areas with elevated background concentrations. In cases where areawide contamination may pose risks, but is beyond the authority provided under CERCLA, EPA may be able to help identify other programs or regulatory authorities that are able to address the sources of area-wide contamination, particularly anthropogenic (US EPA, 1996; US EPA, 1997b; US EPA, 2000c). In some cases, as part of a response to address CERCLA releases of hazardous substances, pollutants, and contaminants, EPA may also address some of the background contamination that is present on a site due to area-wide contamination."
    - Proposal to add this EPA reference and above language to the brief discussion of chloroform as an example of an anthropogenic background constituent that the group agreed to add to the RMD during the September 8, 2021 meeting. No change to the summary proposed.
    - See new agenda topic "Anthropogenic Background."

The group agreed by consensus that no change would be made to the September 8, 2021 meeting summary. This topic was discussed as part of Item 6.

- **Page 5 (bottom of page), Chemical Surrogates for PAHs** – EPA concurs with KY's surrogates. However, pyrene (not acenaphthene) is typically used in CERCLA risk assessments as the appropriate surrogate for phenanthrene.
    - Acknowledged. No change to the summary proposed.
    - See new agenda topic "Chemical Surrogates for PAHs."

The group agreed by consensus that no change would be made to the September 8, 2021 meeting summary. This topic was discussed as part of Item 7.

- **Page 9 (last paragraph), PFAS –** For the potential PFAS groundwater sampling approach, how to define "elevated concentration" should be something the RAWG should discuss. For instance, will it be concentrations 10X > RSL? 100X > RSL? Above 70 ppt lifetime health advisory for individual PFAS or combined (if MCL still unavailable)? What about those PFAS compounds without screening levels, do we report only? Are we only reporting for certain PFAS analytes or all 40? Will this be addressed in the EMP?
    - Added below to the PFAS Watch Topic in Section 7 of this agenda [from 9/8/2021 agenda]. No change to the summary proposed.

The group agreed by consensus that no change would be made to the September 8, 2021 meeting summary. PFAS was discussed as part of Item 8.

- **Page 10, PFAS –** The following sentence needs to be reworded for clarity: "*DOE has proposed a screening approach that includes PFAS sampling of monitoring wells on DOE property and that are already planned to be sampled in the EMP sampled*." Remove the word "sampled" at the end.
    - The summary text will be revised as requested.

This revision to the September 8, 2021 meeting summary was agreed to by consensus.

If there are no additional comments, the meeting summary will be considered final and will appear in Appendix E of the 2022 Risk Methods Document (RMD).

No additional comments were received from the group on the September 8, 2021 meeting summary.

3. Fiscal Year (FY) 2022 Schedule/Work Plan

The FY 2022 Schedule/Work Plan was concurred upon by EPA and KY on 10/12/2021 and 9/30/2021, respectively.

Item/Activity	**Date**
~~RAWG Concurs with FY2022 Work Plan~~	~~10/15/2021~~
~~RAWG Provide Additional Suggested Revisions/Corrections to Human Health (HH) Risk Methods Document (RMD) for FY21~~	~~10/22/2021~~
~~Submit Draft FY2022 HH RMD Appendix A [i.e., Preliminary Remediation Goals (PRGs)] to RAWG for Review~~	~~12/2/2021~~
Quarterly Meeting (December/FY22Q1)	12/8/2021
Provide Draft FY2022 HH RMD Main Text and Appendix B and D to RAWG for Review	12/16/2021
RAWG Comments Due for Draft FY2022 HH RMD Appendix A	1/14/2022
Provide Draft FY2022 HH RMD Appendix E to RAWG for Review	2/10/2022
RAWG concurs with Draft FY2022 HH RMD Appendix A	2/11/2022
RAWG Comments Due for Draft FY2022 HH RMD Main Text and HH Appendix B and D	2/11/2022
Quarterly Meeting (March/FY22Q2)	3/2/2022
RAWG Comments Due for Draft FY2022 HH RMD Appendix E	3/11/2022
RAWG Concurs with Draft FY2022 HH RMD Main Text and HH Appendix B and D	3/11/2022
RAWG Concurs with Draft FY2022 HH RMD Appendix E	3/25/2022
Provide Complete Draft FY2022 HH RMD to RAWG for Review	4/7/2022
RAWG Comments Due for Entire Revised HH RMD	5/6/2022
Quarterly Meeting (June/FY22Q3)	6/1/2022
Submit FY2022 HH RMD to FFA Managers (DOE/LX/07-0107&D2/R13/V1)	7/1/2022
FFA Managers Acknowledge Receipt of FY2022 HH RMD	7/31/2022
Submit Work Plan (FY2023) to RAWG (with September meeting agenda)	8/31/2022
Quarterly Meeting (September/FY22Q4)	9/7/2022

Quarterly meetings will be Web/teleconference 8:30 a.m.–11:00 a.m. (Central), 9:30 a.m.–12:00 p.m. (Eastern)

Color code for schedule:

Due date	Quarterly meeting
Submittal date	Concurrence/acknowledgement date

The group did not have any comments on the schedule/work plan.

4. Revisions to RMD Appendix A

Revisions to RAIS since November 2020 were reviewed and updates made, as appropriate:

- CAS number for Uranium (Soluble Salts) has been updated from N/A to 7440-61-1
- Updates to the table footnotes for Uranium (Insoluble Compounds)
- Updates to naming conventions for cis-1,2-dichloroethylene and trans-1,2-dichloroethylene in the tables
- Updates to trans-1,2-dichloroethylene (toxicity changes to inhalation noncancer in PPRTV database)
- Updates to molybdenum (toxicity changes to inhalation noncancer in ATSDR database)

Other changes include:

- An introduction to the tables in Appendix A and action and no action levels has been added to the text on page A-3.
- The COPC-specific note for chromium on Page A-4 has been updated for clarity.
- The COPC-specific note for lead starting on Page A-4 has been updated consistent with the discussions on the IEUBK model update.
- The COPC-specific note for PFAS on Page A-5 has been updated consistent with discussion during the September 8, 2021 meeting.
- Addition of a footnote to Tables A.8, A.9, and A.10 regarding DOE-STD-1196-2011.

EPA and KY are reviewing the draft Appendix A; they did not have any comments to share with the group during the meeting.

5. C-400 Data

A request for topics was sent to the Working Group three weeks prior to the meeting (November 16, 2021).

Scoping for the C-400 risk assessment is expected to occur toward the end of the first quarter of FY2022. Agreements arrived at during scoping the C-400 risk assessment could lead to changes to the FY2022 RMD. As part of scoping, the group will discuss prior baseline risk assessment performed for WAG 6. Consistent with the Work Plan, the C-400 risk assessment is planned to be a human health screening-level risk assessment.

The group discussed the plan for the C-400 Remedial Investigation/Feasibility Study (RI/FS) Report scoping, specifically the scoping of the risk assessment portion. The risk assessment scoping materials will include a summary of the baseline risk assessment (BRA) performed for WAG 6 and will summarize the risk assessment approach included in the Work Plan. DOE clarified that the goal of the current risk assessment is to confirm or update as appropriate the findings of the previous BRA. The group discussed that scoping may start with general topics (e.g., the definition of "high concentration TCE," etc.), that scoping would evolve with each meeting, and that it is likely that there would be overlap between the different scoping topics and the participants needed for each meeting.

The group discussed the SWMU 211-A/B project remedial action objectives (RAOs) and RAO development process and that while the C-400 project is more complicated, the RAOs for that project would be considered, as appropriate, and that a similar discussion process will be used for C-400.

The group also discussed the C-400 dataset, which has been provided in multiple files to date as data becomes available. Once all data is received and validated, the project plans to consolidate the data into a single data set that will include the newly collected data and the historical data outlined in the Work Plan. This single dataset will be used to generate topic specific datasets (e.g., risk assessment, groundwater modeling, etc.).

EPA and KY each discussed that they are flexible on the data and scoping approaches so as to facilitate the overall project schedule.

6. Anthropogenic Background

The white paper, PAH Contamination and Establishment of Remedial Goals, included in Appendix E of the RMD, establishes the concept of anthropogenic background not related specifically to site-related activities.

During the September 8, 2021 meeting, the group discussed the chloroform results from the VI project sampling and the conclusion that the chloroform is a common disinfection by-product of treating water with chlorine and in this case is not a contaminant from site-related activities. The group agreed that a brief discussion of chloroform as an example of an anthropogenic background constituent would be added to the RMD and that generally anthropogenic background will be addressed on a project-specific basis.

From Agenda Item 2, 3rd bullet, proposal to include reference for and language from EPA OLEM Directive 9200.2-141 A (2018) in the updated main text of the RMD.

Based on the preliminary comments from EPA on the *Plant Industrial Area Vapor Intrusion Preliminary Risk Assessment Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2471&D1, dated September 29, 2021 (VI Report), DOE recommends that the topic of chloroform as anthropogenic background remain a discussion topic of the RAWG and that the RAWG discuss the development of a white paper on this topic (similar to the white paper developed for PAHs).

DOE discussed that the PAH white paper was developed following one of the ditches projects where elevated PAH results were found not to be directly related to PGDP releases, but rather from other on-site or off-site activities. As discussed, the white paper documents that there is a potential for PAHs not associated with PGDP releases to be identified as a risk driver and that PAHs typically are not good candidates to verify cleanup because PAHs may be detected above cleanup criteria at random locations due to their sources.

The group discussed the challenges with analyses for chloroform due to the presence of elevated concentrations of TCE and sample dilution for analysis. The group also discussed that some chloroform at the site may be from environmental releases. The chloroform sample results from the Plant Industrial Area Vapor Intrusion (VI) Project were not correlated with available environmental data and thus the *report concluded that the chloroform results were not environmentally-derived. DOE discussed that chloroform should be evaluated as either anthropogenic background or environmentally-derived on a project-specific basis.*

The group agreed by consensus to develop a broader white paper on anthropogenic background in FY 2023. A draft schedule for the paper will be provided at the next meeting. DOE clarified that the VI project report should inform a white paper (as opposed to the white paper resulting in revisions to the VI project report).

7. Chemical Surrogates for PAHs

During the September 8, 2021 meeting, KY provided their PAHs surrogate list:

- acenaphthene for acenaphthylene,
- pyrene for benzo(e)pyrene,
- pyrene for benzo(g,h,i)perylene, and
- acenaphthene for phenanthrene.

EPA provided concurrence with KY's surrogates in the September 23, 2021 email (Agenda Item 2, 4th bullet), but noted that pyrene (not acenaphthene) is typically used in CERCLA risk assessments as the appropriate surrogate for phenanthrene.

A consensus agreement on the KY surrogates or discussion of an alternative proposal is requested from the group.

The group discussed that various sources of information for PAH surrogates are available, and specifically discussed the EPA CompTox Chemicals Dashboard (https://comptox.epa.gov/dashboard/). EPA noted that they do not publish lists of surrogates and accepted/appropriate surrogates may change based on changes to parameter toxicity values. DOE clarified that the RMD is a tool used by the contractor as a starting point for developing risk assessments and for scoping those projects. Surrogates should be considered/reviewed in each RMD update and as part of scoping each project. If a parameter is found to be important to a project and is not included in the RMD, a surrogate or project-specific PRG would be developed and discussed for inclusion in the next update of the RMD. Currently, there are parameters in the RMD that rely on surrogates.

The group discussed that CompTox suggests naphthalene as a surrogate for phenanthrene; the group agreed by consensus that pyrene is a more appropriate surrogate for phenanthrene.

The group agreed by consensus to use the following PAHs surrogate list for the 2022 RMD revision:

- *acenaphthene for acenaphthylene,*
- *pyrene for benzo(e)pyrene,*
- *pyrene for benzo(g,h,i)perylene, and*
- *pyrene for phenanthrene for baseline risk assessment and acenaphthene for phenanthrene as part of uncertainty evaluations/discussions.*

The group agreed by consensus to add a listing of these surrogates and any others already included in the document to the introduction in Appendix A and also to add references for sources of information on surrogates (e.g., CompTox).

8. Watch Topics:

- **Volatile organics definitions used in RAIS**
  This needs to be watched to see if there are any impacts (especially for PCBs and PAHs). No additional updates at this time.

  The D2/R1 VI Work Plan, submitted and approved in December 2020, was reviewed for relevant information to be discussed for potential inclusion in the FY21 RMD revision. Based upon work completed during the development of the revised QAPP for the D2/R1 VI Work Plan, no revisions to volatile organics' definitions were necessary. Any updates to Section E.9 (VISLs) will follow the development of the Vapor Intrusion project report. Field sampling was completed in March 2021 and a scoping meeting for the report was held on April 27, 2021. The report was submitted on September 29, 2021.

  DOE clarified that this watch topic is intended to track whether changes in the defining parameters for what organic chemicals should be considered volatile organic compounds (VOCs), e.g. previously molecular weight, now vapor pressure greater than 1 mm Hg or Henry's Law constant greater than 0.00001 atm-m^3/mole, have resulted in a chemical's re-classification as a VOC. The group is not aware of any changes at this time.

- **Derivation of Risk-based Surface Water Effluent Limits**
  On December 31, 2020, EPA issued a letter to Oak Ridge Reservation (ORR) conveying the final decision resolving the ORR dispute on discharge to surface water of wastewaters generated during a response action under CERCLA at the ORR. Although that decision is specific to ORR, this topic is relevant to several near-term projects at the site and could have schedule impacts to those projects. Those potential impacts will be managed by those projects.

  On March 8, 2021, DOE provided to EPA and KY the rad effluent materials developed in 2014-2015 by a working group. There is interest among the FFA parties in resuming the working group activities on this topic.

  The RAWG discussed during the June 2, 2021 meeting that the Oak Ridge project was using 10^{-5} risk for screening whereas Kentucky typically uses 10^{-6} risk. The Oak Ridge project is in the process of developing draft screening values, with some questions remaining regarding the origin of the fish and concentration references. EPA and KY noted that they would take the Oak Ridge project screening values into consideration but that any derived screening values would not be directly applicable as the Oak Ridge project is using 10^{-5} risk for screening whereas Kentucky typically uses 10^{-6} risk. The group is discussing the possibility of forming a group to assess this topic.

  DOE noted during the September 8, 2021 meeting that for Paducah, the radionuclide effluent group came to an understanding of most key points. The main exception were the Tc-99 biotransfer factors, which assume whole fish consumption. This assumption is not representative of local fish consumption. The group discussed that there is no work currently being conducted on biotransfer of Tc-99, there is not much Tc-99 in surface water at or near the Paducah Site, and best available technologies exist for treating water for projects where Tc-99 is elevated, such that obtaining funding for a study of this nature would be challenging. DOE noted that the EM National Laboratory lab may be interested in the topic. The need for work in this area was mentioned during the fall 2021 DOE Low-Level Waste Disposal Facility Federal Review Group (LFRG) meeting. The reply from the DOE Office of the Associate Under Secretary for Environment, Health, Safety and Security (AU), who is responsible for development and maintenance of RESRAD and DOE guidance materials, was that they will check with Argonne National Laboratory (RESRAD authors).

The group discussed that there remains disagreement between Oak Ridge and EPA on this topic and that the dispute is on hold. EPA noted that the Oak Ridge dispute resolution is specific to Oak Ridge. DOE clarified that the Paducah Site is tracking this item to incorporate any relevant information into this site's project evaluations.

- **Status of EPA's Policy for Lead in Blood**
  - The December 22, 2016 EPA Memorandum "Updated Scientific Considerations for Lead in Soil Cleanups" on lead in blood was withdrawn in anticipation of a new policy, which is still being worked on and processed through the review and revision steps. As of the December 9, 2020 meeting, EPA was planning to issue an updated toxicokinetic model and the RAWG is tracking the status of the model.

    Shanna is tracking this item and will keep the team posted on any developments.

    This topic is on hold with no updates to relay to the Group on this topic.

  - For the June 2, 2021 meeting, Victor provided the May 4, 2021 EPA Memorandum "Release of Integrated Exposure Uptake Biokinetic Model for Lead in Children Version 2.0 and Revisions to the Default Parameters for the IEUBK Model for Lead in U.S. Children." This update will be crosswalked to the HH RMD and any proposed revisions to the FY2022 HH RMD will be provided during the August meeting for discussion with the working group.

    As discussed during the June 2, 2021 meeting, the IEUBK memorandum did not include an indication of any changes to PRGs or RSLs and new screening levels were in review and anticipated by the end of the year (likely to be lower than the current value of 400 mg/kg, perhaps around 200 mg/kg). The HH RMD approach is to compare individual results against the screening value and if all results are below the screening value, the model is not employed.

    The group discussed during the September 8, 2021 meeting the sections of the RMD that should be reviewed for potential update to reflect the revised IEUBK model, but that the screening value (RSL) of 400 mg/kg has not yet changed and there is no timing for a change available. The revised IEUBK model inputs result in a screening value of approximately 200 mg/kg. The group noted that KY uses a different value for lead in blood than the updated IEUBK model

(2.5 ug/dl vs 5 ug/dl, respectively). DOE clarified for the group that projects first compare analytical results for lead in soil to the screening values. If concentrations exceed the screening values, the IEUBK model is used. The prior lead cleanup project at the site employed a project decision rule of one-fifth of 400 mg/kg (i.e., 80 mg/kg) for composite samples such that any one point in the composite could not exceed the 400 mg/kg screening value. If the screening value were to be revised to 200 mg/kg, a similar project decision rule would be one-fifth of 200 mg/kg (i.e., 40 mg/kg). This presents a challenge for the Paducah Site, where the decision rule would be of a similar concentration to background (36 mg/kg) and it may become difficult to discern between background and exceedances. It was emphasized by the group that this would not be an issue because remedial actions would not be considered based on background levels of contamination. EPA recommended the site continue to use the 400 mg/kg screening level until the RSL is formally updated.

There were no updates available to relay to the group on this topic. EPA continues to recommend using use the 400 mg/kg screening level.

- **PFAS**
  EPA has issued PFAS Groundwater Guidance for Federal Cleanup Programs and companion press releases regarding testing for PFAS in drinking water. Links to the press releases for this information are below.

  https://www.epa.gov/newsreleases/epa-announces-new-method-test-additional-pfas-drinking-water

  https://www.epa.gov/newsreleases/epa-releases-pfas-groundwater-guidance-federal-cleanup-programs-fulfilling-pfas-action

  DOE included PFAS groundwater sample results from the Fire Training Area in the 2019 ASER (https://pubdocs.pad.pppo.gov/?dir=Annual%20Site%20Environmental%20Report%20%28ASER%29). DOE HQ developed a list of PFAS search terms to help sites research historical PFAS uses. Several PFAS compounds have been added to IRIS/FR docket.

  PPPO responded to a survey from DOE Headquarters in December 2020. The blank survey was discussed with the Groundwater Modeling Working Group on January 13, 2021. There have been two follow-up items:

  - DOE developed text to be used by DOE HQ when reporting on the status of PFAS contamination at Paducah and PORTS, completed in April 2021.
  - DOE provided comments on an internal draft DOE HQ report entitled, *Assessment of Per- and Polyfluoroalkyl Substances (PFAS) at DOE-EM Sites*. This draft report includes survey information from across the DOE-EM complex and text taken from materials sent by PPPO in April.

  Of relevance to this group and any investigation that would be performed, if a project were developed: sampling methodology (e.g., specialized sampling protocols versus site standard sampling protocols), screening limits, analytical methods. Data collection protocols and analytical methods would be discussed in the P-QAPP Working Group.

On July 30, 2021, EPA published SW-846 Methods 3512 and 8327 for testing of PFAS in non-potable waters by Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS):

- SW-846 Update VII Announcements: https://www.epa.gov/hw-sw846/sw-846-update-vii-announcements#PhaseII8327
- Method 3512: https://www.epa.gov/hw-sw846/sw-846-test-method-3512-solvent-dilution-non-potable-waters
- Method 8327: https://www.epa.gov/hw-sw846/sw-846-test-method-8327-and-polyfluoroalkyl-substances-pfas-liquid-chromatographytandem
- SW-846 Chapters and Methods: https://www.epa.gov/hw-sw846/sw-846-compendium
- SW-846 Methods home page: https://www.epa.gov/hw-sw846

Presented in the August 18, 2021 PFAS Analytical Methods Update at the DOE ASP Annual Training Workshop Series: Draft EPA 1633 is in development for non-potable waters.

- -40 PFAS (includes all PFAS applicable to EPA 537.1, 533, & SW-846 Method 8327 and 8 additional analytes not covered by these methods)
- -Applicable to groundwater, surface water, wastewater, landfill leachates, soil, sediment, biosolids, and tissue

Once a reliable screening value(s) is available, DOE will provide a proposed update to the RMD for the group to consider. EPA relayed that an MCL is expected in the near future along with a determination that PFAS should be added to the listing of hazardous substances. EPA also expects guidance on disposal/destruction of PFAS in the near future.

The RAWG discussed a potential approach to such an evaluation could be to perform sampling using traditional or slightly modified sampling techniques as a screening step followed by sampling at elevated concentration locations using PFAS-specific sampling techniques. The site sewage treatment plant would be an area of interest for this type of evaluation.

As of the June 2, 2021 meeting, KY reported that they did not find any information or evidence that KY is developing PFAS screening values for drinking water or wastewater.

The contact information for the Brookhaven National Laboratory presentation was provided to the group on August 25, 2021. An update on the Brookhaven project was presented during the July DOE PFAS Working Group Meeting.

On June 7, 2021, EPA has sent a letter to the PGDP DOE Site Lead documenting EPA's "understanding of the dialog among the parties to the Federal Facility Agreement (FFA) and the project status for the Department of Energy's (DOE's) 2019 discovery of per- and polyfluoroalkyl (PFAS) substances having been released into the environment at the Paducah Site; and to propose a reasonable path forward on addressing such contaminants under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the FFA."

New meetings, guidance, letters, sample methods, etc. since the September 8, 2021 meeting:

- August 24, 2021: DOE memorandum, *ACTION: Approval of the Departmental Per- and Polyfluoroalkyl Substances Policy*.
- September 14, 2021: EPA published *Preliminary Effluent Guidelines Program Plan 15* (FR 51155, Vol. 86, No. 175) including revision of the effluent guidelines or pretreatment standard for Organic Chemicals, Plastics & Synthetic Fibers point-source category to address PFAS discharges and Metal Finishing Category to address PFAS discharges, as well as a summary of the preliminary review of the Landfills Category.
- September 16, 2021: DOE memorandum, *Addressing Per-and Polyfluoroalkyl Substances at the Department of Energy*, including guidance on use of aqueous film forming foam, efforts to understand PFAS at DOE sites, and establishment of a PFAS Coordinating Committee.
- September 23, 2021: DOE PFAS Working Group Meeting
    - "An Overview of the Uses of PFAS" 2020 peer-reviewed publication (Glüge et al., 2020) (https://doi.org/10.1039/D0EM00291G).
- October 2021: DoD Quality Systems Manual Version 5.4
    - Per-and Polyfluoroalkyl Substances (PFAS) Using Liquid Chromatography Tandem Mass Spectrometry (LC/MS/MS) With Isotope Dilution or Internal Standard Quantification in Matrices Other Than Drinking Water
    - Per-and Polyfluoroalkyl Substances (PFAS) Analysis by LC/MS/MS (EPA Draft Method 1633)
- October 18, 2021: FACT SHEET: Biden-Harris Administration Launches Plan to Combat PFAS Pollution. (https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/18/fact-sheet-biden-harris-administration-launches-plan-to-combat-pfas-pollution/)
- October 18, 2021: *PFAS Strategic Roadmap: EPA's Commitments to Action 2021–2024*. (https://www.epa.gov/pfas/pfas-strategic-roadmap-epas-commitments-action-2021-2024)
- October 26, 2021: DOE NNSA memorandum, *Direction to Implement Department of Energy Policy on Per- and Polyfluoroalkyl Substances*.
- October 26, 2021: DOE memorandum*, Creation of Per- and Polyfluoroalkyl Substances (PFAS) Coordination Committee*.

On October 26, 2021, DOE PPPO issued a reply to the June 7, 2021, EPA letter to the PGDP DOE Site Lead. The reply included a phased approach:

- PPPO will continue to coordinate with DOE-EM to implement the recommendations that result from the DOE-EM PFAS Survey, and PPPO will communicate that information to EPA and Kentucky through routine Paducah FFA and working group meetings as soon as the report is released. PPPO and DOE-EM will collaborate with DOE-Headquarters as DOE-Headquarters establishes a complex-wide framework for approaching PFAS and through these avenues coordinate with EPA and state representatives.
- PPPO will discuss with DOE-EM and DOE-Headquarters the implementation of the recommendation for a site-wide Paducah Site PFAS sampling effort as part of the ongoing PPPO Environmental Monitoring Program. The Deputy Secretary of Energy issued a

policy on September 16, 2021, that underscores the importance of appropriately characterizing historic PFAS use and releases at DOE sites. Efforts at sites are expected to focus on, among other aspects, ongoing testing and monitoring for PFAS at levels exceeding established health advisory levels or regulatory limits. PPPO will work to establish a plan to address the DOE policy in coordination with EPA and Kentucky.

- PPPO continues to report PFAS chemical inventory and/or usage as required by EPA's Toxic Release Inventory reporting regulations and is evaluating options for eliminating the use of fire-fighting chemicals that contain PFAS at the Paducah Site.
- DOE will continue reporting efforts related to PFAS in the Annual Site Environmental Report in order to keep the public informed regarding this emerging issue and the continued DOE and other stakeholders' activities as all agencies work through their respective processes.

During previous meetings in 2021, DOE previously had discussed a potential sampling approach that includes PFAS sampling of monitoring wells on DOE property and that are already planned to be sampled in the EMP. Regular sampling equipment and methods would be used and samples distant from the FTA or upgradient from the other potential source areas could be useful in understanding the potential for false positives.

Questions to be considered during the development of a sampling approach would include how to define "elevated concentration". Potential approaches brought forward by Shanna Alexander for consideration include concentrations some order of magnitude above a screening level (e.g., 10X > RSL or 100X > RSL) or concentrations above the EPA 70 ppt lifetime health advisory for individual PFAS or combined (if an MCL still unavailable at the time of sampling). Additional questions include how to report PFAS compounds without screening levels (e.g., only reporting for certain PFAS analytes, reporting all PFAS analytes reported by the selected analyses method, etc.) and where will the sampling program be documented (e.g., EMP).

DOE provided the following updates to the group:

- *The Paducah Site continues to participate in the DOE HW PFAS Working Group Meetings*
- *Rich is a member of the DOE PFAS Coordinating Committee (first meeting December 8, 2021)*
- *DOE/FRNP are researching the potential for false negatives, in addition to possible false positives, associated with sampling equipment (either ab/adsorption of PFAS to or release of PFAS from sampling equipment, respectively).*
- *Regarding the recommendation for a site-wide Paducah Site PFAS sampling effort*
    - *A contract Notice to Proceed will be issued to FRNP.*
    - *FRNP's current contract ends June 2022 and addition of the sampling effort scope to their contract requires formal contract extension.*
    - *Current plan is to have project DQOs by the end of this fiscal year to support sampling in FY2023.*

EPA requested correspondence outlining the path forward and the reasoning for the schedule. DOE will discuss internally the appropriate approach for this communication.

9. Poll RAWG Members/Open Discussion

No comments were received from the group.

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ATTACHMENT E1

1995 QUESTIONNAIRE AND RESPONSES REGARDING RECREATIONAL USAGE OF BAYOU AND LITTLE BAYOU CREEKS

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409
North Forbes Road
Lexington, Kentucky
40511-2050

606-233-0574
606-254-4800 FAX

Fuller
Mossbarger
Scott &
May
FMSM
ENGINEERS

October 26, 1995 O.1.1.94355L05

Mr. Charles Logsdon
Kentucky Department of Fish and Wildlife Resources
10535 Ogden Landing Road
Kevil, Kentucky 42053

Re: PCB Risk Calculations
Paducah Gaseous Diffusion Plant

Dear Mr. Logsdon:

FMSM is conducting a preliminary risk calculation for the Little Bayou and Big Bayou areas around the Paducah Gaseous Diffusion Plant. This subject was discussed at a meeting in which you attended on September 7, 1995. During that meeting you indicated that your office could provide information on the recreational use of these areas. In response to your suggestion, we have developed the following list of questions. Please try to research your site use data and answer as many of these questions as possible. If data is not directly available to answer these questions we would appreciate an estimate based on your best professional judgment.

Big Bayou

1. What is the average number of visitors per year to Big Bayou?
2. Of this number, how many are adults and how many are children?
3. Are most of your visitors repeat or one-time visitors on a yearly basis?
4. What is the average time (hours) spent in Big Bayou? Is there a difference in average time spent between adult and child usage?
5. What are the common recreational usages in the area? What is the percentage breakdown of usages by the visitors (i.e. what percentage of visitors fish, hunt, hike, swim, etc.)?
6. What is the number of repeat visits per year by any one individual or group of individuals? What is the average time spent (hours) in the area by the higher frequency visitors?

7. For individuals who are fishing in the area, are they mostly bank fishing or wade fishing? Can you estimate the percentage breakdown between the two? What is the average time spent in the area by a fisherman?

8. Is there a harvestable fish population in Big Bayou? If there is, is there enough to support subsistence fishing (i.e., 0.284 kilograms of meat flesh/meal) for one person to eat 128 meals a year? If not, how much fish, and how often could a person best expect to harvest a meal for consumption?

Little Bayou

I realize that during the September 7th meeting, you stated there is little to no recreational use of the Little Bayou areas. However, it would be helpful if you could answer the same questions about Little Bayou, as asked of Little Bayou. Therefore, we are repeating the following questions.

1. What is the average number of visitors per year to Little Bayou?

2. Of this number, how many are adults and how many are children?

3. Are most of your visitors repeat or one-time visitors on a yearly basis?

4. What is the average time (hours) spent in Little Bayou? Is there a difference in average time spent between adult and child usage?

5. What are the common recreational usages in the area? What is the percentage breakdown of usages by the visitors (i.e. what percentage of visitors fish, hunt, hike, swim, etc.)?

6. What is the number of repeat visits per year by any one individual or group of individuals? What is the average time spent (hours) in the area by the higher frequency visitors?

7. For individuals who are fishing in the area, are they mostly bank fishing or wade fishing? Can you estimate the percentage breakdown between the two? What is the average time spent in the area by a fisherman?

8. Is there a harvestable fish population in Little Bayou? If there is, is there enough to support subsistence fishing (i.e., 0.284 kilograms of meat flesh/meal) for one person to eat 128 meals a year? If not, how much fish, and how often could a person best expect to harvest a meal for consumption?

We appreciate your help in answering these questions. After you have reviewed these, if you have any questions, or if the questions need clarification, please call.

Sincerely,

FULLER, MOSSBARGER, SCOTT AND MAY
ENGINEERS, INC.

Stephen L. Scott, P.E.
Project Manager

/esh

c: David Asburn
Tom McGee
Bob Sneed
David Brancato

facsimile
TRANSMITTAL

to: Stephen Scott, P.E.
fax #: 606-254-4800
re: Big Bayou & Little Bayou
date: November 8, 1995
pages: 4, including this cover sheet.

From the desk of...

Charlie Logsdon
WMA Supervisor
Ky. Dept. Of Fish & Wildlife Resources
10535 Ogden Landing Rd.
Kevil, KY. 42053

(502)488-3233
Fax

Stephen Scott, P.E.
Fuller, Mossbarger, Scott and May
Engineers, Inc.
1409 North Forbes Road
Lexington, Ky. 40511-2050

Dear Mr. Scott:

I have answered these question as accurately as possible. If you have any other questions, or questions about my answers feel free to contact me. Sorry about the delay, but you're letter came during some of our deer hunting seasons.

Sincerely,

Charlie Logsdon

Charlie Logsdon

cc: Wayne Davis
Don Walker

Little Bayou

1. The number of people visiting Little Bayou is essentially zero, with the exception of PGDP personnel and a few fishermen(maybe, 20 visits annually) that fish a large beaver pond above the outfalls of the plant. A few people (bowhunters and dog trainers) may cross the creek occasionally, but these visits would be brief(the majority would be measured in seconds or minutes). Field trial galleries do cross the creek(over a large dirt-covered culvert) north of McCaw Road, however, they do not enter the creek and the whole process takes seconds.

2. The visitors would be adults.

3. Refer to Big Bayou question 3. Visitors to Little Bayou would be repeat users, probably less than 10 visits per year and most of them in the brief encounter scenario described in question 1.

4. Most encounters with Little Bayou would be measured in seconds. Fishermen that use the beaver pond above the outfalls, may fish on average 2 hours.

5. See Big Bayou question 5.

6. Field trials that cross the creek may occur 12-15 weekends of the year. Most of the participants would be repeat users. The sum of all the encounters with Little Bayou would be measured in minutes for the most frequent user and most would only cross the creek on the culvert and dirt crossings.

7. All fishermen in the beaver pond would be bank fishermen as the pond is too deep to wade.

8. Other than the beaver pond above the outfalls, it would be nearly impossible to catch 0.284 kgs of fish from Little Bayou. There is a fish population, but most would fall in the minnow category and are not desirable by fishermen. In the beaver pond, it would be possible to catch this amount, but it would not support subsistence fishing(128 meals/year).

Big Bayou

Question 1: The number of visits by people using Big Bayou specifically, is estimated to be 150 visits. This is for a specific activity involving Big Bayou, such as fishing. More people may be in the vicinity while using the WKWMA, but their use of Big Bayou maybe for only an instant(i.e., using a log to cross Big Bayou to hunt on the other side of the creek).

Question 2: Of the 150 visits of people using Big Bayou, 100 are adults and 50 are children. This is an estimate based on our observations of people using the area.

Question 3: Most of these people would be one time users. However, 10% of the total number of users could be classified as repeat users. The highest number of visits by one person specifically using Big Bayou, would probably be <10.

Question 4: The average time spent in Big Bayou by users is unknown. However, I feel the amount of time spent/trip would be similar to other activities. During 1994, the average number of hours spent/trip for the following activities were: Quail hunting - 3.49 hrs/trip(n= 158), rabbit hunting - 3.25(n=168), bowhunting for deer - 3.48(n=1115), duck hunting - 2.4(n=69), and raccoon hunting - 2.63(n=20). Raccoon hunting and duck hunting would be the activities most likely associated with Big Bayou. There would be little, if any, difference between adult and child usage of the area.

Question 5: This question is difficult to answer. Do you mean for WKWMA or Big Bayou? WKWMA is heavily used by a wide variety of users. Annually, the estimated number of visits for the following activities are: fishing - 5000 visits/year, hunting and dog training 4-6000, field trials - 1500, hiking - 100, berry & nut picking - 200, driving through for a variety of reasons - 50,000.
For activities involving Big Bayou alone: fishing - 150, hunting - ?(explained in question 1).

Question 6: Refer to questions 3 and 4.

Question 7. Most, if not all would be bank fishermen. Most of the fishing would occur at 3 points: 1) where the iron bridge in tract 4 crosses Big Bayou, 2) where the collapsed bridge in tract 4 crosses Big Bayou(by weir constructed by PGDP), and 3) where the concrete crossing bridges Big Bayou in tract 6. While it may occur, no wade fishing has been observed. No actual data is available, but should be similar to the length of visits noted in question 4.

Question 8: There is a harvestable fish population in Big Bayou. A person could potentially expect to catch 0.284 kgs of fish on a regular basis(depending on the skill of the fisherman), however, this is assuming that the person is not culling(throwing back extremely small fish). The frequency of being able to catch 0.248 kgs of fish would increase as one approaches the mouth of Big Bayou. Also, the only way the creek could support 128 meals a year is if there was major influx of fish from the Ohio River. This does occur when there is a backwater. During the backwater periods catches of 50 to several hundred pounds of catfish can be taken(this has been observed) on trotlines. This would not be indicative of risks associated with the plant.

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ATTACHMENT E2

2014 E-MAIL UPDATE REGARDING RECREATIONAL USAGE OF BAYOU AND LITTLE BAYOU CREEKS

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Used with permission for inclusion in *Methods for Conducting Risk Assessment and Risk Evaluation at the Paducah Gaseous Diffusion Plant Paducah, Kentucky, Volume 1. Human Health.*

Garner, Leanne K (YLN)

From:	Kreher, Timothy (FW) <Timothy.Kreher@ky.gov>
Sent:	Tuesday, January 21, 2014 11:41 AM
To:	Garner, Leanne K (YLN)
Subject:	RE: Update of Recreational Use of Bayou and Little Bayou Creeks near PGDP

LeAnne,

I would concur with the numbers and estimates originally provided by Charlie Logsdon for the most part. I would suggest that there are brief exposures to both Little Bayou and Bayou Creeks by dog trainers riding horses where they cross the creek via the method of the horse and dog wading through the creek while the rider is mounted (i.e., the riders does not have contact with the water for the most part). Such crossings are brief, less than 10 seconds at a time. I would also suggest that there may be cases where hunters cross one or both creeks by wading through shallow spots, but in most cases these people are wearing rubber boots or waders, and I would not consider this a major source of exposure (?). When hunters do wade through the creeks, it is again a brief exposure of less than 30 seconds each time.

I would suggest increasing the **frequency** of visits / exposures by a factor of 1.5 for all of Charlie's answers to factor in increased use of the WMA.

I almost never see fishing activity in the creeks outside of the portion that crosses through TVA-owned property near where the creeks join and meet the Ohio River (what we refer to as Tract 6 of the WKWMA). As Charlie mentioned, the great majority of this fishing activity occurs when the Ohio River levels are elevated and have the creeks "backed up" with water from the river. I assume this also decreases the effects of any particular exposure during these instances.

Tim Kreher
Wildlife Biologist, Kentucky Department of Fish and Wildlife Resources
Doug Travis, Obion Creek, and West Kentucky Wildlife Management Areas
10535 Ogden Landing Road, Kevil, KY 42053
office 270-488-3233; cell 270-292-9010; fax 270-488-2589
email Timothy.Kreher@ky.gov

From: Garner, Leanne K (YLN) [mailto:Leanne.Garner@lataky.com]
Sent: Tuesday, January 21, 2014 8:52 AM
To: Kreher, Timothy (FW)
Subject: RE: Update of Recreational Use of Bayou and Little Bayou Creeks near PGDP

Any thoughts on this, Tim?
If there are no updates, I can just use to older information.

Thanks.

LeAnne

From: Garner, Leanne K (YLN)
Sent: Tuesday, January 07, 2014 8:56 AM
To: 'Timothy.Kreher@ky.gov'
Subject: RE: Update of Recreational Use of Bayou and Little Bayou Creeks near PGDP

Good morning, Tim!
I hope you had a good holiday!

We are updating the Risk Methods Document (the *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant Paducah, Kentucky Volume 1. Human Health*) with more current information.

Some of the information we are updating is "Recreational Use of Bayou and Little Bayou Creeks near PGDP." I have attached that information.
The entire document can be found here:
http://www.paducaheic.com/media/112385/ENV1.A-00440-ARI41.pdf

If you could, please look at the attached and let me know if you think any of the information needs updating.
If so, do you have that information?

I would appreciate any help you could give.

Thank you.

LeAnne Garner
Scientist
LATA Kentucky
leanne.garner@lataky.com
270-441-5436