APPENDIX E

TECHNICAL INFORMATION

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CONTENTS

E.1. DATA AND DOCUMENTS USED TO ESTABLISH BACKGROUND CONCENTRATIONS E-7

E.2. SITE-SPECIFIC EXPOSURE INFORMATION E-9
- E.2.1. PHASE I SITE INVESTIGATION RESULTS OF SURFACE WATER AND GROUNDWATER USERS SURVEY TO DETERMINE GROUNDWATER USE NEAR PGDP E-9
- E.2.2. SUMMARY OF AGRICULTURAL PRACTICES IN BALLARD COUNTY, KENTUCKY E-9
- E.2.3. SUMMARY OF AGRICULTURAL PRACTICES IN MCCRACKEN COUNTY, KENTUCKY E-11
- E.2.4. AREA OF CROP LAND IN BALLARD AND MCCRACKEN COUNTY, KENTUCKY E-12
- E.2.5. RECREATIONAL USE OF BAYOU AND LITTLE BAYOU CREEKS NEAR PGDP E-12
- E.2.6. ANNUAL HARVESTS OF TURKEYS AND DEER IN MCCRACKEN AND BALLARD COUNTIES, KENTUCKY, AND WATERFOWL IN BALLARD COUNTY, KENTUCKY E-15
- E.2.7. USE OF EXPOSURE UNITS IN RISK CALCULATIONS AND REMEDIAL DECISIONS E-22

E.3. KENTUCKY REGULATORY GUIDANCE E-39

E.4. FLOWCHART FOR UNCERTAINTY MANAGEMENT FOR UNKNOWN AREAS OF CONTAMINATION E-41

E.5. COMPILED PARAMETERS FOR PROBABILISTIC RISK ASSESSMENTS E-45

E.6. LEAD-210 AT PGDP E-89

E.7. PAH CONTAMINATION AND ESTABLISHMENT OF REMEDIAL GOALS E-101

E.8. SITE-SPECIFIC SOIL SCREENING LEVELS AND SITE-SPECIFIC DILUTION ATTENUATION FACTORS AT THE PADUCAH GASEOUS DIFFUSION PLANT E-113

E.9. HUMAN HEALTH INFORMATION FOR THE PADUCAH VAPOR INTRUSION EVALUATION E-127

E.10. PERTINENT TOXICITY VALUES AND INFORMATION E-153

E.11. MEETING MINUTES FROM PADUCAH RISK ASSESSMENT WORKING GROUP E-157

ATTACHMENT E1: 1995 QUESTIONAIRE AND RESPONSES REGARDING RECREATIONAL USAGE OF BAYOU AND LITTLE BAYOU CREEKS E1-1

ATTACHMENT E2: 2014 E-MAIL UPDATE REGARDING RECREATIONAL USAGE OF BAYOU AND LITTLE BAYOU CREEKS..... E2-1

FIGURES

E.1. Map of West Kentucky Wildlife Management Area E-16
E.2. Map of West Kentucky Wildlife Management Area Horse Trails E-17
E.3. Map of Ballard Wildlife Management Area E-18
E.4. Wildlife Management Area Map Legend E-19
E.5. Total Turkey Harvest in Ballard and McCracken Counties 2000–2016 ..... E-20
E.6. Total Deer Harvest in Ballard and McCracken Counties 2000–2016 ..... E-21
E.7. Lead-210 Decay Chain E-89
E.8. Lead-210 Soil/Sediment Samples E-90
E.9. Total PAH Concentrations by Depth E-103
E.10. Total PAH in Surface (0-1 ft bgs) Soil/Sediment Samples E-105
E.11. Total PAH Subsurface (1-10 ft bgs) Soil/Sediment Samples E-107
E.12. Total PAH Deep Subsurface (>10 ft bgs) Soil/Sediment Samples E-109
E.13. Probabilistic DAF Distribution E-116

TABLES

E.1. Turkey Harvested on Public Land in Western Kentucky in 2016 ..... E-20
E.2. Deer Harvested on Public Land in Western Kentucky in 2016 ..... E-21
E.3. Waterfowl Counts in Ballard Wildlife Management Area E-22
E.4. Sample Results for Lead-210, Radium-226, and Uranium-238 in Soil and Sediment E-92
E.5. Results of Filtering E-96
E.6. Maximum Benzo(a)pyrene Concentrations by Sample Depth E-102
E.7. Maximum Total PAHs by Depth E-102
E.8 Modeling Matrix for Groundwater E-117
E.9 Example Site-Specific and Default Inputs for Key COPCs E-120
E.10. Human Health Information for the Paducah Vapor Intrusion Evaluation E-129

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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: http://www.paducaheic.com/media/32632/I-02004-0002-ARI52.PDF.

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.

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: http://www.paducaheic.com/media/45063/i-02300-0001f-ARI14.pdf. Appendix 2B-15 begins on page 276 of the pdf.

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 kgs 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.

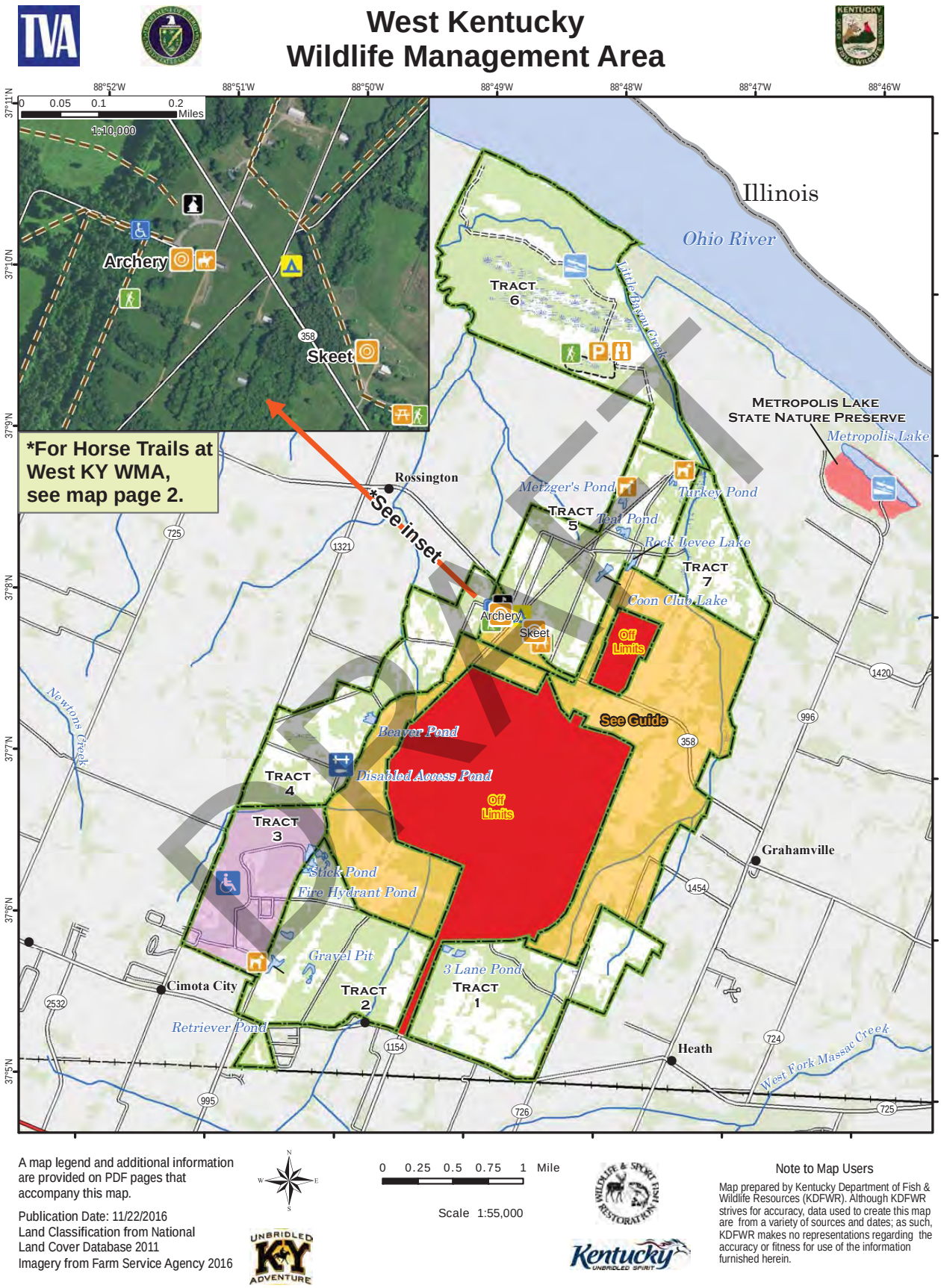
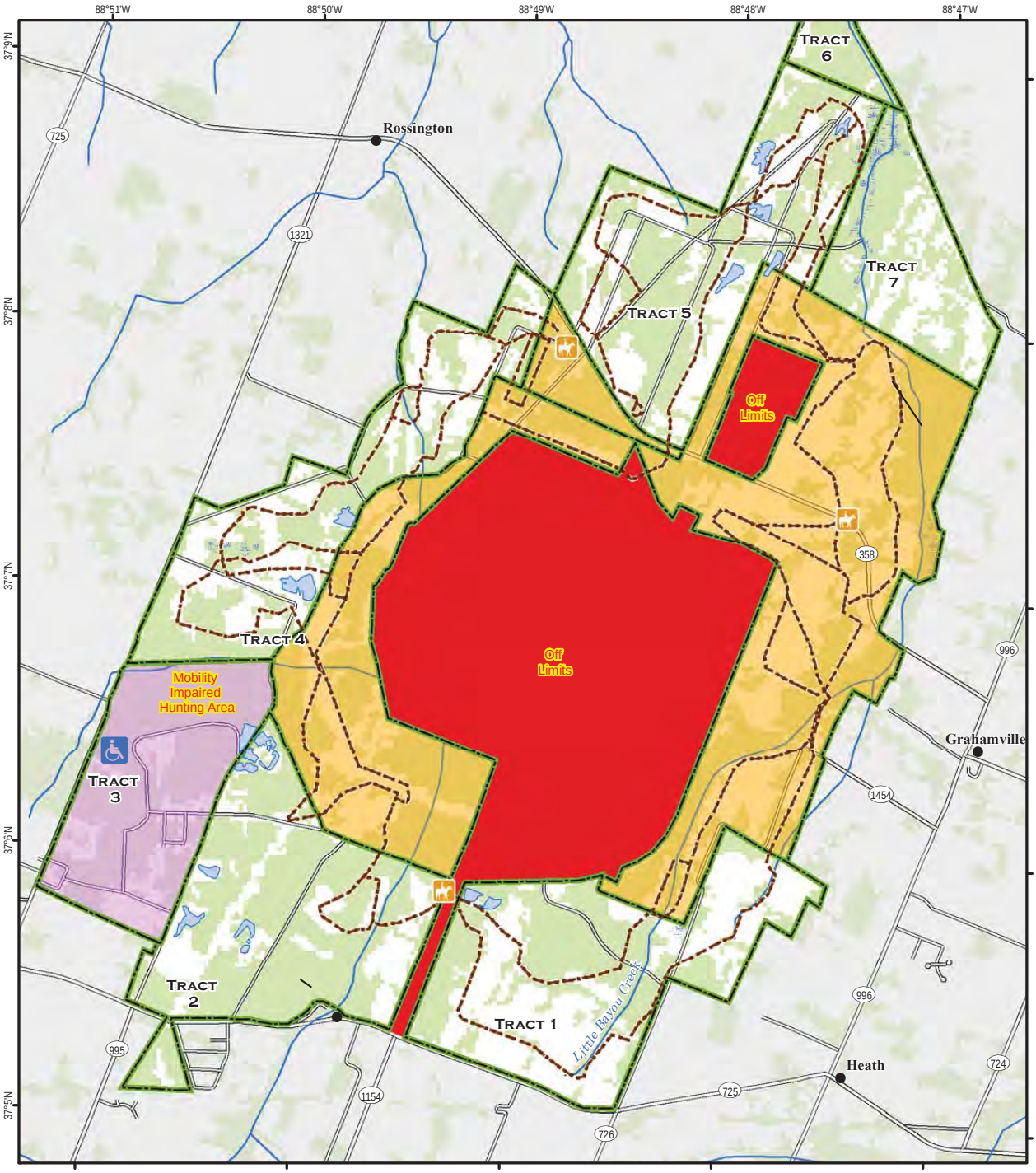


Figure E.1. Map of West Kentucky Wildlife Management Area

West Kentucky Wildlife Management Area Horse Trails



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

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

0 0.25 0.5 0.75 1 Mile

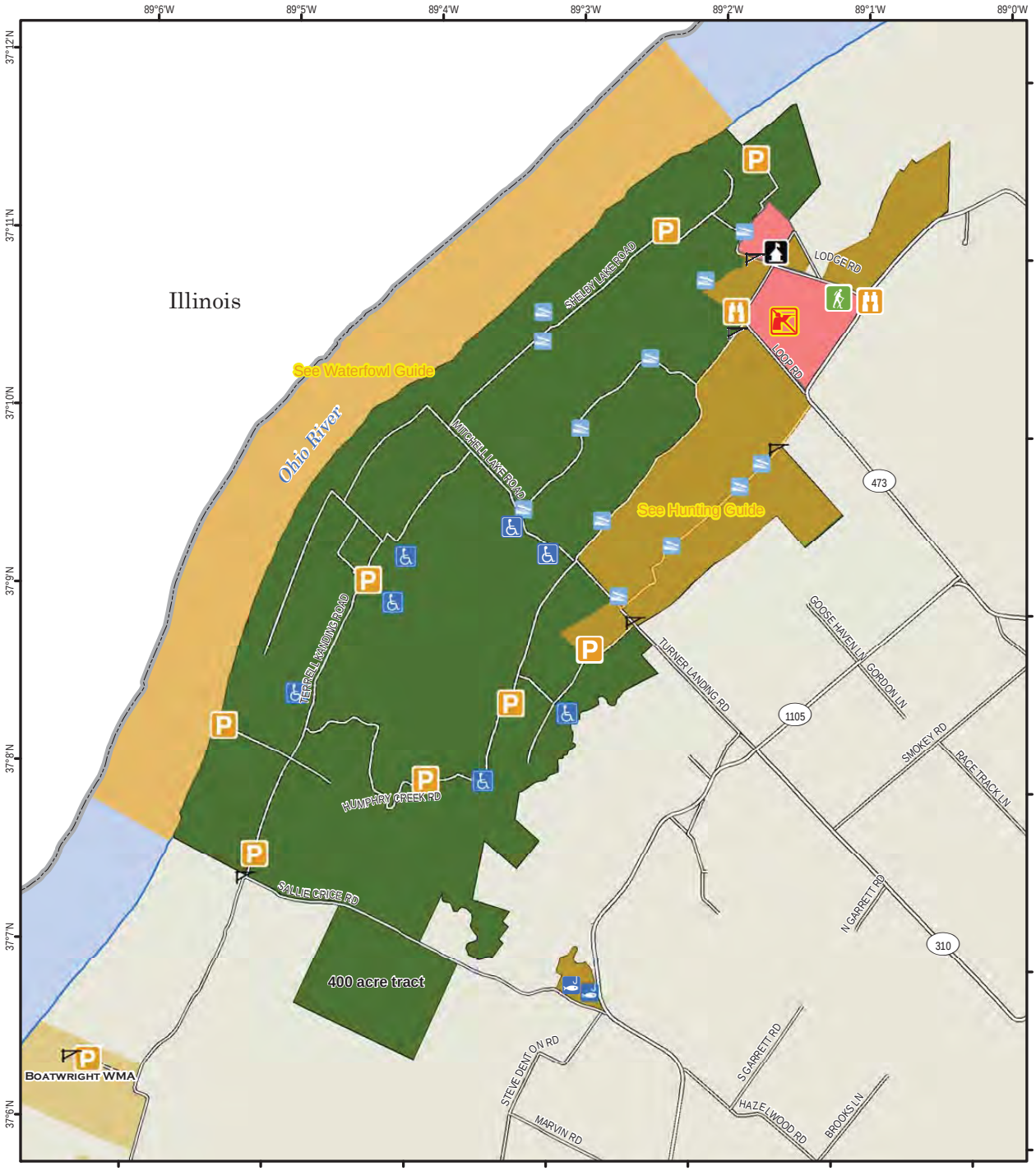
Scale 1:37,000

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

Ballard Wildlife Management Area
Index Map



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
- 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
- Area Off Limits
- No Hunting
- Seasonally Restricted Access
- Mobility Impaired Hunting Area
- Primitive Hunting Only
- Foot Traffic Only
- Open Water
- Wetland
- Woodland

- Populated Place
- Kentucky Boundary
- Interstate Highway
- Kentucky Parkway
- U.S. Highway
- State Highway
- Local Road
- 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.

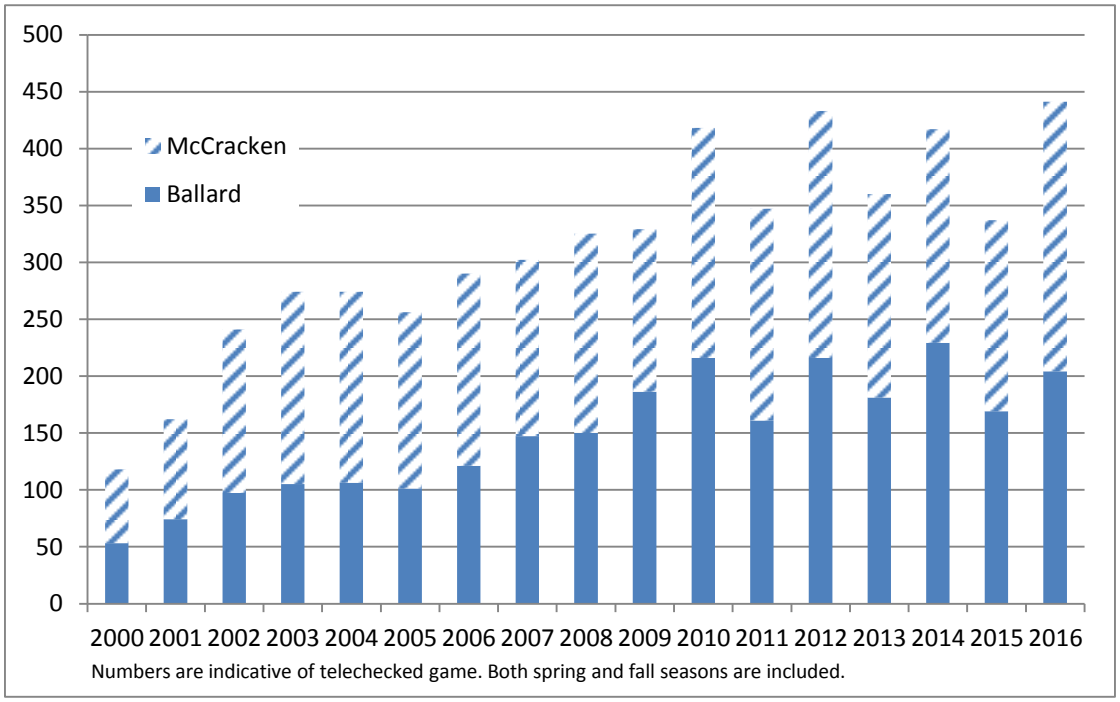


Figure E.5. Total Turkey Harvest in Ballard and McCracken Counties 2000–2016

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).

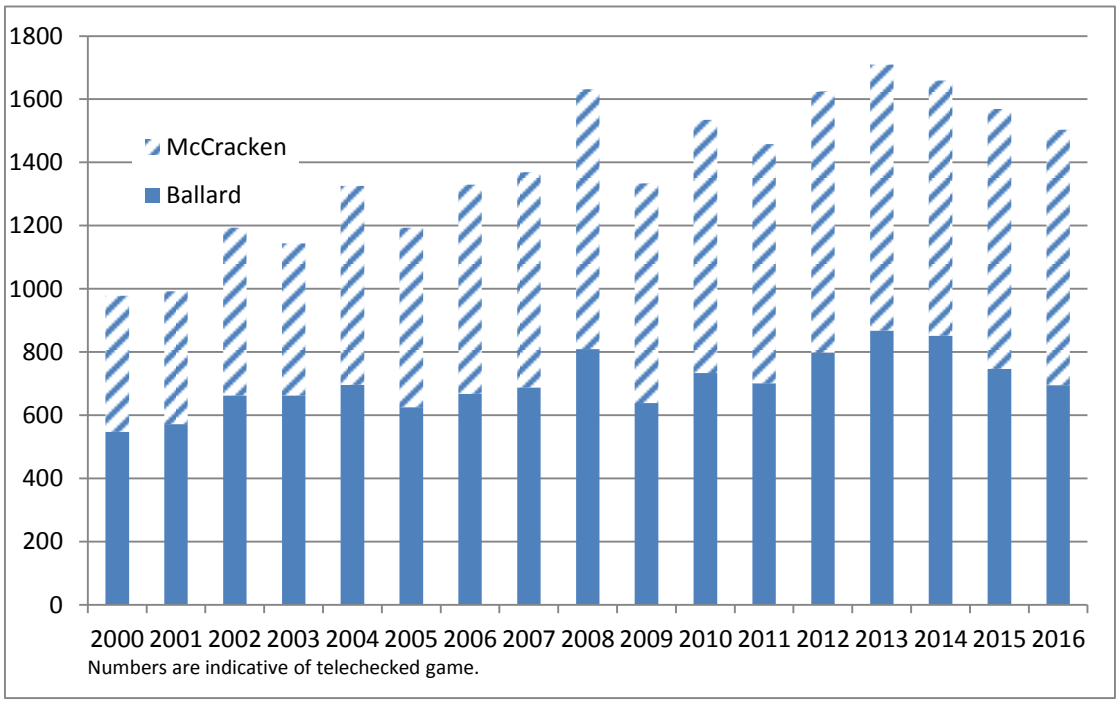


Figure E.6. Total Deer Harvest in Ballard and McCracken Counties 2000–2016

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

Date	Population Count		Harvest			Date	Population Count		Harvest		
	Ducks	Geese	Ducks	Canada Geese	Other Geese		Ducks	Geese	Ducks	Canada Geese	Other Geese
12/16/2015	43,000	2,600	19	0	1	12/7/2016	35,900	65	85	2	1
12/17/2015	43,000	2,600	16	0	0	12/8/2016	35,900	65	72	3	0
12/18/2015	43,000	2,600	24	0	0	12/9/2016	35,900	65	27	0	0
12/19/2015	41,500	500	26	0	0	12/10/2016	35,900	65	17	0	1
12/20/2015	41,500	500	28	0	0	12/11/2016	35,900	65	70	0	0
12/30/2015						12/14/2016	60,672	120	45	0	0
12/31/2015						12/15/2016	60,672	120	6	0	0
1/1/2016						12/16/2016	60,672	120	19	2	0
1/2/2016						12/17/2016	60,672	120	88	2	0
1/3/2016						12/18/2016	60,672	120	78	0	0
1/6/2016						12/21/2016	64,122	564	55	0	0
1/7/2016	No counts on					12/22/2016	64,122	564	62	0	0
1/8/2016	waterfowl due to		WMA closed			12/23/2016	64,122	564	56	0	0
1/9/2016	flood waters					12/28/2016	54,000	350	73	2	2
1/10/2016						12/29/2016	54,000	350	50	2	0
1/13/2016						12/30/2016	54,000	350	41	0	0
1/14/2016						12/31/2016	54,000	350	80	2	0
1/15/2016						1/4/2017	22,500	350	49	0	0
1/16/2016						1/5/2017	22,500	350	40	0	0
1/17/2016						1/6/2017	22,500	350	0	0	1
1/27/2016			93	1	0	1/7/2017	22,500	350	5	0	0
1/28/2016			104	1	4	1/8/2017	22,500	350	2	0	0
1/29/2016			86	2	4	1/11/2017	55,000	600	61	1	6
1/30/2016			114	0	0	1/12/2017	55,000	600	62	0	3
1/31/2016			110	0	2	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

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

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

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 list of COCs was confirmed on a subset of 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]e positive is where the actual risk posed by the site is less than 1 in 1,000,000 addi-

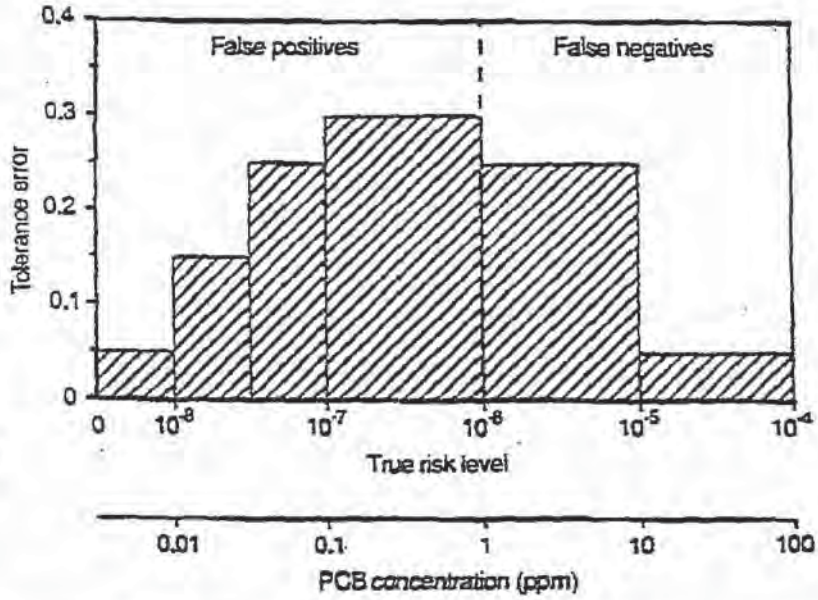
TABLE 1

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.

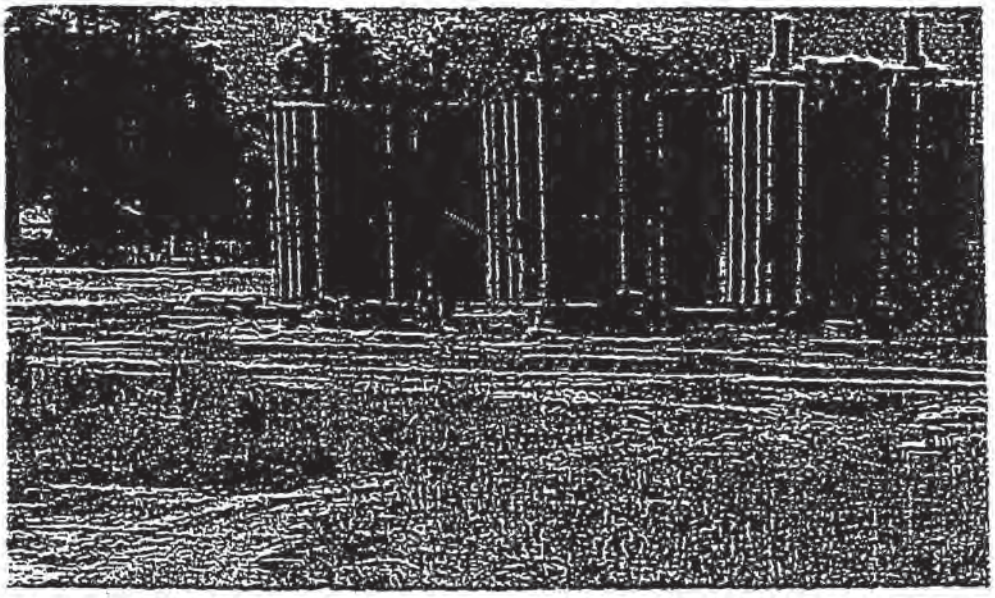
The data resolution needed for the location question is dependent on the spatial distribution of the contaminant within the exposure units (EU) (1/2 acres units in this example). Should an all-or-none approach be used for EU cleanup, or should remediation units (RUs) be defined as sub-units of EUs? In 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.

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

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).



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

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 are limited, the Superfund program must be 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 estimate 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

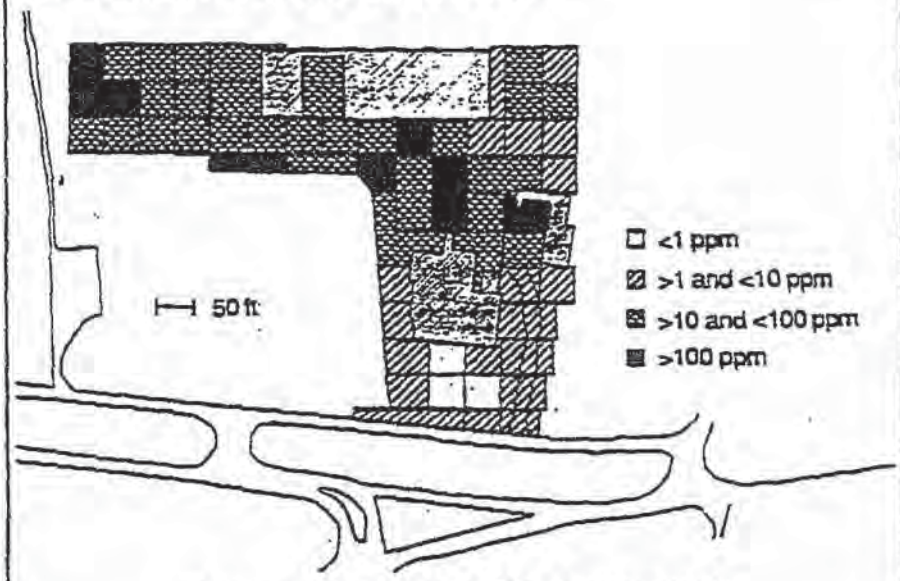
We have shown that the Data Quality Objectives process can help define questions and the data quality in ways that can lead to statistically-based sampling designs. The DQO process allowed Region 4 to collect the right data at the right time. It should be noted that at each step from the pilot survey 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

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

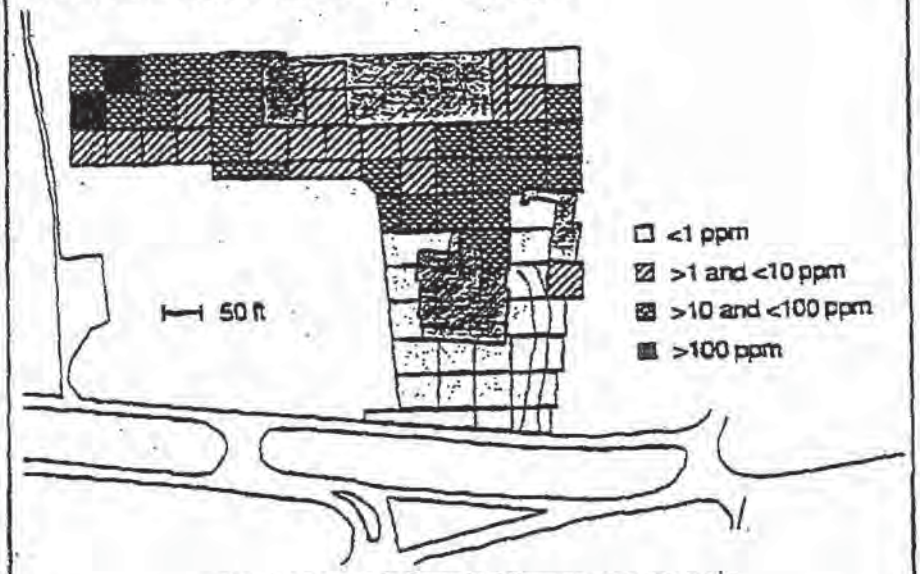
[1] n=62
[2] n=61, one RU was concrete below the top 8"

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



Hatched areas indicate buildings or concrete pads

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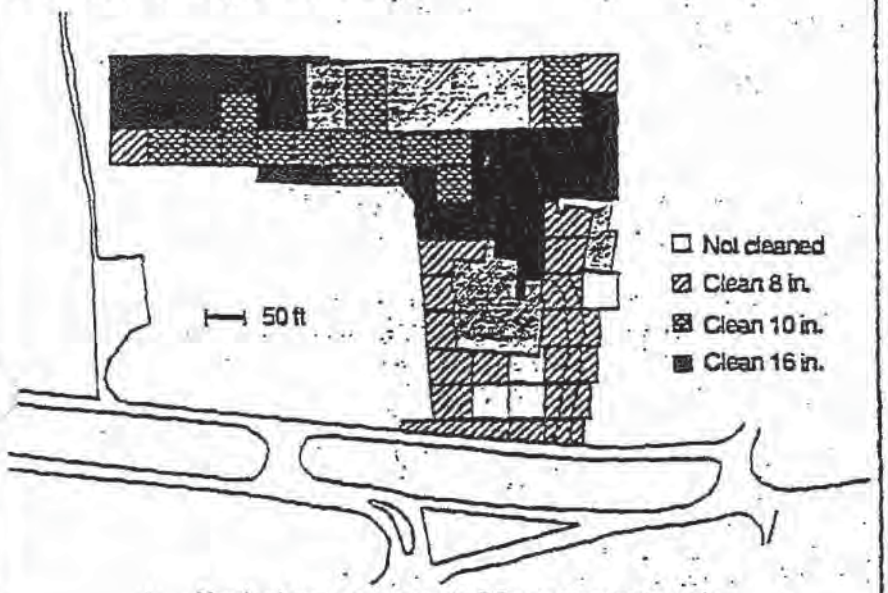
TABLE 4
'mmary of cleanup strategy

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).

Acknowledgments
We thank the following personnel in US-EPA Region 4 for their cooperation and interest in this project: M. Glenn, J. Johnston, D. Thoman, B. Fox, and E. Akin. We thank D. Michael of RTI for his involvement in the initial stages of the DQO development, and J. Pickett of MSU for his comments throughout the DQO development and design implementation. D. Goodman and J. Pickett kindly read earlier versions of the manuscript.

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To whom correspondence should be addressed. Readers interested in the technical details of the approach taken at Carolina Transformer can request a copy of the "Technical Appendix to Planning for Superfund Site Remediation."

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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").

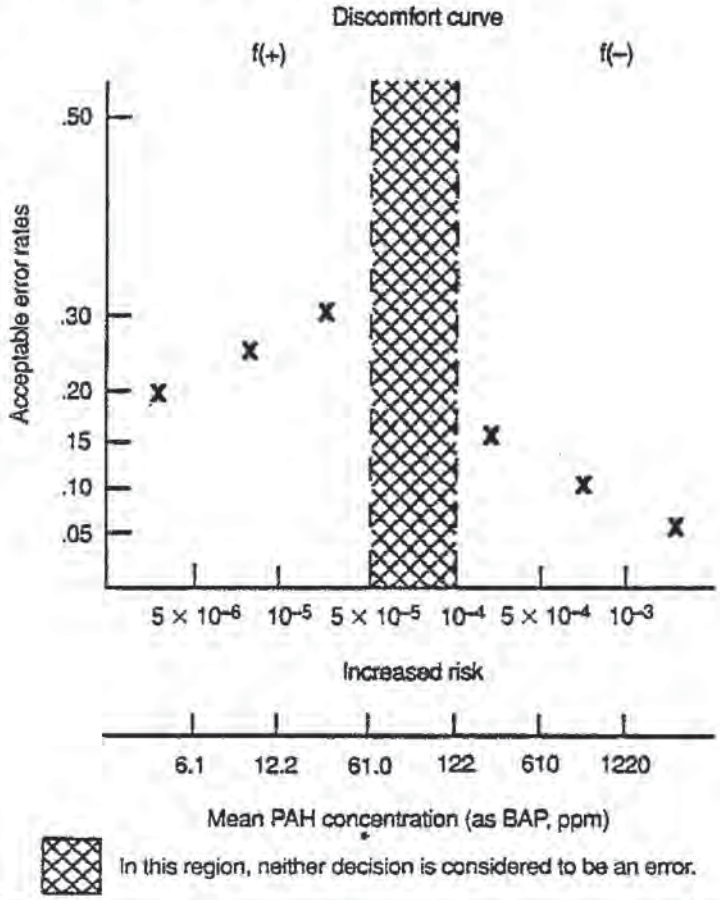
Design and optimization

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



In this region, neither decision is considered to be an 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 ran-

dom 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.

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

FIGURE 2
Frequency distribution of soil PAH concentrations

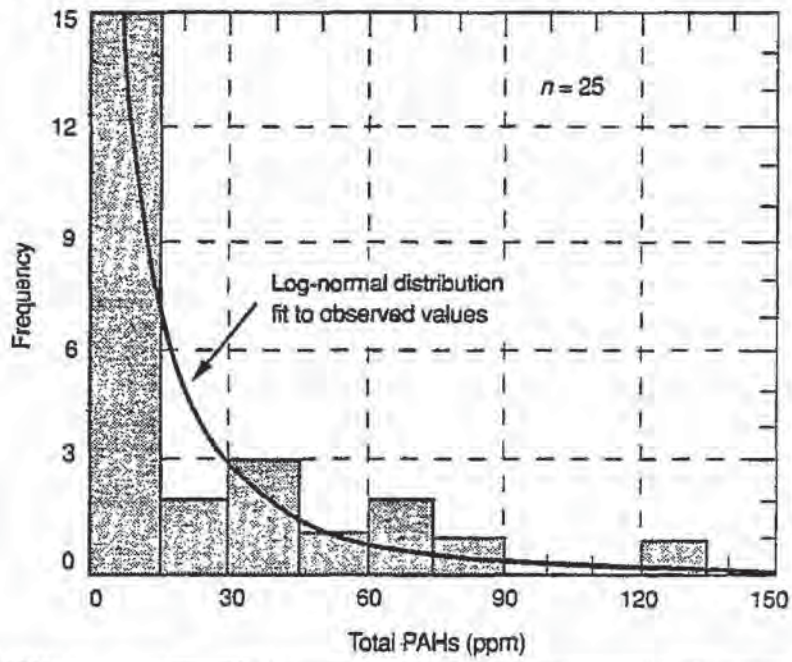


TABLE 1
Results of initial power calculations

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 μ = 122 ppm and α = .30.
Note: α = probability of concluding EU is a problem when μ is 61 ppm.

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

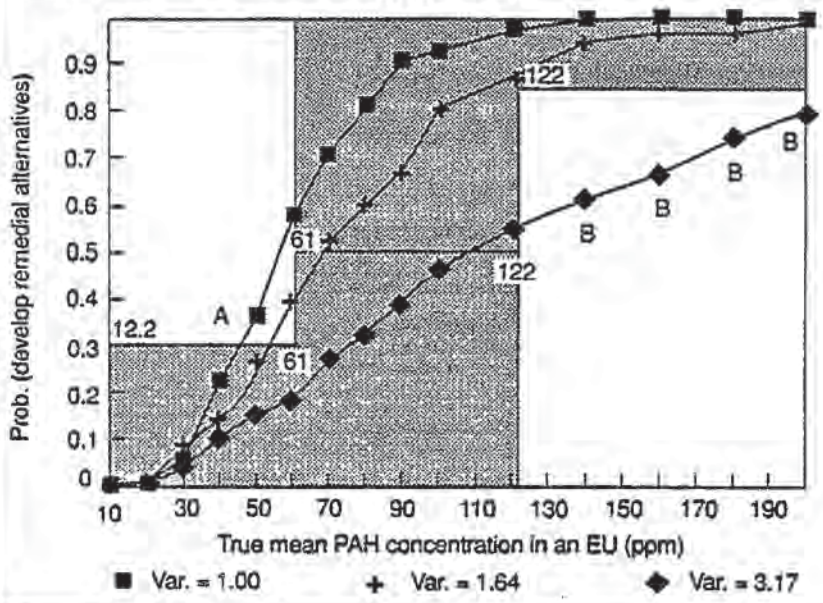
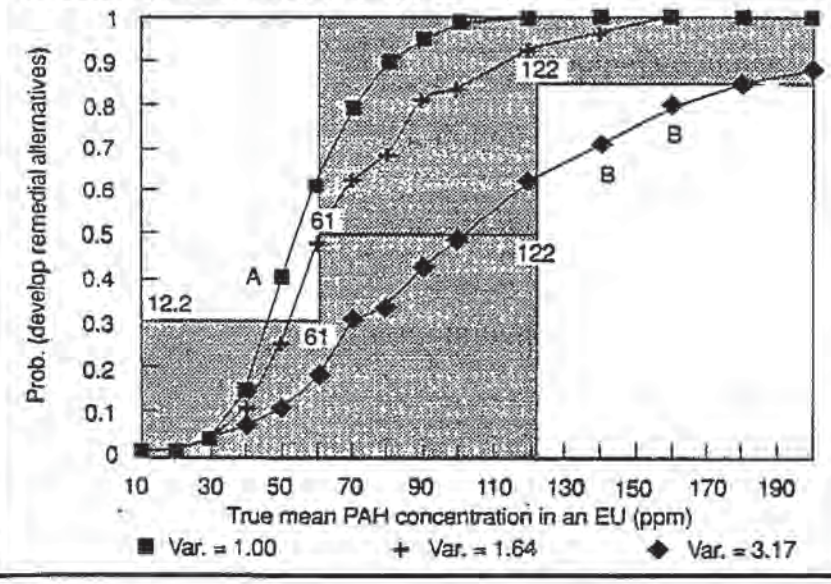


FIGURE 4

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.

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(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.
  http://waste.ky.gov/SFB/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.
  http://waste.ky.gov/SFB/Documents/AmbientBackgroundAssessment.pdf

- Kentucky Guidance for Groundwater Assessment Screening, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, January 15 2004.
  http://waste.ky.gov/SFB/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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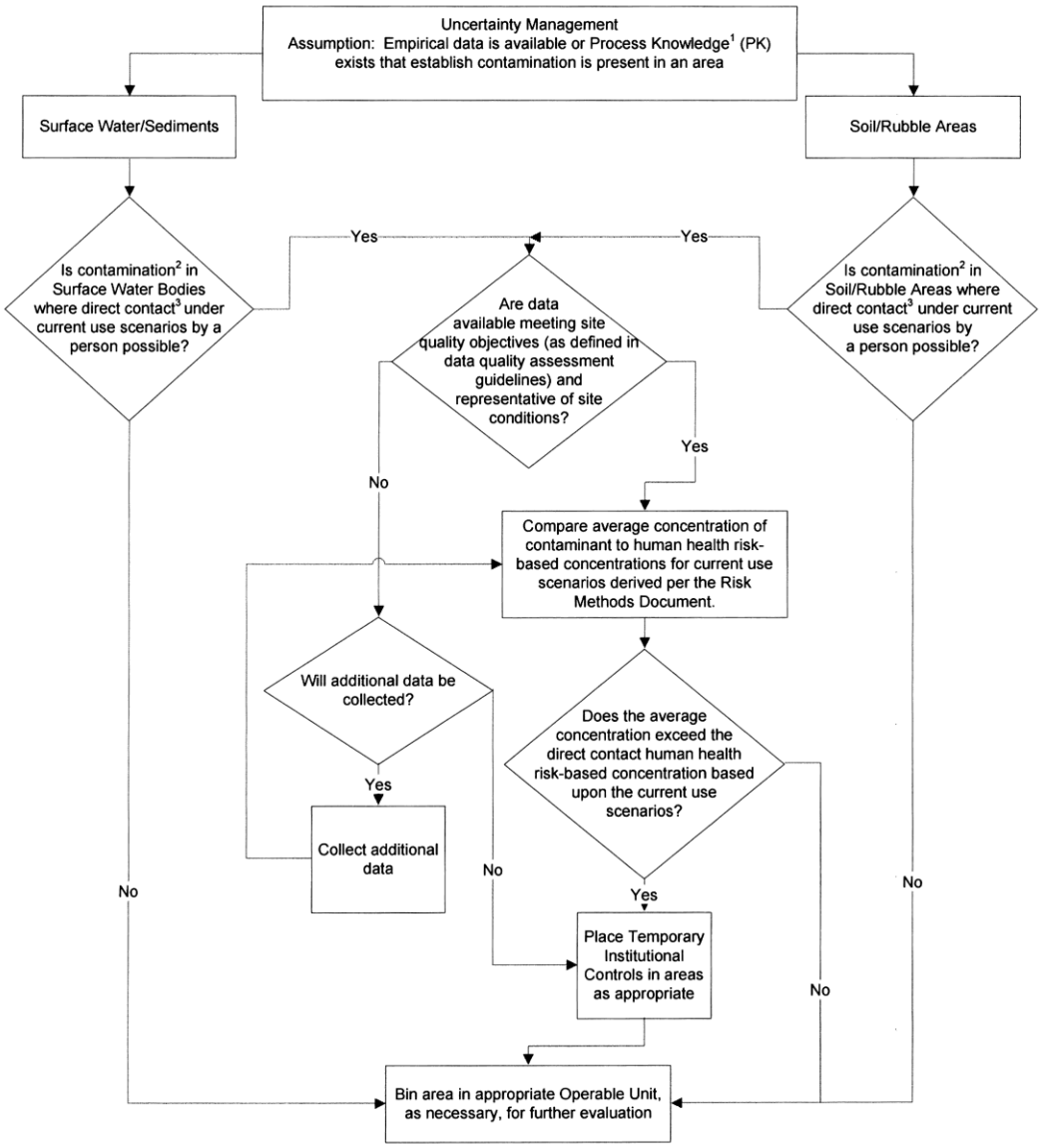
Enclosure

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.

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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:

$$\lambda = \frac{\ln 2}{t_{1/2}} \tag{3}$$

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.

[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.

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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

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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)

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

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

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			√

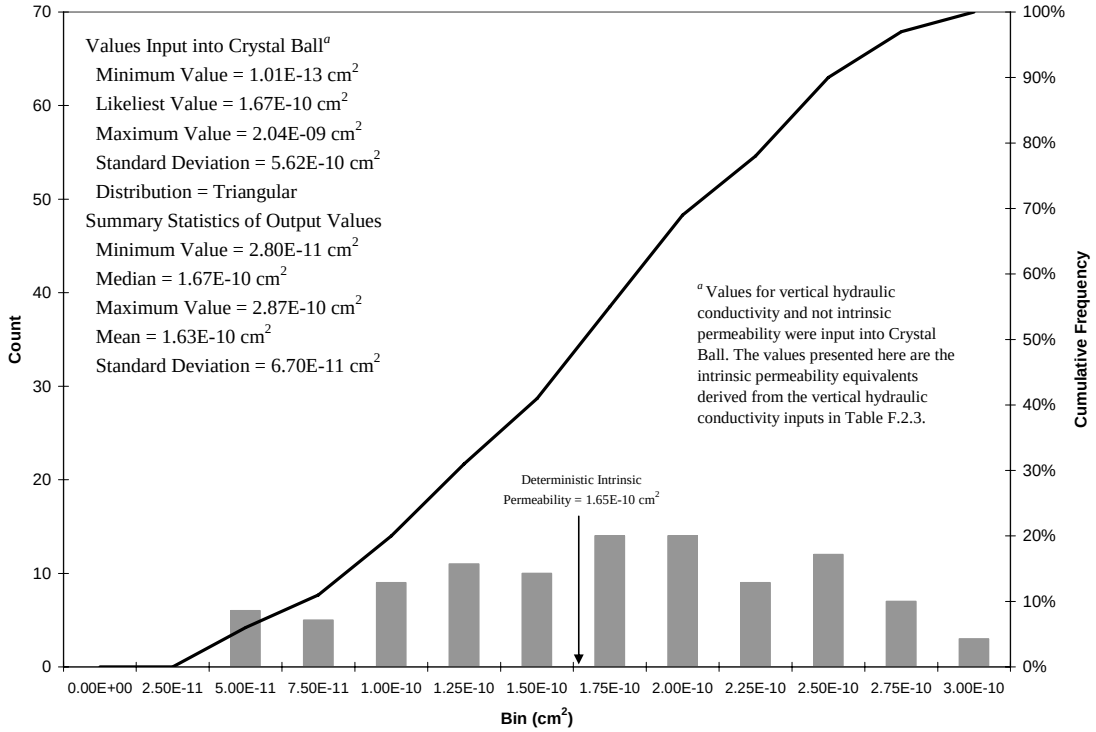

Fig. F.2.1. Histogram of Intrinsic Permeability SESOIL inputs for SWMU 1.

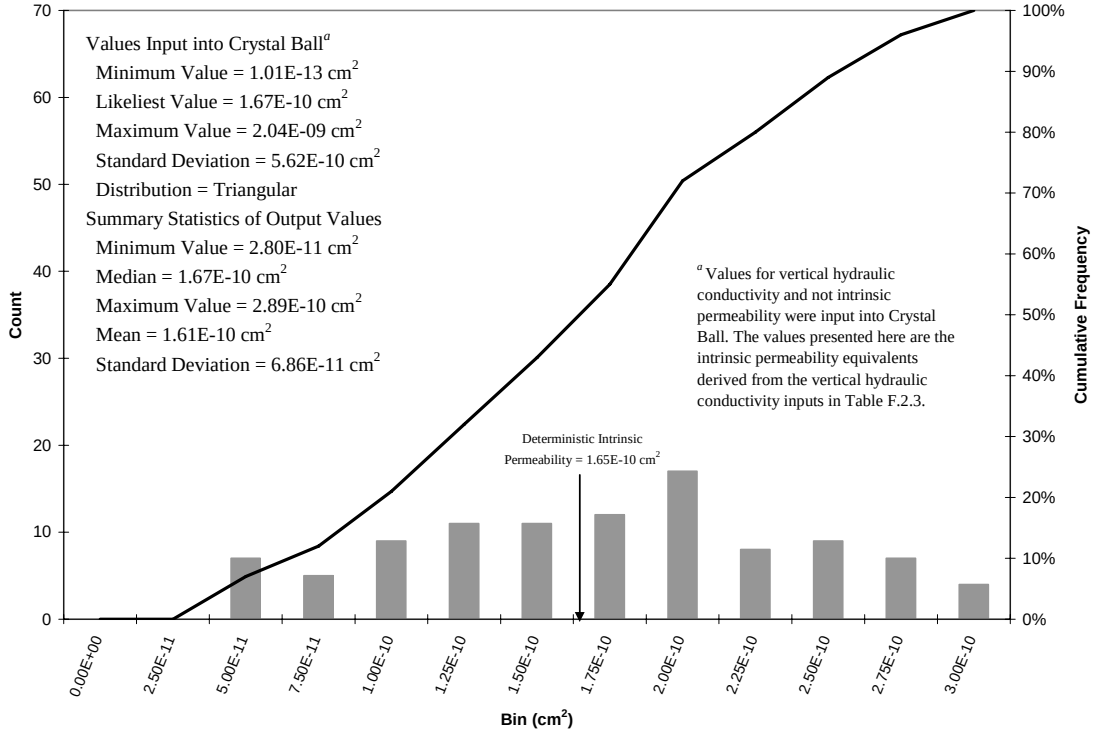

Fig. F.2.2. Histogram of Intrinsic Permeability SESOIL inputs for the C-720 Area.

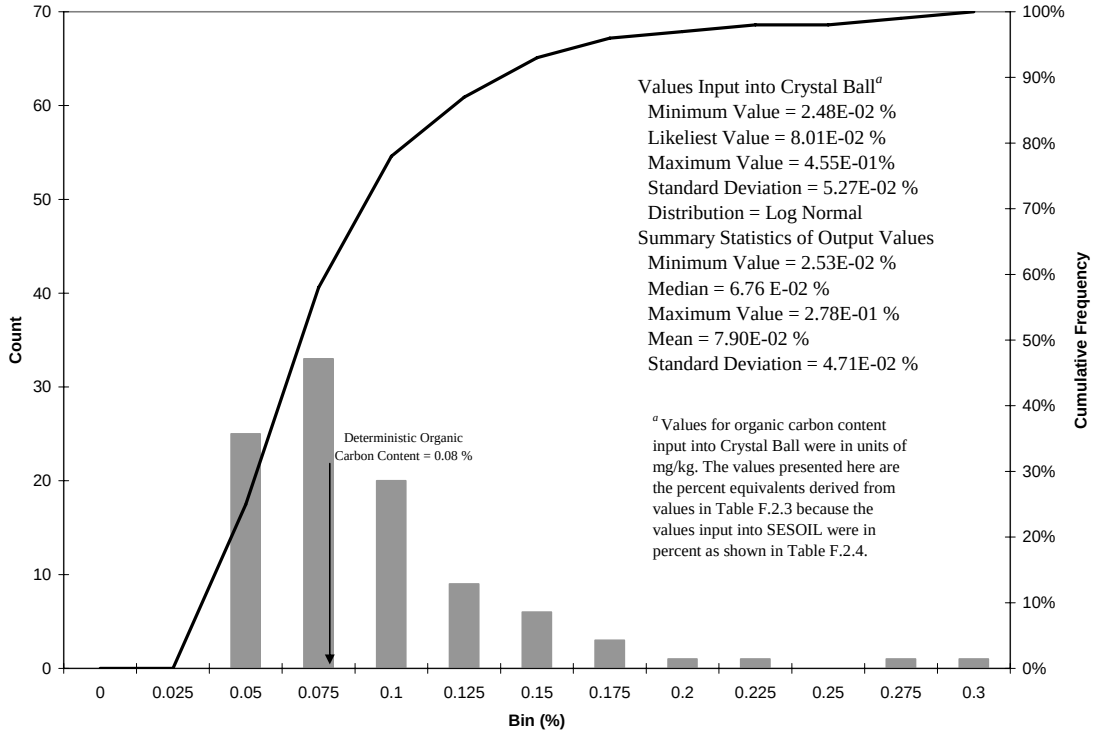

Fig. F.2.3. Histogram of Organic Carbon Content SESOIL inputs for SWMU 1.

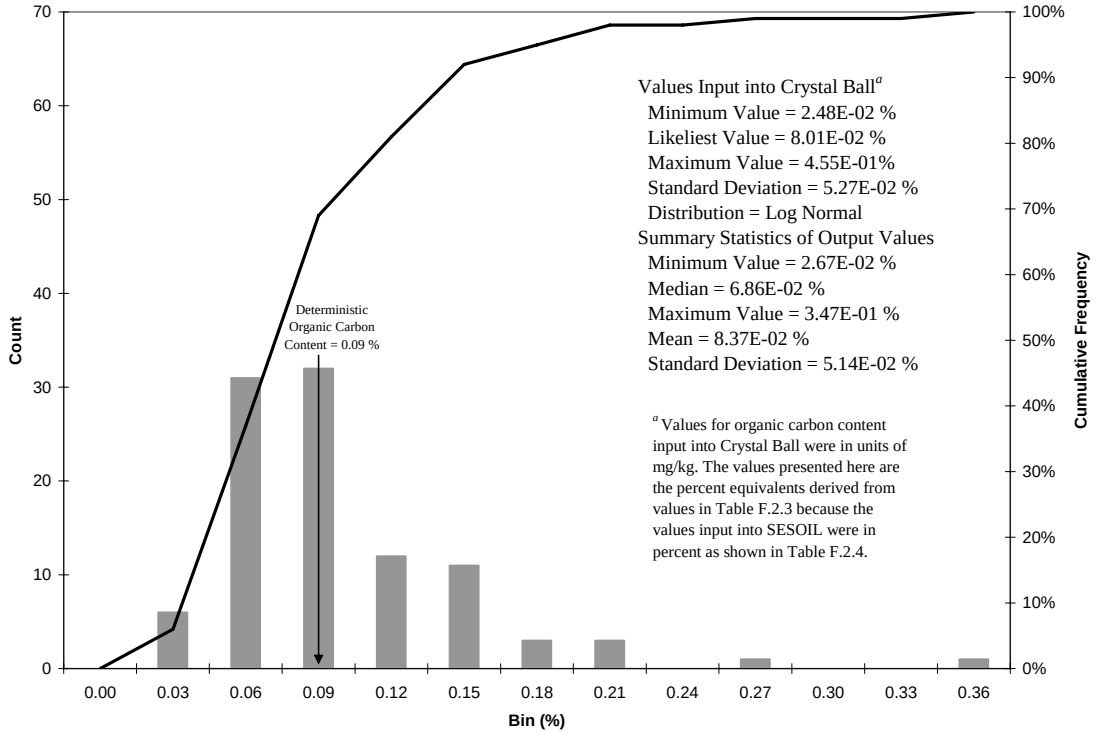

Fig. F.2.4. Histogram of Organic Carbon Content SESOIL inputs for the C-720 Area.

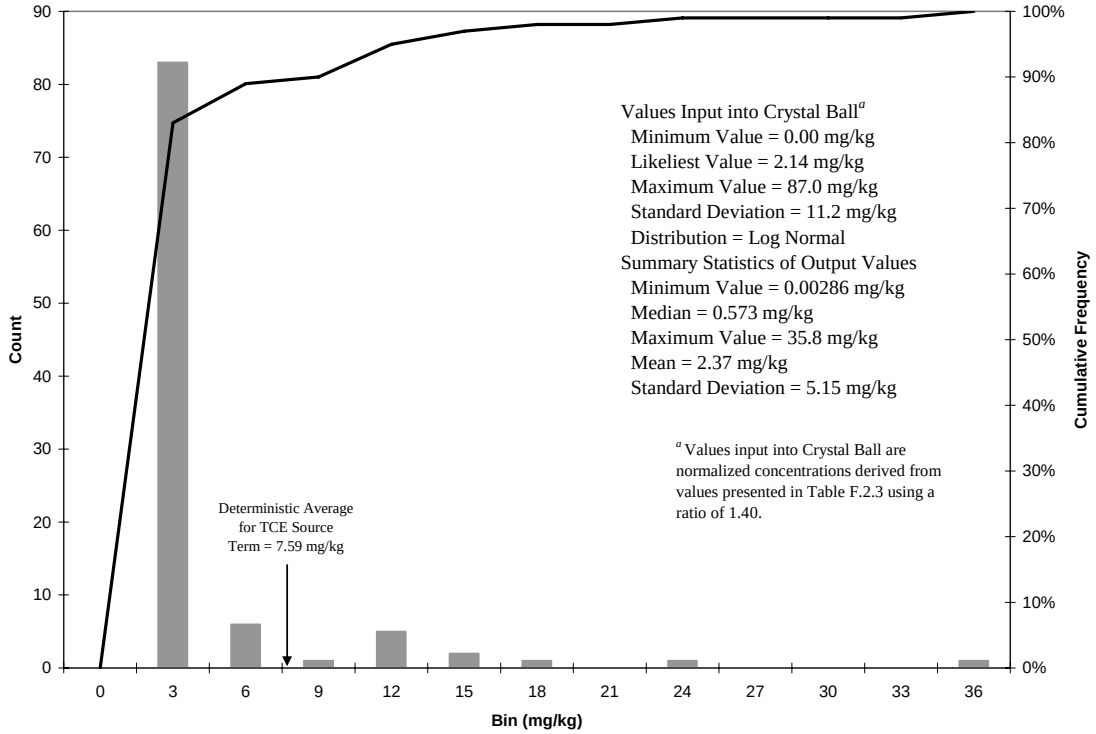

Fig. F.2.5. Histogram of Layer 1 TCE concentrations at SWMU 1 used as SESOIL inputs.

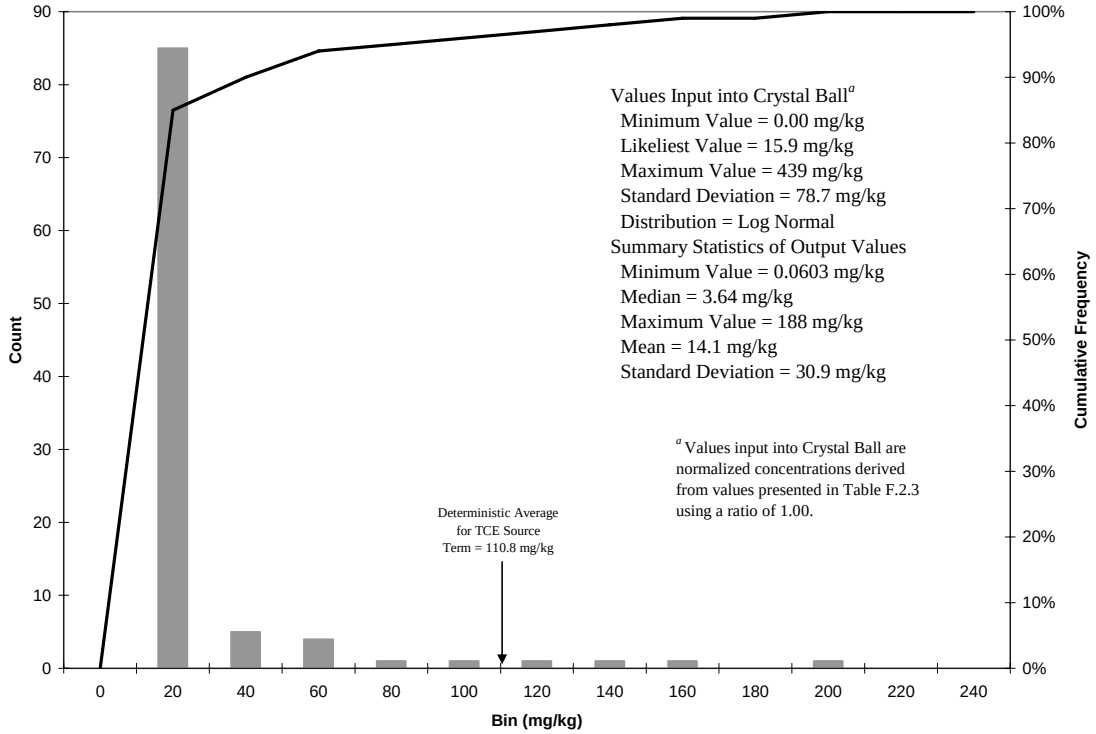

Fig. F.2.6. Histogram of Layer 2 TCE concentrations at SWMU 1 used as SESOIL inputs.

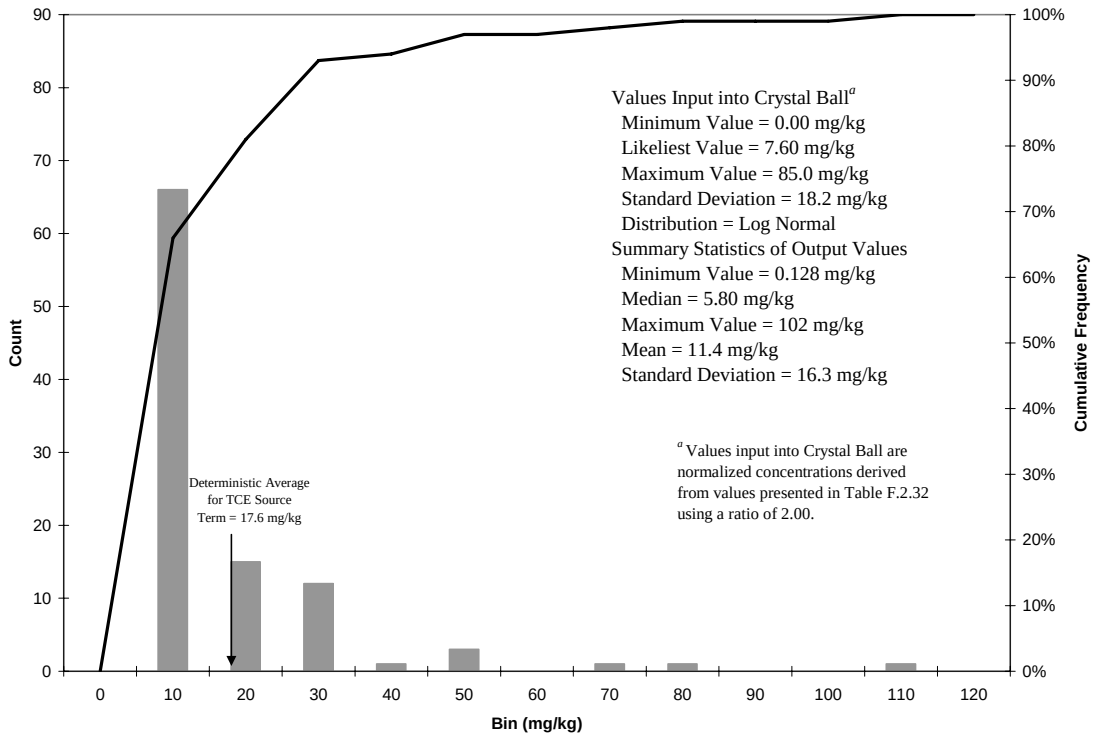

Fig. F.2.7. Histogram of Layer 3 TCE concentrations at SWMU 1 used as SESOIL inputs.

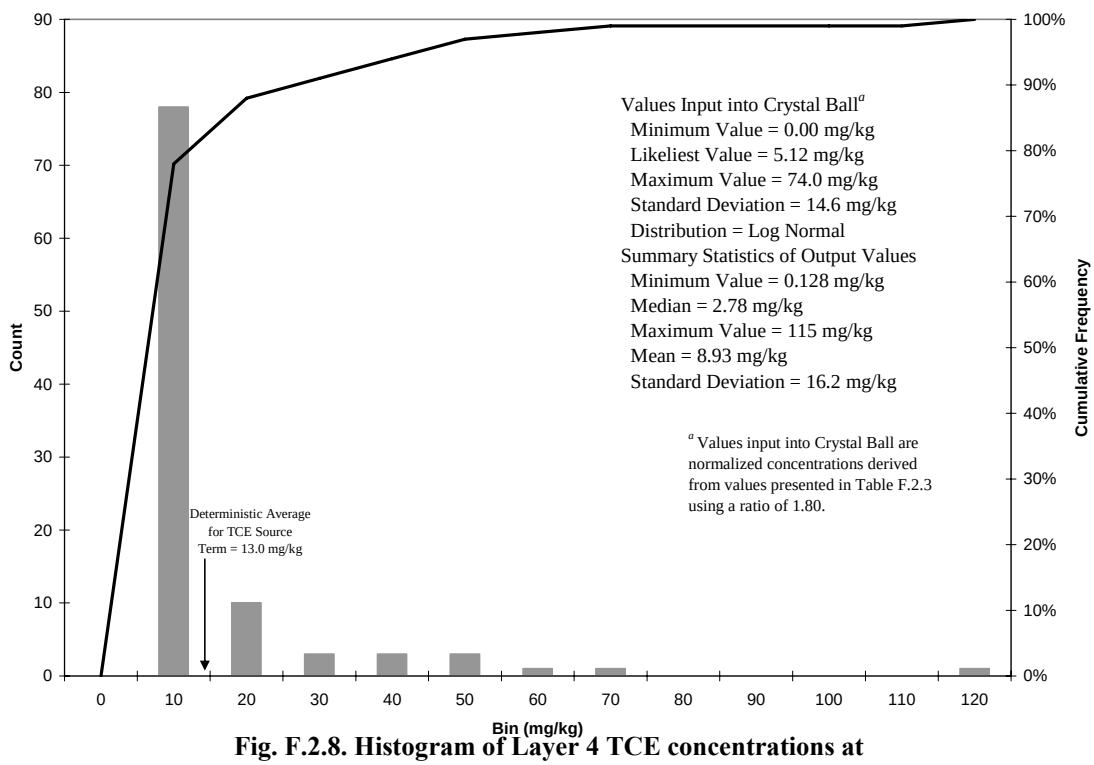

Fig. F.2.8. Histogram of Layer 4 TCE concentrations at SWMU 1 used as SESOIL inputs.

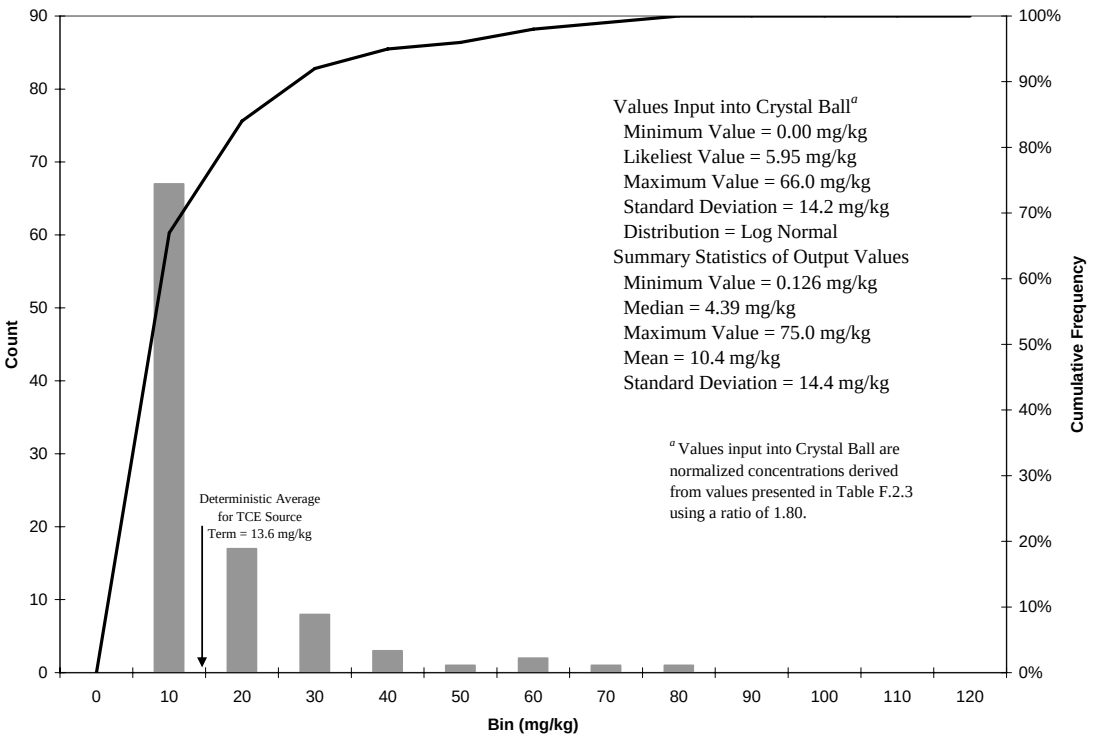

Fig. F.2.9. Histogram of Layer 5 TCE concentrations at SWMU 1 used as SESOIL inputs.

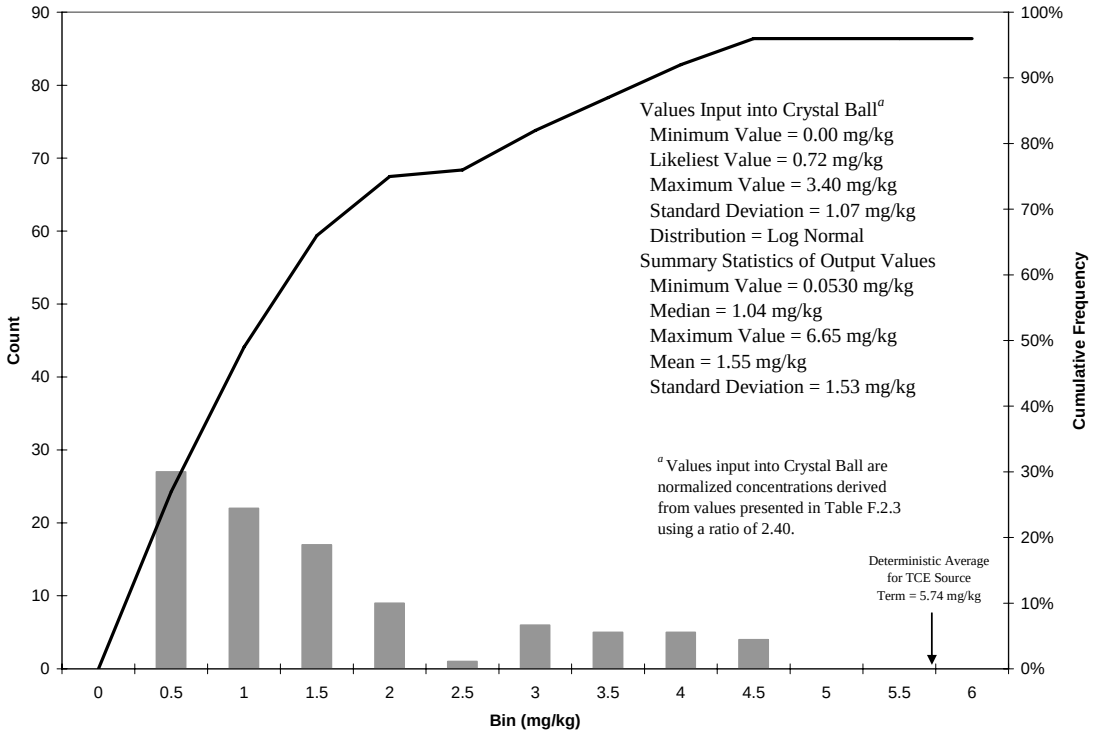

Fig. F.2.10. Histogram of Layer 6 TCE concentrations at SWMU 1 used as SESOIL inputs.

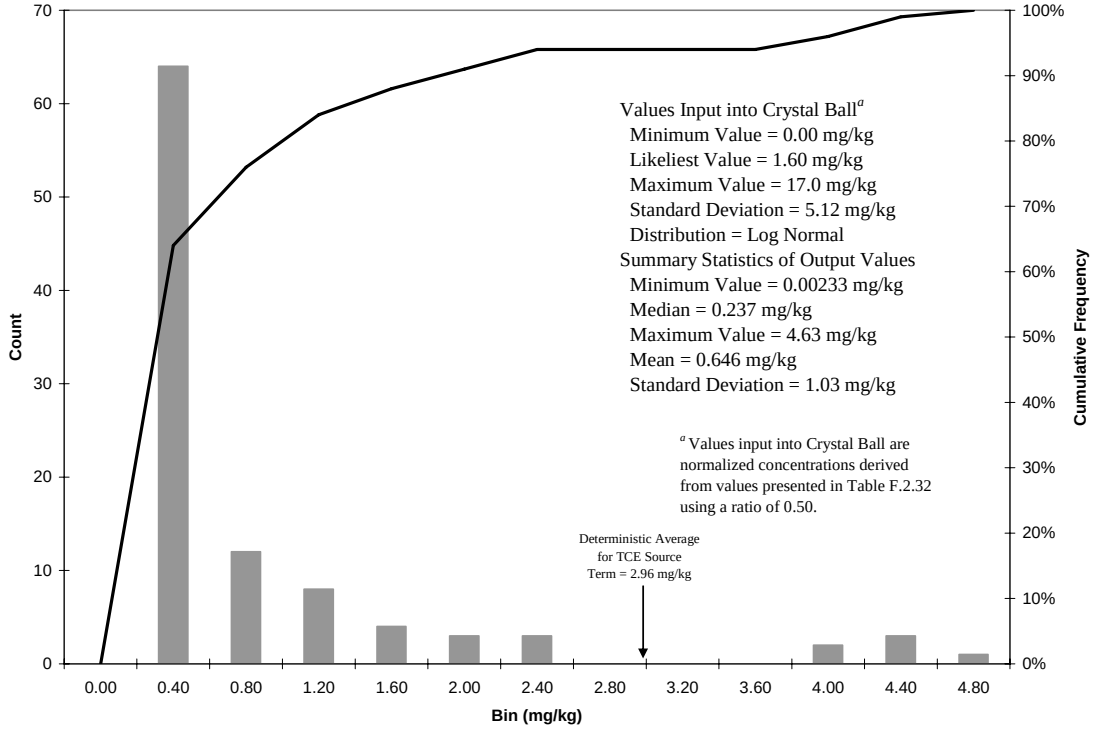

Fig. F.2.11. Histogram of Layer 1 TCE concentrations at C-720 Area used as SESOIL inputs.

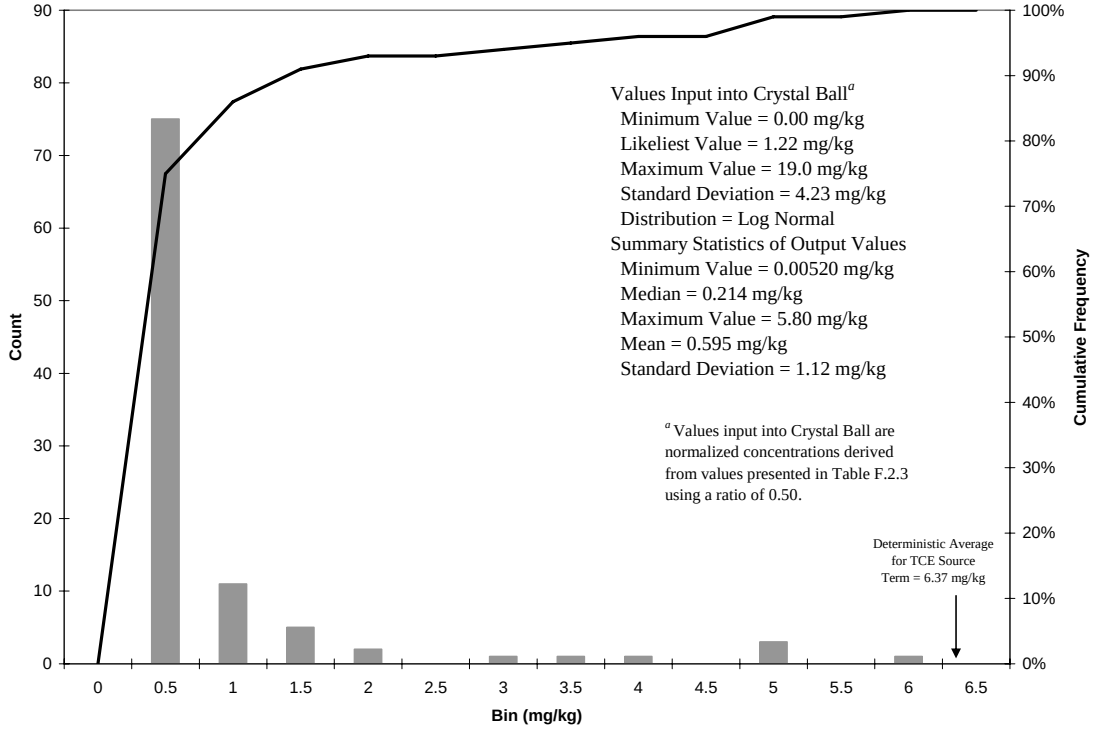

Fig. F.2.12. Histogram of Layer 2 TCE concentrations at C-720 Area used as SESOIL inputs.

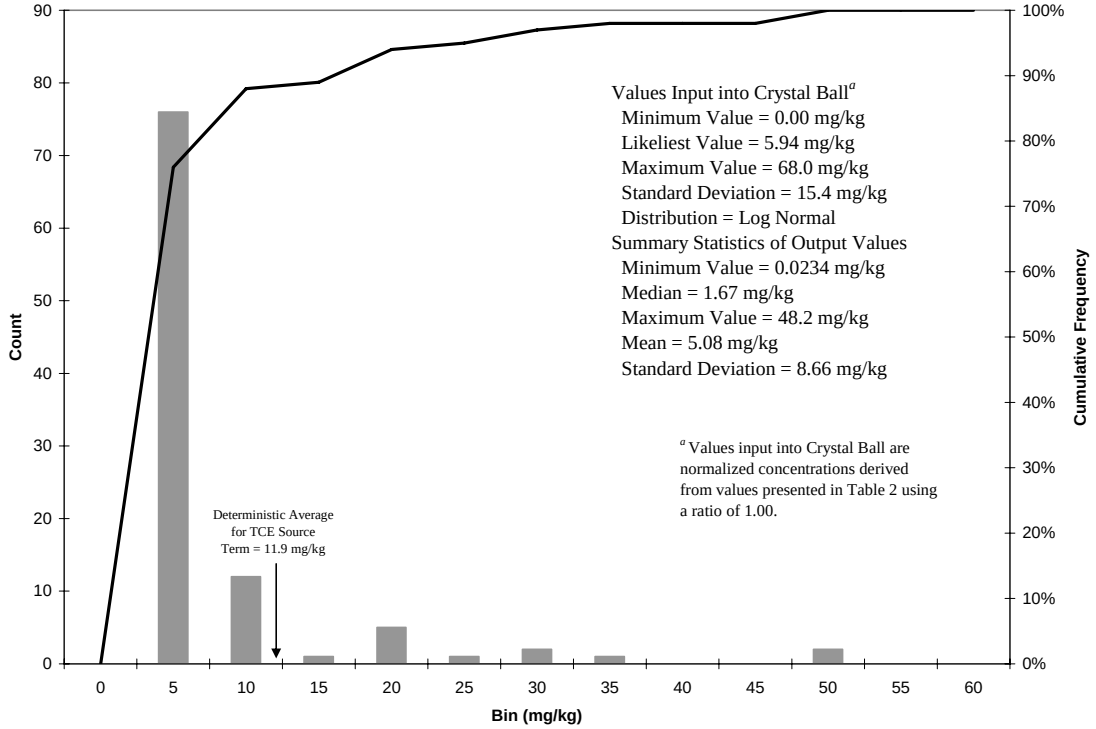

Fig. F.2.13. Histogram of Layer 3 TCE concentrations at C-720 Area used as SESOIL inputs.

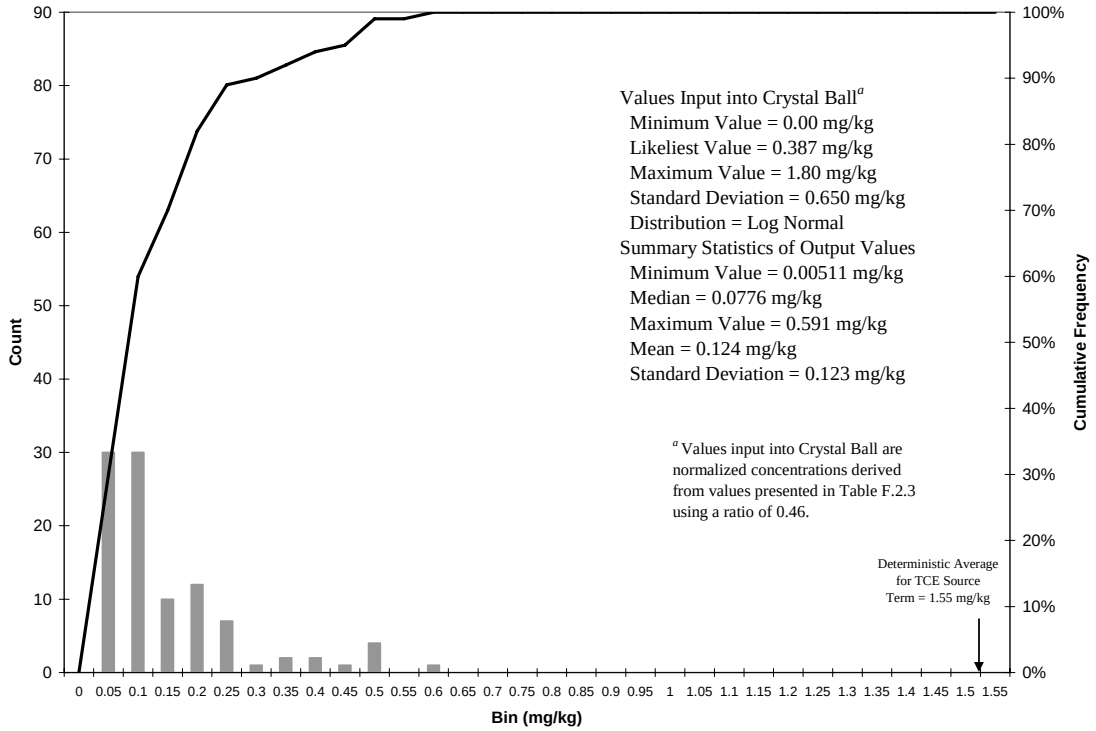

Fig. F.2.14. Histogram of Layer 4 TCE concentrations at C-720 Area used as SESOIL inputs.

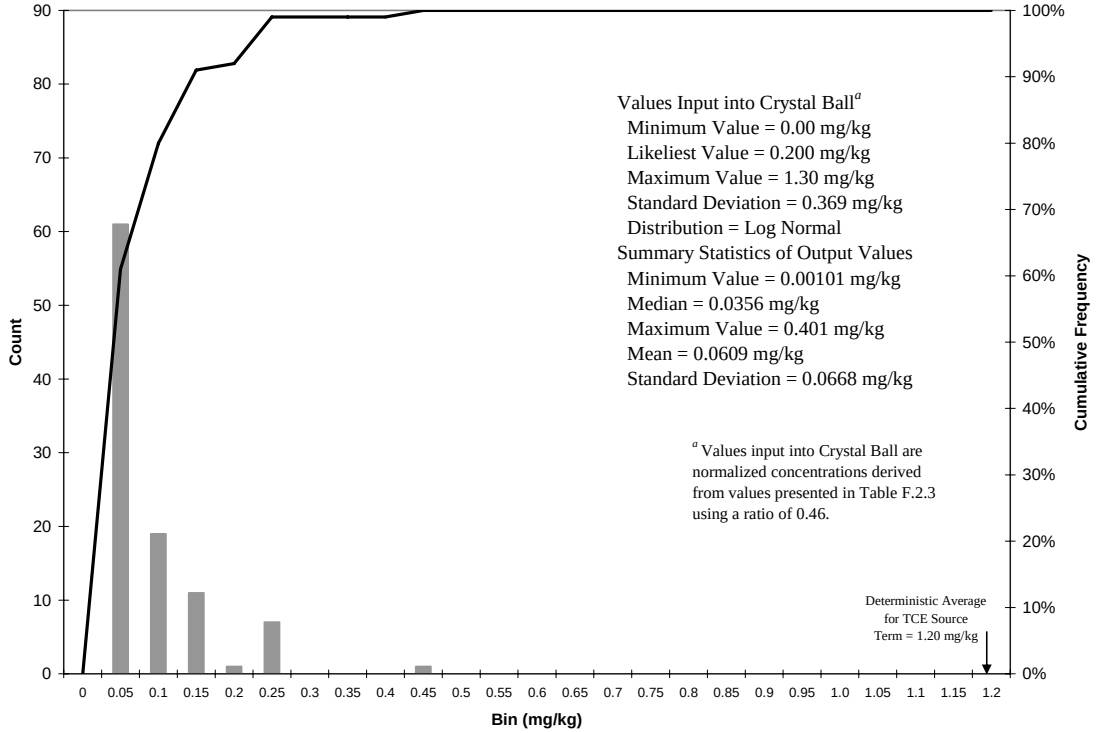

Fig. F.2.15. Histogram of Layer 5 TCE concentrations at C-720 Area used as SESOIL inputs.

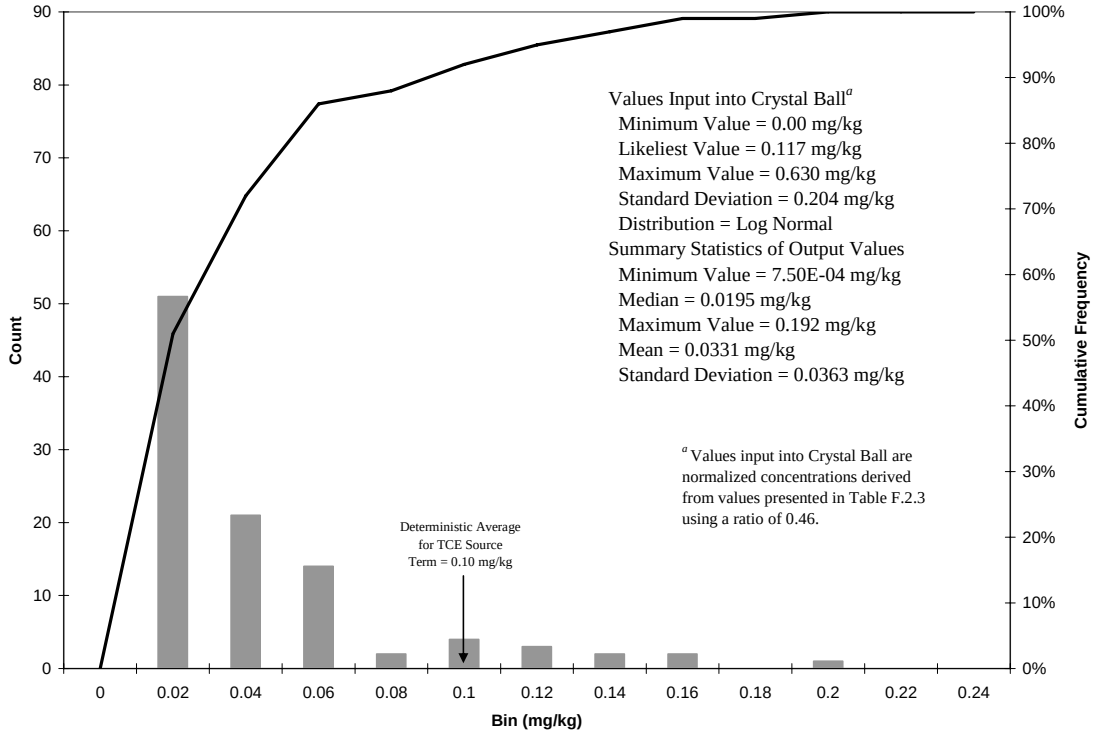

Fig. F.2.16. Histogram of Layer 6 TCE concentrations at C-720 Area used as SESOIL inputs.

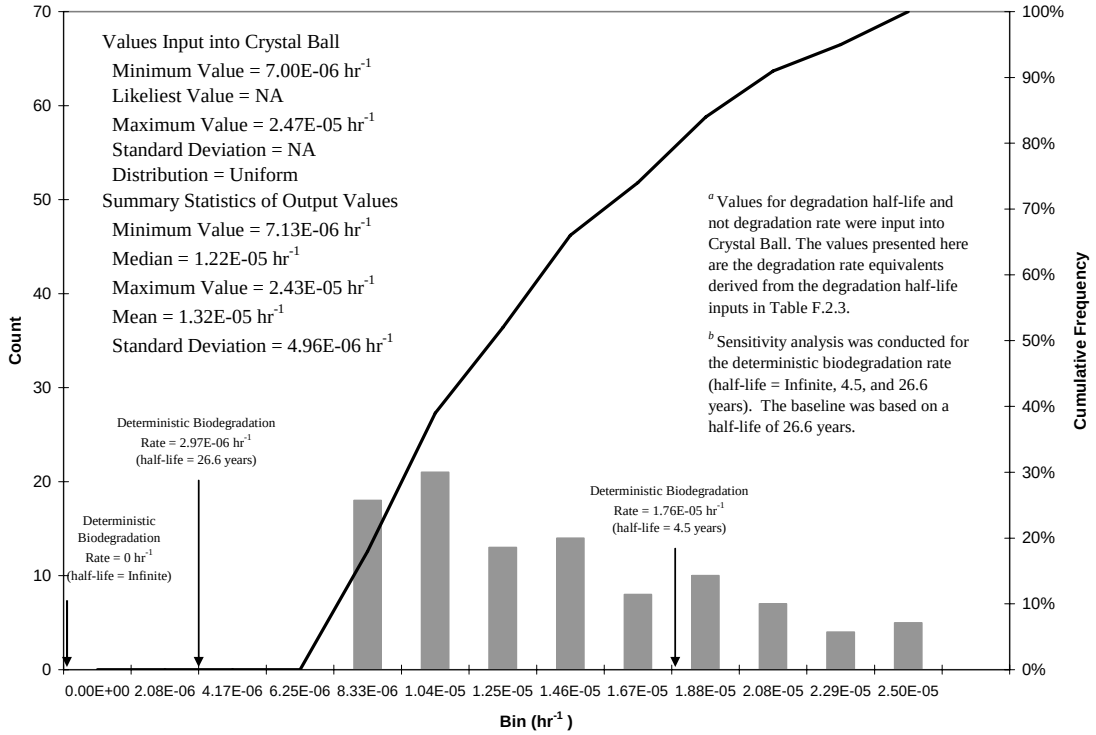

Fig. F.2.17. Histogram of Degradation Rate SESOIL inputs for SWMU 1.

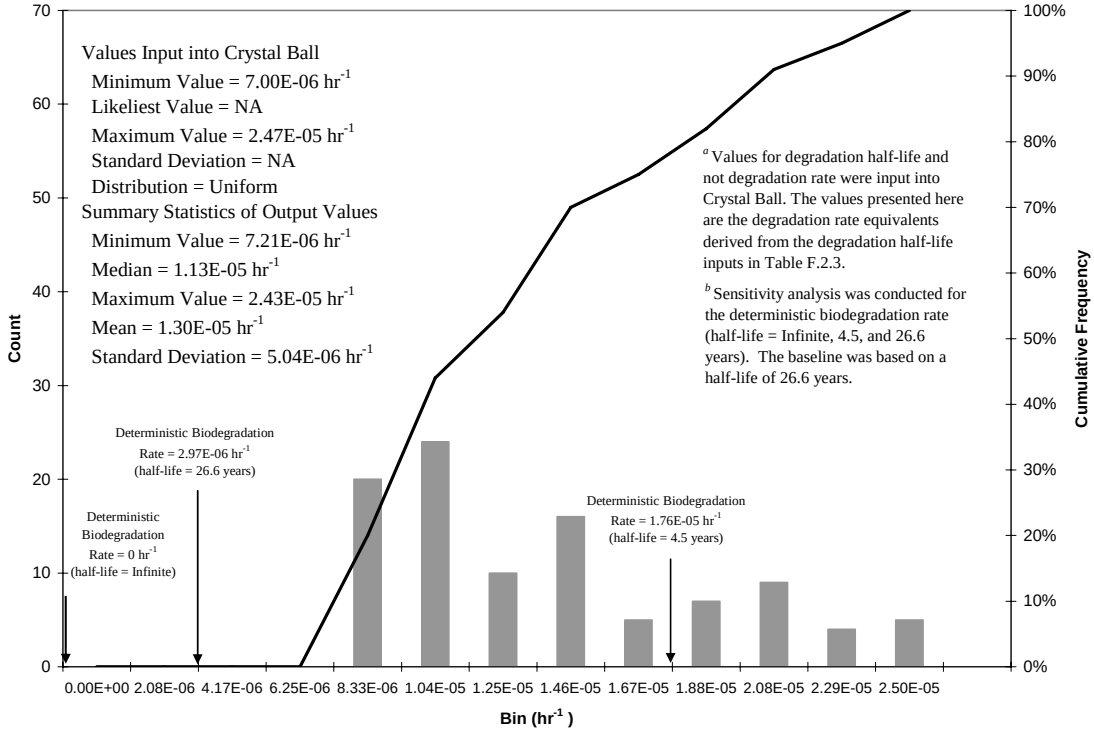

Fig. F.2.18. Histogram of Degradation Rate SESOIL inputs for C-720 Area.

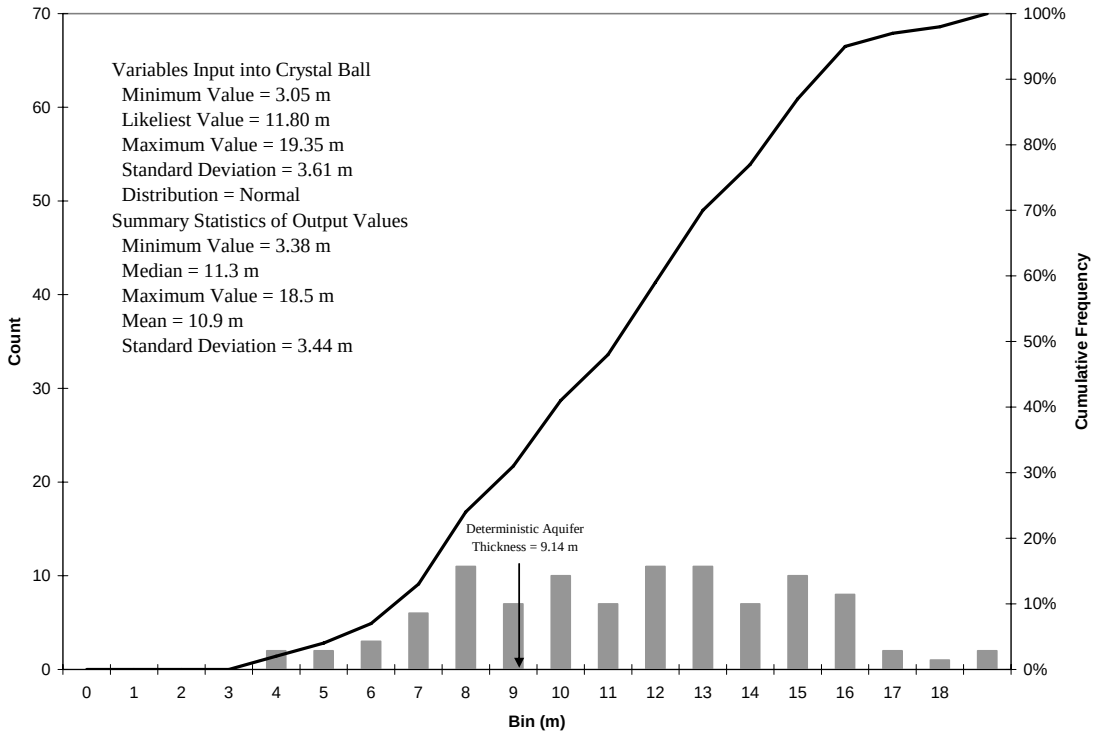

Fig. F.2.19. Histogram of Aquifer Thickness AT123D inputs for SWMU 1 and the C-720 Area.

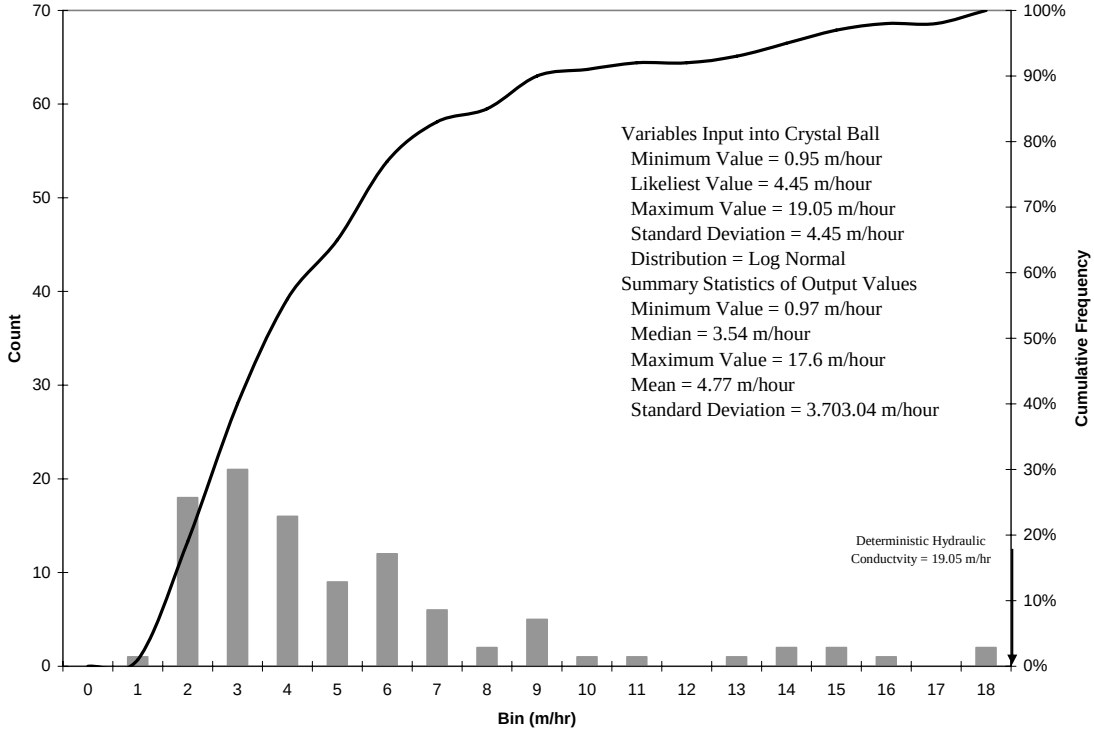

Fig. F.2.20. Histogram of Hydraulic Conductivity AT123D inputs for SWMU 1 and the C-720 Area.

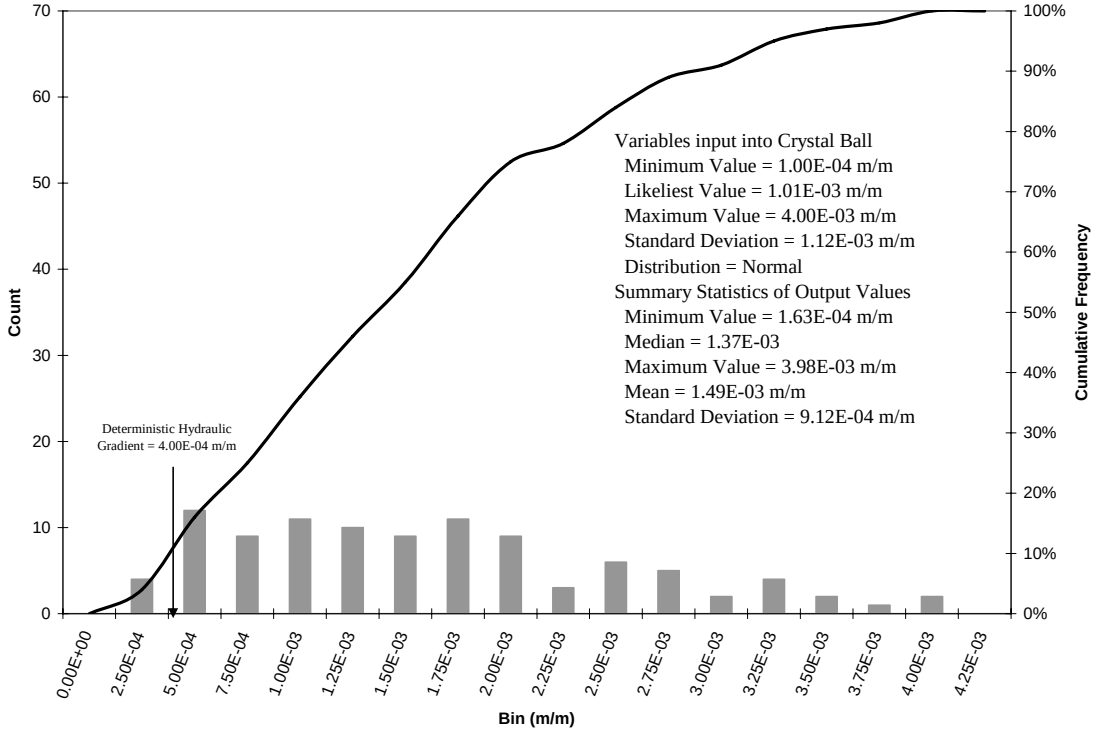

Fig. F.2.21. Histogram of Hydraulic Gradient AT123D inputs for SWMU 1 and the C-720 Area.

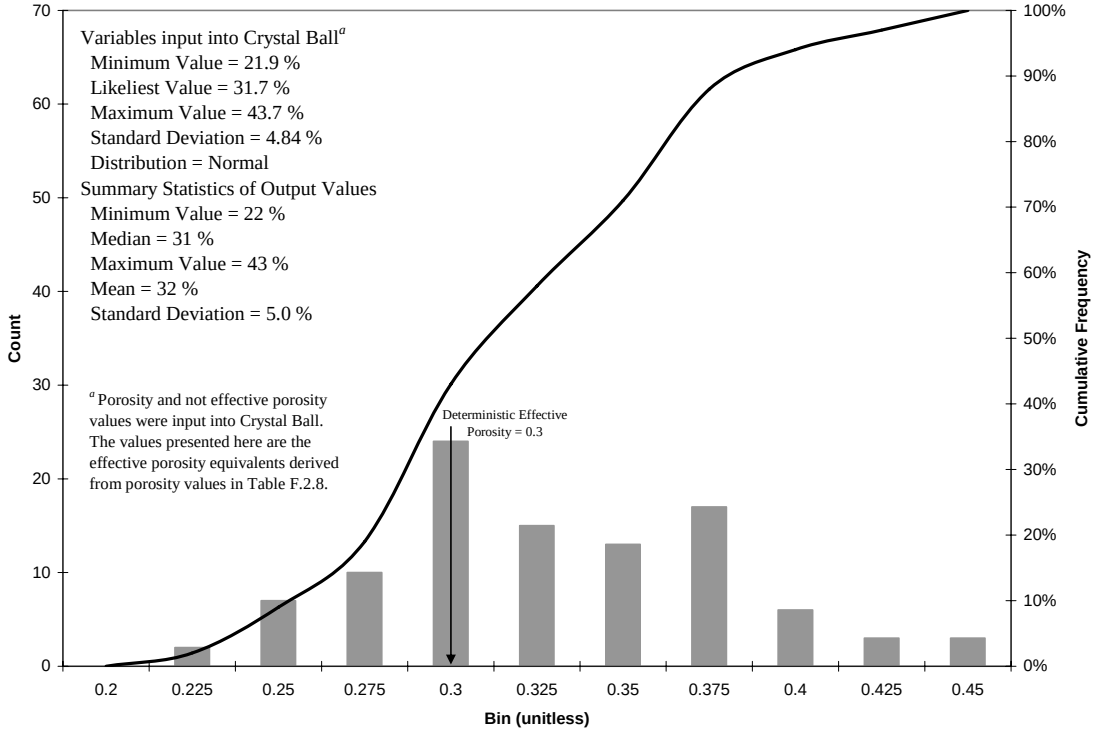

Fig. F.2.22. Histogram of Effective Porosity AT123D inputs for SWMU 1 and the C-720 Area.

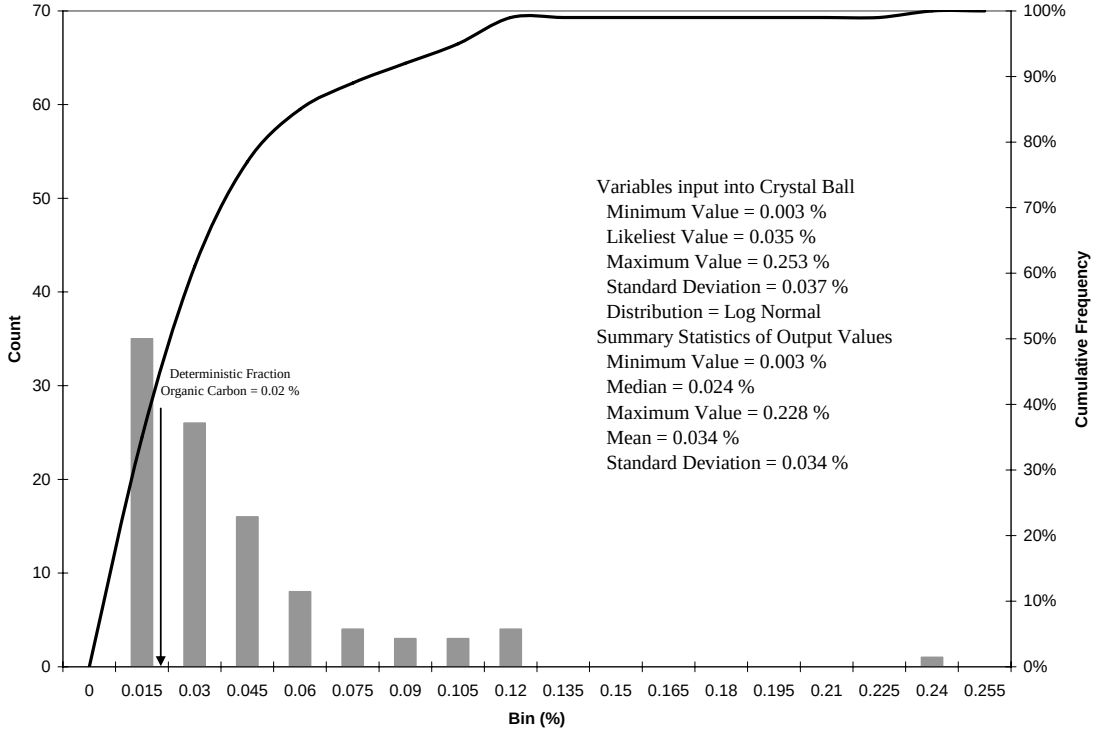

Fig. F.2.23. Histogram of Organic Carbon Content AT123D inputs for SWMU 1 and the C-720 Area.

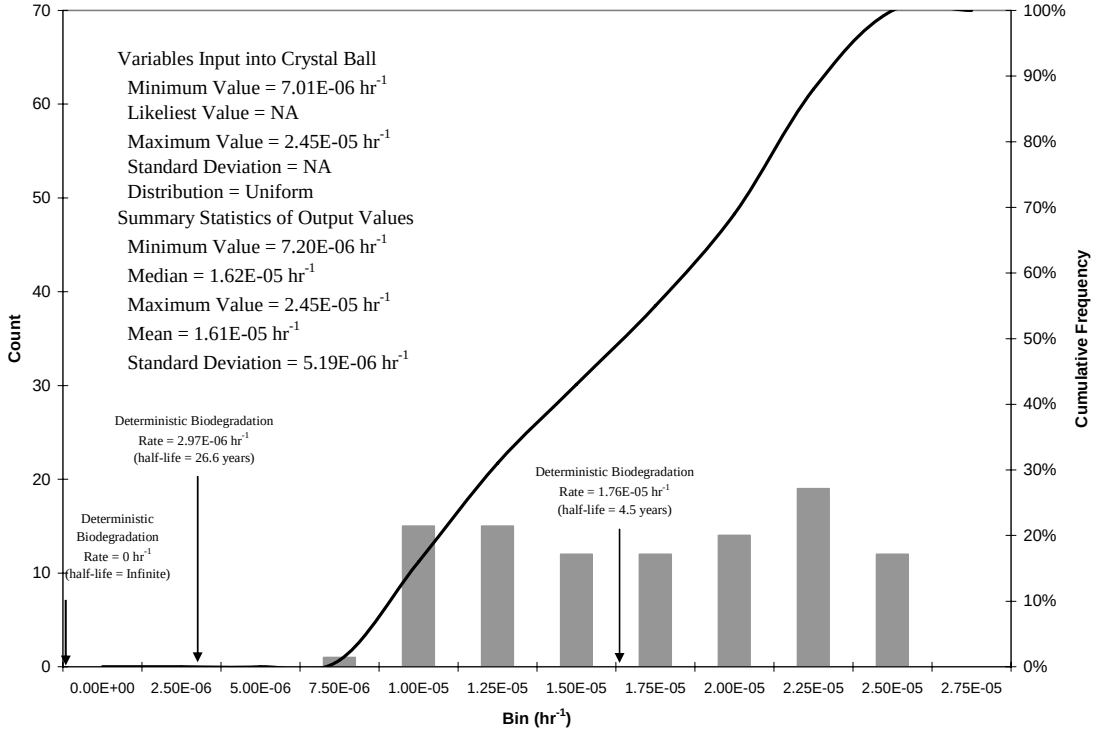

Fig. F.2.24. Histogram of Degradation Rate inputs for SWMU 1, and the C-720 Area.

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.

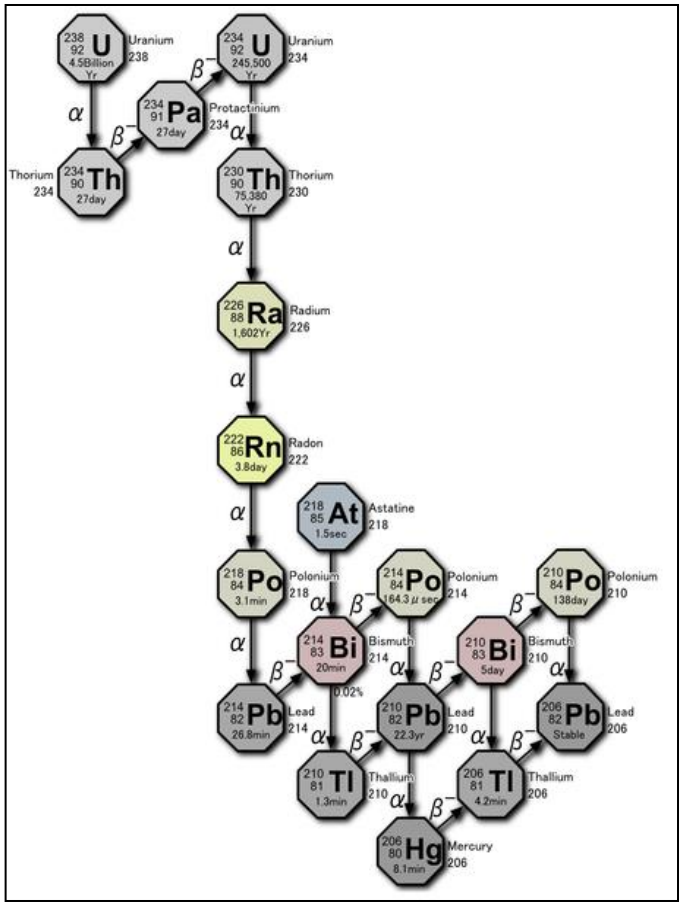

Figure E.7. Lead-210 Decay Chain

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.

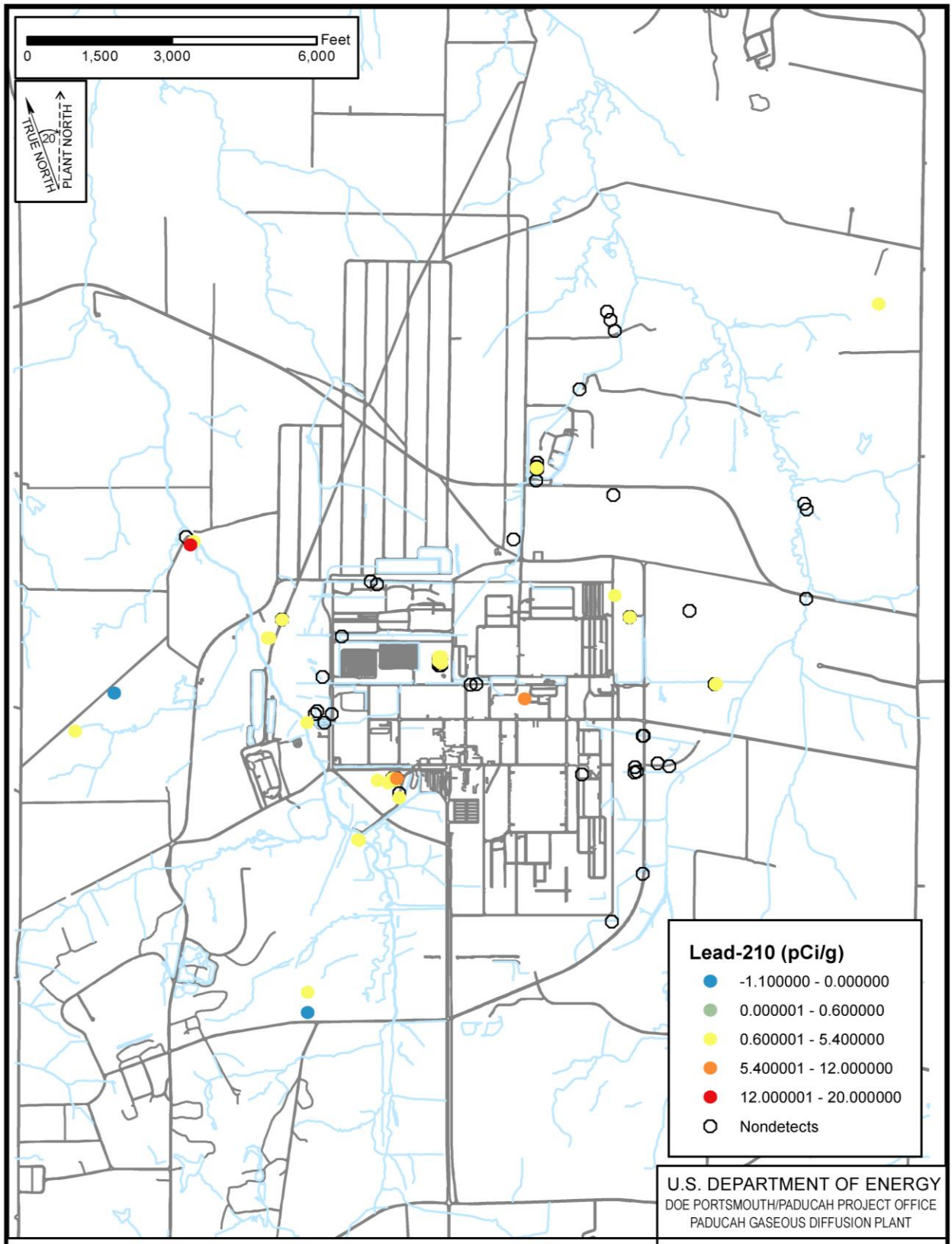

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Figure E.8. Lead-210 Soil/Sediment Samples

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	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?
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 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

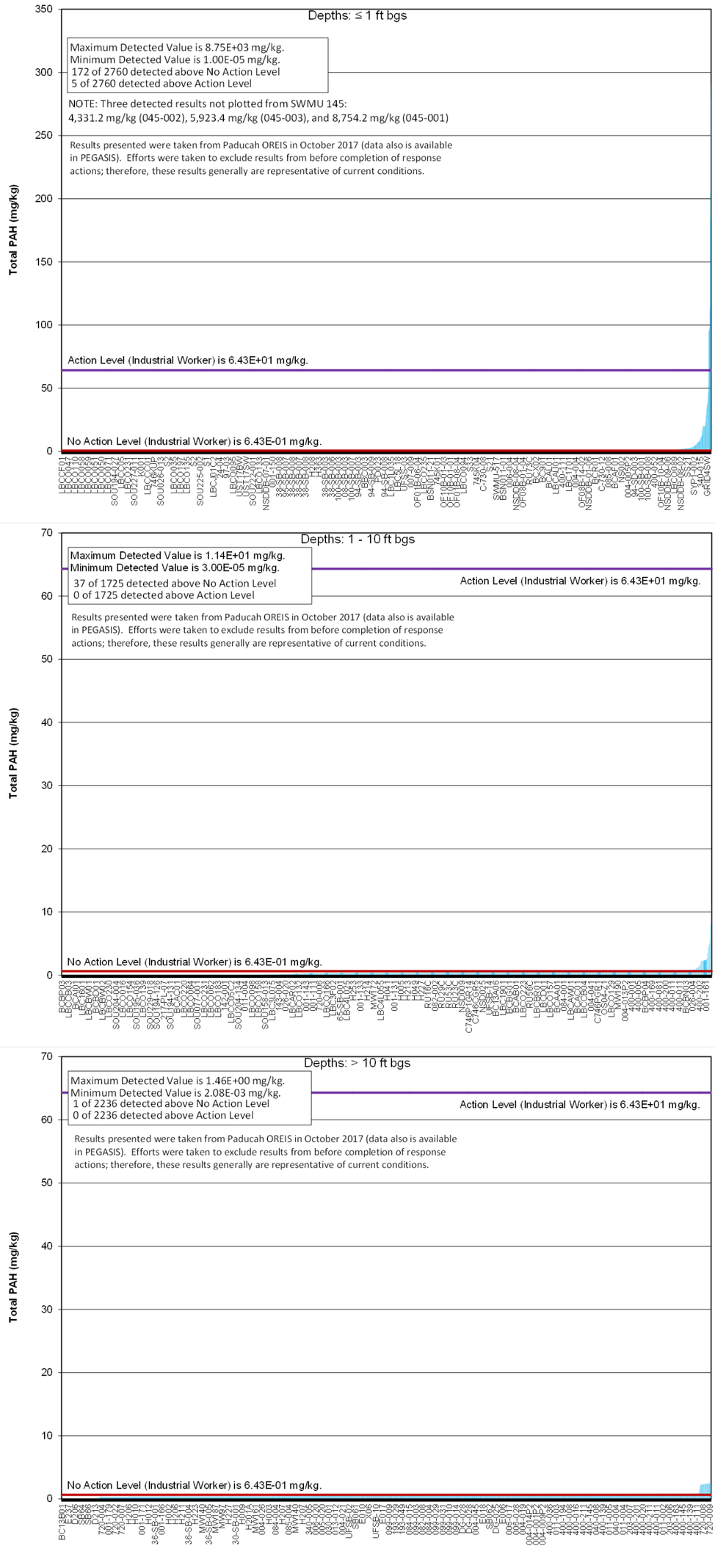

Figure E.9. Total PAH Concentrations by Depth

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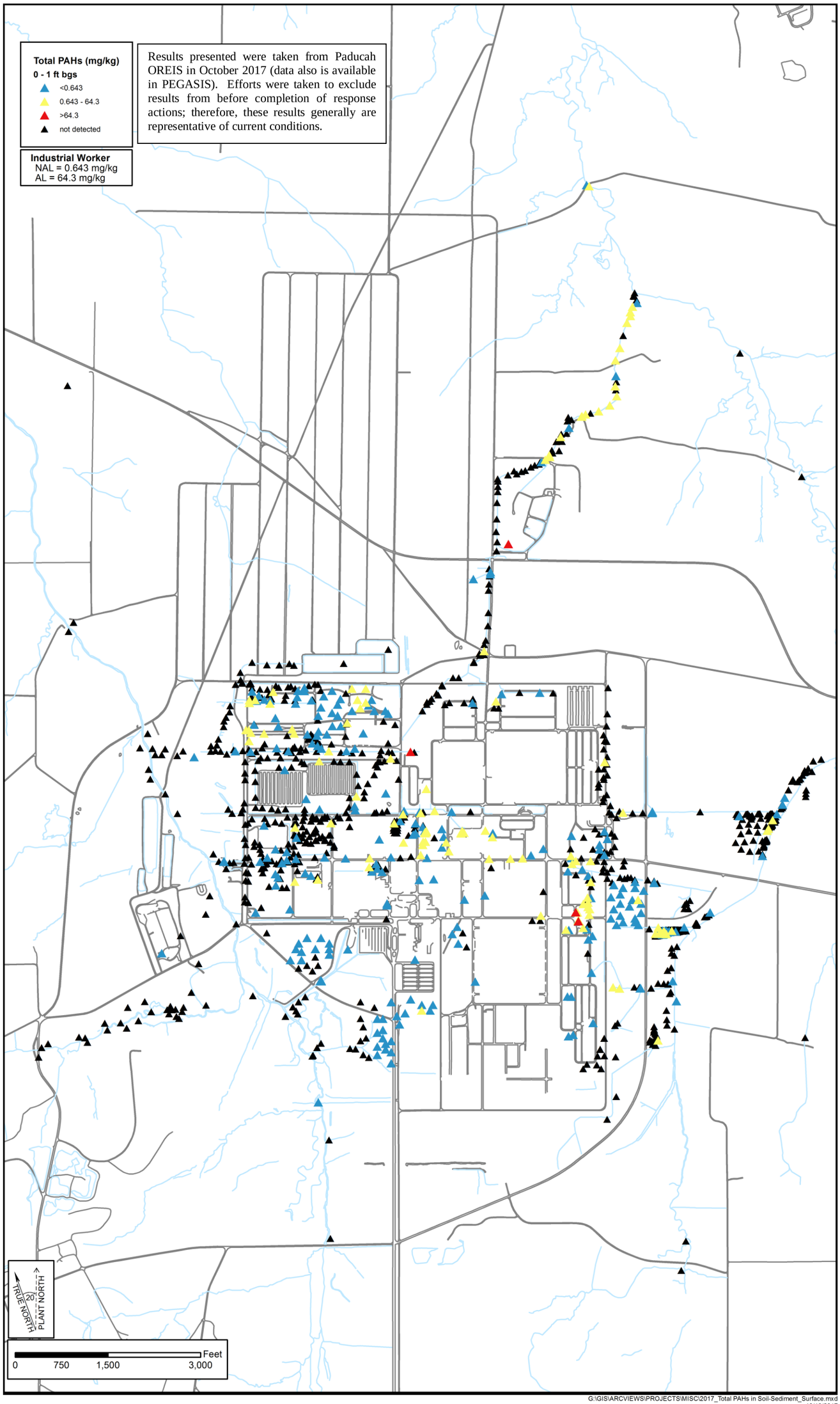

Figure E.10. Total PAH in Surface (0-1 ft bgs) Soil/Sediment Samples

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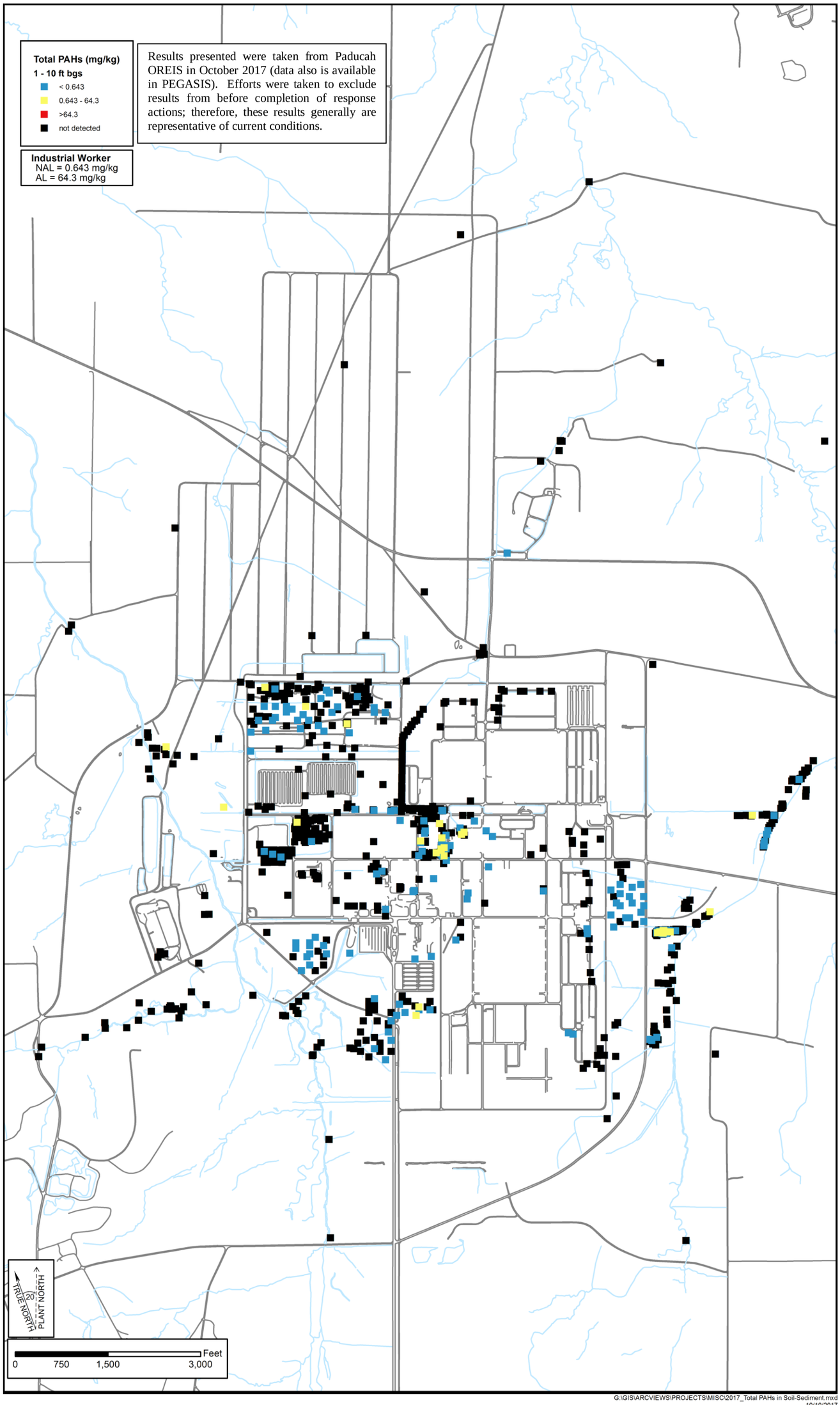

Figure E.11. Total PAH Subsurface (1-10 ft bgs) Soil/Sediment Samples

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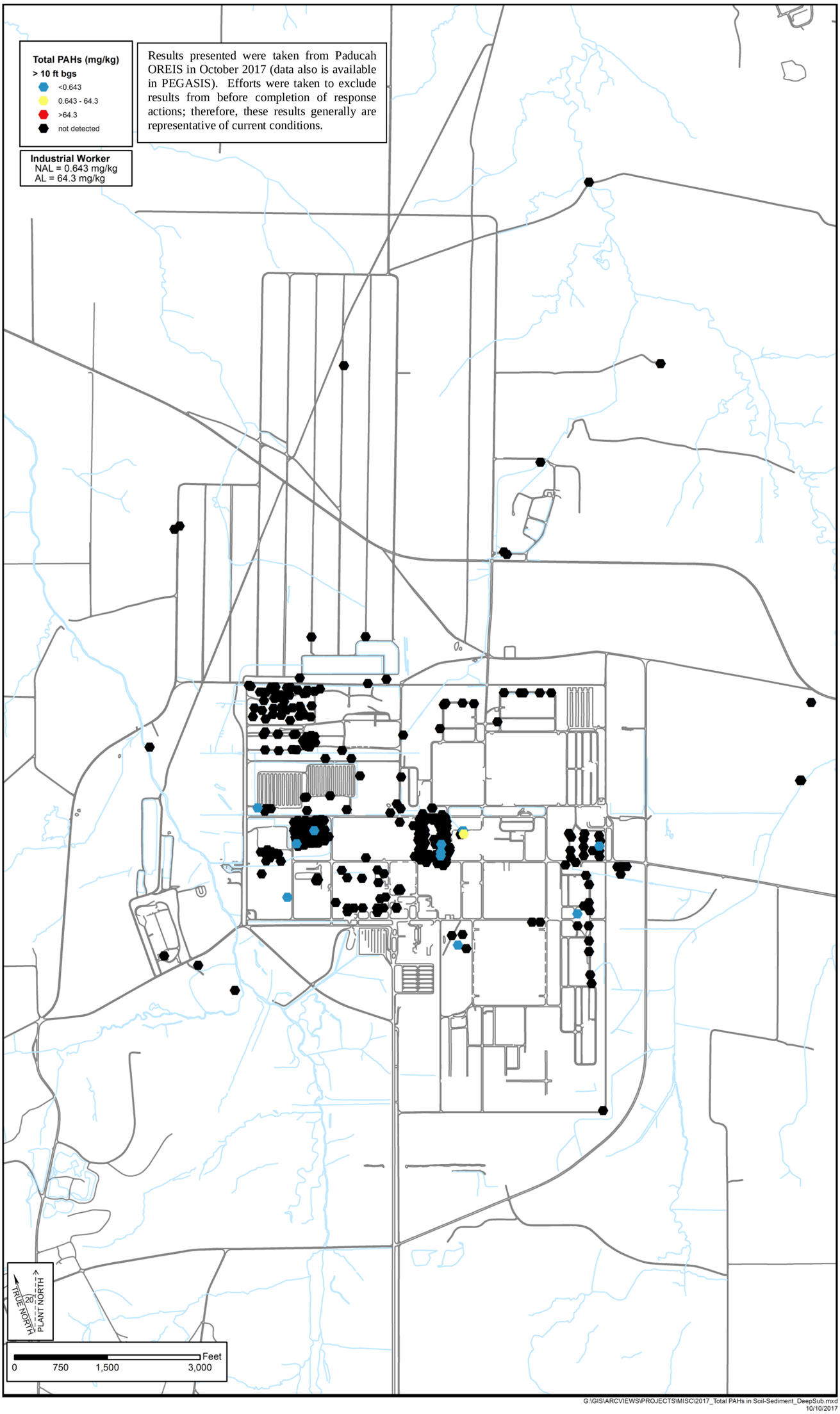

Figure E.12. Total PAH Deep Subsurface (>10 ft bgs) Soil/Sediment Samples

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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.

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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 break-down 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).

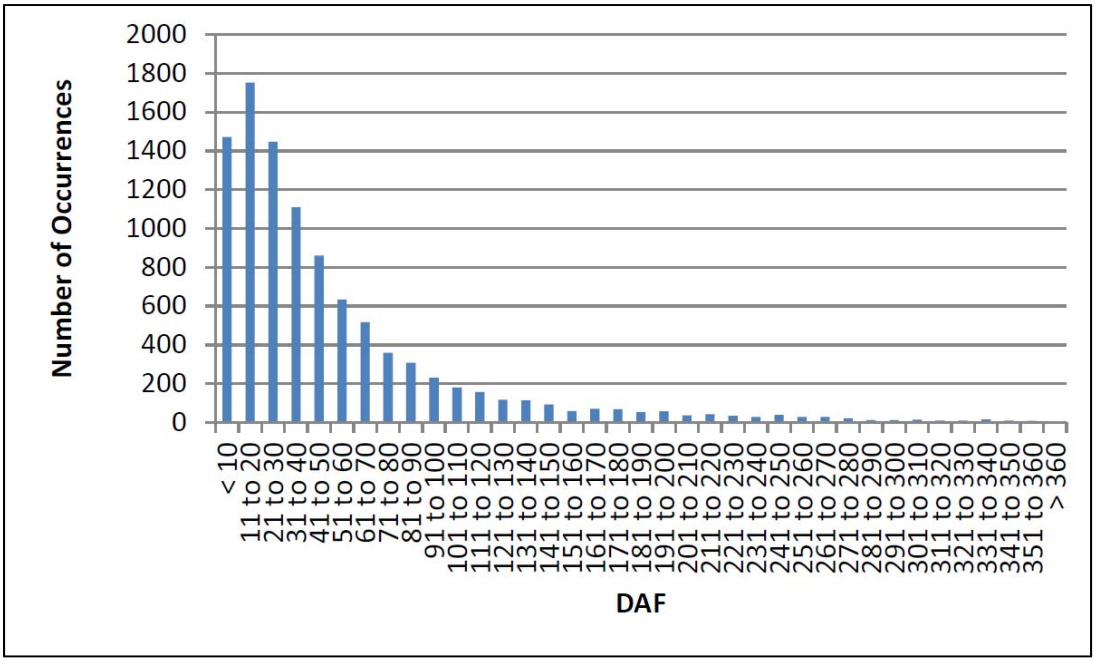

Figure E.13. Probabilistic DAF Distribution

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.

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

Where:

Variable	Explanation	Recommended Input
C_w	Target soil leachate 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] $\rho_b = [1.00-0.37\ (\theta_{total})] \times 2.65$ 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.

$$SSL = C_w \times DAF \times \frac{\left(K_d + \left(\frac{\theta_w}{\rho_b}\right)\right)}{1{,}000}$$

Where:

Variable	Explanation	Recommended Input
C_w	Target soil leachate 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).

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

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:

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

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

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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.

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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.

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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 December 2014), "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. Human Health Information for the Paducah Vapor Intrusion Evaluation

Volatile Organic Compound	Chemical Abstract Services Registry Number	OSHA PEL [a] (ppm)	OSHA PEL [a] (µg/m^3)	ACGIH TLV [b] (ppm)	ACGIH TLV [b] (µg/m^3)	OSWER Vapor Intrusion Calculator (EPA 2017) [c]		Using RAIS' Calculator (10/9/2017) [d]					
						Residential ELCR = 1E-06 in µg/m^3	Residential HI = 1 in µg/m^3	Resident PRG: ELCR= 1E-06 in µg/m^3	Resident PRG: ELCR= 1E-04 in µg/m^3	Resident PRG: HI=1 in µg/m^3	Indoor Worker PRG: ELCR=1E-06 in µg/m^3	Indoor Worker PRG: ELCR=1E-04 in µg/m^3	Indoor Worker PRG: HI=1 in µg/m^3
Benzene	71-43-2	1.00E+00	3.19E+03	5.00E-01	1.60E+03	3.60E-01	3.10E+01	3.60E-01	3.60E+01	3.13E+01	1.57E+00	1.57E+02	1.31E+02
1,1-Dichloroethane	75-34-3	1.00E+02	4.00E+05	1.00E+02	4.05E+05	1.80E+00	N/A	1.75E+00	1.75E+02	5.21E+02	7.67E+00	7.67E+02	2.19E+03
1,2-Dichloroethane	107-06-2	N/A	N/A	N/A	N/A	1.10E-01	7.30E+00	1.08E-01	1.08E+01	7.30E+00	4.72E-01	4.72E+01	3.07E+01
1,2-Dichloroethene	540-59-0	2.00E+02	7.90E+05	2.00E+02	7.93E+05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
cis-1,2-Dichloroethene	156-59-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
trans-1,2-Dichloroethene	156-60-5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.26E+01	N/A	N/A	2.63E+02
1,4-Dioxane	123-91-1	1.00E+02	3.60E+05	2.00E+01	7.20E+04	5.60E-01	3.10E+01	5.62E-01	5.62E+01	3.13E+01	2.45E+00	2.45E+02	1.31E+02
Ethylbenzene	100-41-4	1.00E+02	4.35E+05	2.00E+01	8.70E+04	1.10E+00	1.00E+03	1.12E+00	1.12E+02	1.04E+03	4.91E+00	4.91E+02	4.38E+03
1,1,1-Trichloroethane	71-55-6	3.50E+02	1.90E+06	N/A	N/A	N/A	5.20E+03	N/A	N/A	5.21E+03	N/A	N/A	2.19E+04
1,1,2-Trichloroethane	79-00-5	1.00E+01	4.50E+04	1.00E+01	5.50E+04	1.80E-01	2.10E-01	1.75E-01	1.75E+01	2.09E-01	7.67E-01	7.67E+01	8.76E-01
Trichloroethene	79-01-6	1.00E+02	5.37E+05	1.00E+01	5.40E+04	4.80E-01	2.10E+00	4.78E-01	4.78E+01	2.09E+00	2.99E+00	2.99E+02	8.76E+00
Vinyl Chloride	75-01-4	1.00E+00	2.56E+03	1.00E+00	2.56E+03	1.70E-01	1.00E+02	1.68E-01	1.68E+01	1.04E+02	2.79E+00	2.79E+02	4.38E+02
Xylenes	1330-20-7	1.00E+02	4.35E+05	1.00E+02	4.35E+05	N/A	1.00E+02	N/A	N/A	1.04E+02	N/A	N/A	4.38E+02

Notes:

ELCR = Excess Lifetime Cancer Risk
HI = Hazard Index
For *cis*- and *trans*-1,2-dichloroethene, toxicity information (slope factors and reference doses/concentrations) are not available; therefore risk-based values are not available (N/A) at this time.

[a] Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) are for 8-hour time-weighted average from online source: https://www.osha.gov/dsg/annotated-pels/. Online source states: "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."
NIOSH calculator **(**National Institute for Occupational Safety and Health) 10/10/2017 at http://www.cdc.gov/niosh/docs/2004-101/calc.html used to convert ppm to µg/m^3 where not provided by the standard.

[b] American Council of Governmental and Industrial Hygienists (ACGIH) list of threshold limit values (TLV) (as 8 hour time-weighted averages) of concentrations from https://www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html,

[c] EPA's 2017 Office of Solid Waste and Emergency Response (OSWER) guidance calculator at https://www.epa.gov/vaporintrusion/vapor-intrusion-screening-levels-visls (Version 3.5) uses ET= 24 hr/d; EF=350 d/yr; ED=26 yrs; AT(nc)=26 yrs; and AT(c)=70 yrs. Populations considered are the elderly, women of child bearing years, people suffering from a chronic illness, and disadvantaged populations.

[d] The RAIS (Risk Assessment Information System) Preliminary Remedial Goal (PRG) Chemical Calculator at http://rais.ornl.gov/ uses: ET= 24 hr/d; EF=350 d/yr; ED=26 yrs; AT(nc)=26 yrs x 365 d/yr; and AT(c)=70 yrs x 365 d/yr for the residential scenario. RAIS' Calculator uses ET= 8 hr/d; EF=250 d/yr; ED=25 yrs; AT(nc)=25 yrs x 365 d/yr; and AT(c)=70 yrs x 365 d/yr for the indoor worker scenario.

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-----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(3)		RSL(3)		RML(2)		RML(2)		RSL Sub-slab(1)	RSL 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.

Internal Use Only: Air Screening Table for Residential Sites											
	RSL(3)		RSL(3)		RML(2)		RML(2)		RSL Sub-slab(1)		RSL 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):

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

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 $LOAEL_{HEC}$ becomes 189 mg/m^3:

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

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

$$\begin{aligned} &\text{Since } 9.58 > 6.04, \\ &= 189\ \text{mg/m}^3 \times [1] = 189\ \text{mg/m}^3 \end{aligned}$$

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:

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

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.

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

This chapter presents meeting minutes from the Paducah RAWG held in 2017. 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/R8/V1 (DOE 2017), 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).

The meeting minutes included here and in DOE 2017 are provided for historical information to promote program consistency over time and facilitate succession planning.

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Risk Assessment Working Group
Meeting Minutes—March 1, 2017

✓Gaye Brewer
✓Nathan Garner
✓Mike Guffey
✓Jeri Higginbotham
✓Jerri Martin
✓Tim Frederick
✓Jon Richards
✓Rich Bonczek
✓Martin Clauberg
✓LeAnne Garner
✓Bobette Nourse
✓Joe Towarnicky

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

No additional issues.

2. FY 2017 Schedule/Work Plan (Remaining)

RAWG Concur with Human Health (HH) Risk Methods Document (RMD) Appendix A	2/13/2017
Comments due for HH Main Text and HH Appendix B and D	2/13/2017
Quarterly Meeting (March)	3/1/2017
RAWG concur with HH Main Text and HH Appendix B and D	4/10/2017
Submit Entire Revised HH RMD to RAWG for Review	4/17/2017
Comments due for entire revised HH RMD	5/15/2017
Quarterly Meeting (June)	6/7/2017
Submit HH RMD to FFA Managers (DOE/LX/07-0107&D2/R8/V1)	6/20/2017
FFA Managers acknowledge receipt of HH RMD	7/17/2017
Quarterly Meeting (September)	9/13/2017

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

3. Appendix A Comments

Kentucky Department for Environmental Protection's (KDEP's) comments have been addressed. One comment regarding teen resident exposure parameters is included for discussion as item 6 below.

Environmental Protection Agency's (EPA's) comments have been received regarding background values; dilution attenuation factor (DAF) discussion; Table A.14 information included in No Action Level (NAL)/Action Level (AL) tables; chromium (see item 7 below); lead; groundwater units. A comment response summary (CRS) is attached, as Attachment 1. It has been updated based on discussion during the meeting.

4. Appendix B, D, and Main Text Comments

KDEP had no comments. Department of Energy (DOE) had editorial comments.
EPA comments are found in the attached CRS, as Attachment 2.

5. Vapor Intrusion

EPA will suggest updates to be made to the RMD with respect to Vapor Intrusion. The RMD does not discuss data collection, but can list types of samples that could be collected.

6. Teen Resident Exposure Parameters

For the recreator, we have the teen broken out, but for the resident we do not. Whether these exposure parameters should be added to the 2018 revision of the RMD was discussed.

Text will be added to Appendix B to state that the teen recreator cohort is broken out because the exposure parameters are different than other cohorts. For the resident, teen and adult cohorts are more similar. For the residential scenario, only the child and the adult cohorts are presented. If risk values to the teen resident is important to the project, additional inputs should be considered.

7. Total Chromium Screening Levels

Total chromium NAL/AL should not be used. The NAL for Total chromium in groundwater was higher than the MCL. Because this NAL was higher than the MCL, EPA requested the Primary MCLs be added to the groundwater screening level tables for comparison (Tables A.2 and A.5) (see also Attachment 1, EPA Comment 3). It was noted during the discussion that MCLs are not risk-based. Chromium III and Chromium VI screening values are provided in Appendix A. Chromium VI screening values are to be used, unless it can be determined that Chromium VI is not present. For the 2017 RMD, NAL/AL values for Total chromium in Tables A.1 through A.6 will be dropped, and a footnote that the values are being reconsidered for the 2018 RMD will be added.

8. NALs/ALs adjustment for saturation

Due to the change from mg/L to µg/L for groundwater and surface water NALs and ALs, there is no longer an upper limit value for groundwater and surface water. A note has been added to these tables as follows: "Action levels are not adjusted for saturation limits." This comparison, and any necessary changes, will be added to the 2018 revision of the RMD.

9. Uranium RfDs

EPA has added a directive, "Considering a Noncancer Oral Reference Dose for Uranium for Superfund Human Health Risk Assessments." This document provides information and recommendations about an oral reference dose (RfD) for non-radiological, non-cancer toxicity of soluble uranium that Regions should consider during various stages of response selection and implementation at CERCLA sites, including the Remedial Investigation (RI)/Feasibility Study (FS) process (e.g., assessing baseline health risks, evaluating risks of remedial alternatives) and five-year reviews. The document and formal transmittal memo are available at https://semspub.epa.gov/src/document/11/196808.

Whether the ATSDR uranium RfDs should be added to the 2018 revision of the RMD was discussed. The uranium metal values should be added to the screening tables, so that both soluble and insoluble uranium is presented. These values will be added to the 2017 revision of the RMD and sent to the RAWG for review.

10. Watch Topics:

- New definitions for volatile organics are being used in RAIS. This needs to be watched to see if there are any impacts (especially for PCBs and PAHs). PAH values changed recently; toxicity values tied to benzo(a)pyrene will be revised. A footnote for these values that they were changed after October 2016 will be added to the 2017 revision of the RMD.

- **Derivation of Risk-based Surface Water Effluent Limits**
  Burial Grounds Operable Unit Solid Waste Management Units 2, 3, 7, and 30 FS has been in formal dispute. Waste Disposal Alternative RI/FS is moving forward. Effluent Limits will be addressed at a future date.

- **Status of EPA's Policy for Lead in Blood**
  Tim provided EPA's Directive for "Recommendations for Sieving Soil and Dust Samples at Lead Sites for Assessment of Incidental Ingestion" after the December 2016 meeting. It is included with the final December 2016 meeting minutes.

  Additional guidance is attached to these meeting minutes regarding IEUBK. For the 2017 RMD, footnote suggested model inputs that they are under consideration for possible changes. Additional discussion will take place during the June 2017 quarterly meeting.

11. Poll RAWG Members/Open Discussion

Use of the RMD is being reviewed by EPA for the Soils Operable Unit Addendum (Solid Waste Management Unit 1).

It was noted that a contract changeover is coming up. This year's schedule (item 2 of these meeting minutes) was planned based on that changeover.

ATTACHMENT 1

Response to Kentucky Department for Environmental Protection Comments Submitted by Jerri Martin

Specific Comments:

Comment 1: SOIL/SEDIMENT NALs (Table A.4). Excavation Worker (chemical calculator, outdoor worker used)

- It is unclear why the "outdoor worker" receptor was used instead of the "excavation worker"
- When the outdoor worker receptor was used in RAIS, the hazards listed in the No Action Levels are different than my calculations using the excavation worker receptor (see Excavation_Worker_chem_prg_DRAFT.pdf and Outdoor_Worker_chem_prg_DRAFT EXCAVATION.pdf)
    - For arsenic, the hazard-based PRG in Appendix A is 1.2E+01 mg/kg, and my calculation is 1.97E+02 mg/kg
    - For TCE, the hazard-based PRG in Appendix A is 2.26+00 mg/kg, and my calculation is 2.40E+00 mg/kg
    - It is unclear why, particularly for arsenic, the values are so different – please clarify

Response 1: No change has been made. The difference in the excavation worker and the outdoor worker primarily is the use of the subchronic/chronic RfDs. The difference in subschronic/chronic RfDs causes the difference in the calculated hazard PRGs for arsenic and TCE.

The Risk Methods Document (RMD) says "Although RAGS, Part A, (EPA 1989a) states that toxicity values for subchronic exposure should be used for exposure durations less than seven years in length, these will not be used because they are not available for many chemicals (in which case the chronic value should be used)."

The RAWG discussed use of chronic/subchronic RfDs for the excavation worker in the March 2014 Quarterly Meeting (page E-305 of 2016 RMD). It was decided that chronic toxicity values are more conservative, in terms of protecting human health, and few subchronic values are available. The RAWG preferred to stay with chronic values at that time.

Comment 2: Teen Recreator (chemical calculator, using only "Adult" results)
The row for age 16-30 must be included in order to accurately calculate the risk-based PRGs

Response 2: The risk-based PRGs are taken from the calculation which includes <u>all</u> the rows (i.e., rows for age segments 0-2 yrs, 2-6 yrs, 6-16 yrs, and 16-30 yrs). This is not explained very well in the RAIS screen shots that were sent with the draft Appendix A. These screen shots will not be included in the RMD.

Comment 3: Adult Recreator (chemical calculator, using only "Adult" results)

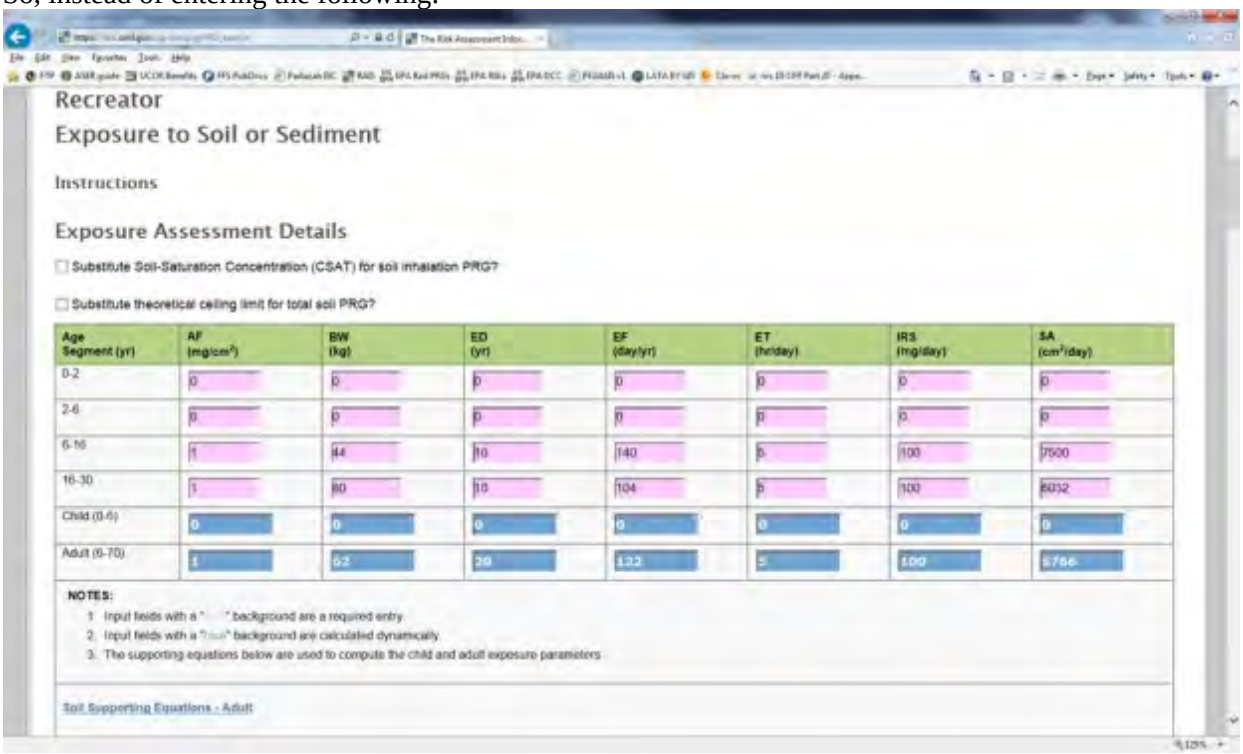
- The row for age 6-16 must be included in order to accurately calculate the risk-based PRGs

- The adult hazard-based PRGs listed in the No Action Levels are different than my calculations (see Recreator_chem_prg_ADULT + 6-16.pdf)
    - For arsenic, the adult hazard-based PRG in Appendix A is 3.18E+01 mg/kg, and my calculation is 2.06E+01 mg/kg
    - For TCE, the adult hazard-based PRG in Appendix A is 7.07E+00 mg/kg, and my calculation is 5.94E+00 mg/kg

Response 3: Based on Table B.4 durations for the recreator, we consider 0-6 child; 6-16 teen; and 16-26 adult.

The "blue" fields on the RAIS form are automatically calculated from the entries in the "pink" fields.

So, instead of entering the following:



Recreator

Exposure to Soil or Sediment

Instructions

Exposure Assessment Details

☐ Substitute Soil-Saturation Concentration (CSAT) for soil inhalation PRG?

☐ Substitute theoretical ceiling limit for total soil PRG?

Age Segment (yr)	AF (mg/cm²)	BW (kg)	ED (yr)	EF (day/yr)	ET (hr/day)	IRS (mg/day)	SA (cm²/day)
0-2	0	0	0	0	0	0	0
2-6	0	0	0	0	0	0	0
6-16	1	44	10	140	5	100	7500
16-30	1	80	10	104	5	100	8032
Child (0-6)	0	0	0	0	0	0	0
Adult (6-70)	1	62	20	122	5	100	6766

NOTES:
1. Input fields with a " " background are a required entry
2. Input fields with a "blue" background are calculated dynamically
3. The supporting equations below are used to compute the child and adult exposure parameters

Soil Supporting Equations - Adult

where the PRG for the "Adult (6-70)" is calculated from the system-generated blue fields: BW = 62, ED = 20, EF = 122, and SA = 6766 (which do not match our "adult").

To isolate the 16-26 year-old "adult," the "teen" is "zeroed out" so that it looks like this:

Age Segment (yr)	AF (mg/cm²)	BW (kg)	ED (yr)	EF (day/yr)	ET (hr/day)	IRS (mg/day)	SA (cm²/day)
0-2	0	0	0	0	0	0	0
2-6	0	0	0	0	0	0	0
6-16	0	0	0	0	0	0	0
16-30	1	80	10	104	5	100	6032
Child (0-6)	0	0	0	0	0	0	0
Adult (6-70)	1	80	10	104	5	100	6032

NOTES:

1. Input fields with a " " background are a required entry
2. Input fields with a "" background are calculated dynamically
3. The supporting equations below are used to compute the child and adult exposure parameters

Soil Supporting Equations - Adult

So that what is calculated for the PRG (from the blue fields) is the same as what was entered (in the pink fields).

Comment 4: Adult and Child Resident (chemical calculator)

- The risk-based PRGs are different than my calculations, due to the following differences (see Resident_chem_prg_DRAFT + Corrections.pdf)
    - Body weight for age 6-16 should be changed from 80 kg to 44 kg
    - Surface area for age 6-16 should be changed from 6032 cm^2/day to 7500 cm^2/day
- The adult hazard-based PRG listed in the No Action Levels are different than my calculations (see Resident_chem_prg_DRAFT + Corrections.pdf)
    - For arsenic, the adult hazard-based level in Appendix A is 1.03E+01 mg/kg, and my calculation is 7.35E+00 mg/kg
    - For TCE, the adult hazard-based level in Appendix A is 4.56E-01 mg/kg, and my calculation is 4.54E-01 mg/kg
- It appears that the values in Appendix A should be modified, based on the differences in BW and SA noted above

Response 4: For the recreator, we have the teen broken out, but for the resident we do not. Table B.4 shows 80 kg and 6032 cm^2/day for an exposure duration of 20 years (which is also the RAIS default).

No change to this year's numbers, but the topic was discussed during the March 2017 quarterly meeting meeting. Text has been added to Appendix B, as described in the meeting minutes.

The change to break out the teen would cause PRGs to be lower, but not by as much as an order of magnitude. A comparison is shown below.

Comparison of Selected Resident NALs with 20-year Adult Exposure Parameters and 10-year Teen/10-year Adult Exposure Parameters:

	Soil/Sediment NALs					Groundwater NALs				
	20-yr Adult Exposure Parameters		10-yr Teen/10-yr Adult Exposure Parameters		Old NAL/ New NAL*	20-yr Adult Exposure Parameters		10-yr Teen/10-yr Adult Exposure Parameters		Old NAL/ New NAL*
Analyte	**Cancer (mg/kg)**	**Hazard (mg/kg)**	**Cancer (mg/kg)**	**Hazard (mg/kg)**		**Cancer (mg/L)**	**Hazard (mg/L)**	**Cancer (mg/L)**	**Hazard (mg/L)**	
Aluminum	-	7.46E+04	-	5.93E+04	1	-	3.32E+00	-	2.57E+00	1
Antimony (metallic)	-	3.34E+01	-	2.59E+01	1	-	1.28E-03	-	1.00E-03	1
Arsenic, Inorganic	3.56E-01	1.03E+01	3.02E-01	7.35E+00	1	5.17E-05	9.95E-04	4.33E-05	7.72E-04	1
Barium	-	1.35E+04	-	1.09E+04	1	-	6.15E-01	-	4.84E-01	1
Beryllium and compounds	1.59E+03	1.58E+02	1.59E+03	1.24E+02	1	-	3.61E-03	-	3.06E-03	1
Cadmium (Diet)	2.12E+03	2.40E+01	2.12E+03	1.72E+01	1	-	1.49E-03	-	1.18E-03	1
Chromium(III), Insoluble Salts	-	1.00E+05	-	9.70E+04	1	-	3.44E+00	-	2.83E+00	1
Chromium(VI)	3.01E-01	2.46E+02	2.92E-01	1.91E+02	1	3.47E-05	6.79E-03	2.90E-05	5.60E-03	1
Cobalt	4.24E+02	2.43E+01	4.24E+02	1.90E+01	1	-	9.99E-04	-	7.74E-04	1
Copper	-	3.34E+03	-	2.59E+03	1	-	1.33E-01	-	1.03E-01	1
Manganese	-	1.56E+03	-	1.27E+03	1	-	6.97E-02	-	5.54E-02	1
Mercury, Inorganic Salts	-	2.50E+01	-	1.94E+01	1	-	9.23E-04	-	7.26E-04	1
Molybdenum	-	4.17E+02	-	3.23E+02	1	-	1.66E-02	-	1.29E-02	1
Nickel Soluble Salts	1.47E+04	1.48E+03	1.47E+04	1.17E+03	1	-	6.48E-02	-	5.05E-02	1
Selenium	-	4.17E+02	-	3.23E+02	1	-	1.66E-02	-	1.29E-02	1
Silver	-	4.17E+02	-	3.23E+02	1	-	1.53E-02	-	1.21E-02	1
Thallium (Soluble Salts)	-	8.34E-01	-	6.47E-01	1	-	3.32E-05	-	2.57E-05	1
Uranium (Soluble Salts)	-	2.40E+02	-	1.88E+02	1	-	9.95E-03	-	7.72E-03	1
Vanadium and Compounds	-	4.08E+02	-	3.19E+02	1	-	1.37E-02	-	1.10E-02	1
Benzene	1.16E+00	1.07E+01	1.15E+00	1.06E+01	1	4.54E-04	4.05E-03	4.27E-04	3.72E-03	1
Carbon Tetrachloride	6.53E-01	1.49E+01	6.50E-01	1.47E+01	1	4.53E-04	6.96E-03	4.18E-04	6.01E-03	1
Chloroform	3.16E-01	2.59E+01	3.16E-01	2.57E+01	1	2.21E-04	1.22E-02	2.17E-04	1.10E-02	1
Dichloroethane, 1,2-	4.64E-01	3.32E+00	4.62E-01	3.31E+00	1	1.71E-04	1.36E-03	1.64E-04	1.33E-03	1
Dichloroethylene, 1,1-	-	2.40E+01	-	2.39E+01	1	-	3.25E-02	-	3.07E-02	1
Dichloroethylene, 1,2- (Mixed Isomers)	-	7.51E+02	-	5.82E+02	1	-	2.66E-02	-	2.11E-02	1
Dioxins/Furans, Total (as TCDD)	3.08E-06	2.07E-05	2.67E-06	1.49E-05	1	1.19E-10	1.83E-09	1.14E-10	1.49E-09	1
Ethylbenzene	5.78E+00	5.52E+02	5.75E+00	5.41E+02	1	1.49E-03	1.04E-01	1.43E-03	9.43E-02	1
Polychlorinated Biphenyls, Total	7.88E-02	-	6.46E-02	-	1	4.36E-05	-	4.18E-05	-	1
Polycyclic aromatic hydrocarbons, Total Carcinogenic	6.55E-03	-	5.82E-03	-	1	3.43E-06	-	2.72E-06	-	1
Tetrachloroethylene	2.36E+01	9.61E+00	2.34E+01	9.55E+00	1	1.12E-02	4.99E-03	1.05E-02	4.62E-03	1
Trichloroethane, 1,1,1-	-	8.55E+02	-	8.54E+02	1	-	8.80E-01	-	8.46E-01	1
Trichloroethane, 1,1,2-	1.15E+00	1.50E-01	1.14E+00	1.50E-01	1	2.75E-04	4.16E-05	2.65E-04	4.15E-05	1
Trichloroethylene	9.43E-01	4.56E-01	9.38E-01	4.54E-01	1	4.93E-04	3.23E-04	4.49E-04	3.05E-04	1
Vinyl Chloride	5.92E-02	9.59E+00	5.90E-02	9.48E+00	1	1.88E-05	6.41E-03	1.81E-05	5.39E-03	1
Xylene, Mixture	-	5.96E+01	-	5.95E+01	1	-	1.98E-02	-	1.97E-02	1

*Value shows to the nearest whole number the 20-yr Adult Exposure Parameters divided by the 10-yr Teen/10-yr Adult Exposure Parameters, meant to show order of magnitude difference.

Comment 5: GROUNDWATER NALs (Table A.5)
Adult and Child Resident (chemical calculator)

- Both risk-based and hazard-based No Action Levels are different than my calculations, due to the following difference (see Resident_chem_prg_H2O_DRAFT + Corrections.pdf) - body weight for age 6-16 should be changed from 80 kg to 44 kg

  - Risk-based NALs

    - For arsenic, the risk-based PRG listed in Appendix A is 5.17E-05 mg/liter, and my calculation is 4.33E-05 mg/liter
    - For b(a)p, the risk-based PRG listed in Appendix A is 3.43E-06 mg/liter, and my calculation is 2.72E-06 mg/liter
    - For TCE, the risk-based PRG listed in Appendix A is 4.93E-04 mg/liter, and my calculation is 4.44E-04 mg/liter

  - Hazard-based NALs

    - For arsenic, the hazard-based PRG listed in Appendix A is 9.95E-4 mg/liter for a resident adult, and my calculation is 7.71E-04 mg/liter

For TCE, the hazard-based PRG listed in Appendix A is 3.23E-4 mg/liter for a resident adult, and my calculation is 3.03-04 mg/liter

Response 5: Please see response to KDEP-4.

Comment 6: SURFACE WATER NALs (Table A.6)
In addition to the comments/corrections below, I would like to know why are there no NALs for the cPAHs for the Outdoor Worker, the Excavation Worker, or the Industrial Worker?

Response 6: Because the Outdoor Worker, the Excavation Worker, and the Industrial Worker are not ingesting surface water, any risk/hazard from surface water is solely from dermal contact. For the cPAHs, the "EPD" (effective predictive domain) is "0," from RAGS Part E which states, "…do not recommend that the model be used to quantify exposure and risk to contaminants in water that are outside the EPD in the 'body' of the risk assessment. Rather, it is recommended that such information be presented in the discussion of uncertainty in the risk assessment."
This uncertainty has been added to Appendix B of the 2017 RMD.

Comment 7: Outdoor Worker – Wading (chemical calculator Recreator used: "Adjusted" results for Hazard values)

- The risk-based PRGs are different than my calculations, due to the following difference (see Oudoor_Worker_chem_prg_H2O + Corrections.pdf) – Exposure Duration for age 0-2 should be changed from 1 year to 2 years

  - For arsenic, the risk-based PRG listed in Appendix A is 9.66E-02 mg/liter, and my calculation is 9.29E-02 mg/liter

- For TCE, the risk-based PRG listed in Appendix A is 1.89E-01 mg/liter, and my calculation is 1.74E-01 mg/liter

Industrial Worker – Wading (chemical calculator, Recreator used: "Adjusted" result for Hazard Values)

- The risk-based PRGs are different than my calculations, due to the following difference (see Industrial_Worker_chem_prg_H2O + Corrections.pdf) – Exposure Duration for age 0-2 should be changed from 1 year to 2 years

  - For arsenic, the risk-based PRG listed in Appendix A is 2.38E-02 mg/liter, and my calculation is 2.29E-02 mg/liter

For TCE, the risk-based PRG listed in Appendix A is 3.99E-02 mg/liter, and my calculation is 3.33E-02 mg/liter

Response 7: Originally (when the Paducah RMD first start[ed] using the website), RAIS did not allow exposure durations greater than the age segment duration, so the 25-year duration had to be distributed among the child, teen, and adult segments. This feature was changed in RAIS a few years ago to allow longer durations for adult only scenarios, but the practice was never changed in our PRG calculations.

PRGs for Industrial Worker and Outdoor Worker exposures to Surface Water have been updated for those Paducah site-related COPCs classified as mutagens (i.e., chromium VI, TCE, and vinyl chloride).

Comment 8: Teen Recreator – Wading (chemical calculator, using only "Adult" results)
The row for age 16-30 must be included in order to accurately calculate the risk-based PRGs

Response 8: The risk-based PRGs are taken from the calculation which includes <u>all</u> the rows (i.e., rows for age segments 0-2 yrs, 2-6 yrs, 6-16 yrs, and 16-30 yrs). This was not explained very well in the RAIS screen shots that were provided with the Appendix A values. These screen shots are not included in the RMD.

Comment 9: Adult Recreator - Wading (chemical calculator, using only "Adult" results)

- The row for age 6-16 must be included in order to accurately calculate the risk-based and hazard-based PRGs

- The adult hazard-based PRGs listed in the No Action Levels are different than my calculations (see Recreator_chem_prg_ADULT H2O Wading + 6-16.pdf)

  - For arsenic, the adult hazard-based PRG in Appendix A is 6.11E-01 mg/liter, and my calculation is 3.01E-01 mg/liter

  - For TCE, the adult hazard-based PRG in Appendix A is 6.21E-02 mg/liter, and my calculation is 3.05E-02 mg/liter

Response 9: Please see responses to KDEP-8 and -3.

Comment 10: Teen Recreator – Swimming (chemical calculator, using only "Adult" results)

- The row for age 16-30 must be included in order to accurately calculate the risk-based PRGs

Response 10: Please see response to KDEP-8.

Comment 11: Adult Recreator - Swimming (chemical calculator, using only "Adult" results)

- The row for age 6-16 must be included in order to accurately calculate the risk-based and hazard-based PRGs

- The adult hazard-based PRGs listed in the No Action Levels are different than my calculations (see Recreator_chem_prg_ADULT H2O Swimming + 6-16.pdf)

  - For arsenic, the adult hazard-based PRG in Appendix A is 1.06E-01 mg/liter, and my calculation is 8.66E-02 mg/liter

  - For TCE, the adult hazard-based PRG in Appendix A is 3.18E-02 mg/liter, and my calculation is 2.94E-02 mg/liter

Response 11: Please see responses to KDEP-8 and -3.

Response to Environmental Protection Agency Comments Submitted by Tim Frederick

Specific Comments:

Comment 1: Page A-3, Bullet 5. The text states that the background values are provisional and subject to change. EPA recommends that additional language should be added to this bullet to describe how/why these values might change and how the RAWG would captue, evaluate, and/or present any potential changes.

Response 1: Text has been added to Bullet 5 of the 2017 RMD—please see redline below:

> Background values for soil and groundwater presented in this appendix are provisional. Soil background values, except as noted, were derived as detailed in DOE 1996 and DOE 1997. Groundwater background values were derived from a study presented in the Groundwater Operable Unit Feasibility Study Report (DOE 2000). These values have not been approved for all uses by the PGDP Risk Assessment Working Group; therefore, these background values are subject to change should other values be more appropriate or should a new project be initiated to update the site background values.

Comment 2: Page A-3, Bullet 6. Please provide brief discussion on the DAF = 58 calculations that are included in the SSL tables.

Response 2: Text has been added to Bullet 6 of the 2017 RMD—please see redline below:

> Soil screening levels for chemicals for protection of groundwater were derived using RAIS. The Soil Screening Level (SSL) values based upon a dilution attenuation factor (DAF) of 1 should be considered to be "no action values." "Action" SSLs have not been selected to date for the PGDP. In addition to the SSLs at a DAF of 1, SSLs at DAFs of 20 and 58 also are included. The derivation of the DAF of 58 is presented in Appendix E. The presentation in Appendix E discusses the derivation of the DAF using the equation from EPA's Soil Screening Guidance Technical Background Document (EPA 1996). This attachment also provides a sensitivity analysis of the screening of Soils Operable Unit soil concentrations against values calculated using a DAF of 58 and a DAF of 20.

Comment 3: Page A-3, Bullet 7. This bullet addresses regulatory values (e.g., MCLs). EPA recommends that this section include additional information and recommendations to ensure that appropriate regulatory values are not missed when data are screened. EPA recommends that these values (in Table 14) should be included with the media-specific screening values.

Response 3: Text has been expanded in Bullet 7 of the 2017 RMD—please see redline below. Primary MCL values from Table A.14 have been included with groundwater screening values (Tables A.2 and A.5) in addition to being shown in Table A.14.

> Regulatory values are for planning purposes only. These values include maximum contaminant levels (MCLs), maximum contaminant level goals (MCLGs), and secondary maximum contaminant levels (SMCLs) for groundwater and state water supply water quality criteria (WQC), state fish consumption WQC, and federal combined WQC for surface water. MCL values are included with

the Risk Methods Document's groundwater action levels and no action levels. A qualified regulatory specialist should be consulted before using these values for other purposes.

Comment 4: Page A-4, 9B Chromium. EPA requests additional discussion on the chromium screening values presented in these tables, especially regarding the basis for deriving total chromium screening values. The method described is not consistent with EPA recommendations for screening total chromium concentrations. Accordingly, please add the derivation of the total chromium screening values to the next RAWG conference call, and please provide the RAIS calculator input/output screens to facilitate the discussion.

Response 4: Appendix A has been revised, consistent with discussion from the March 2017 quarterly meeting. See meeting minutes for additional information.

Comment 5: Page A-4, 9C Lead. What is the rationale for evaluating blood lead levels >2.5 ug/dl in the IEUBK when screening levels are exceeded?

Response 5: That text was added for the 2011 version of the RMD. Updates for lead have been put on hold pending EPA's new guidance (see meeting minutes from February 24, 2016). See also Appendix B CRS.

Comment 6: Table A-1 and subsequent tables. Why are groundwater screening values in mg/L when site data and RAIS output are in µg/L? EPA recommends using consistent units.

Response 6: Groundwater and surface water screening values have been revised to µg/L in the 2017 RMD. As a follow-on change, screening values for groundwater and surface water no longer have an upper limit value of 100,000. A note has been added that concentrations are not adjusted for saturation. Additionally text has been added to the bullet on page A-4, "9A General," as follows: "Surface water and groundwater screening values (especial those on the action level tables) may exceed their saturation limit for the analyte; a comparison has not been performed."

The topic of saturation limit with respect to PRGs was discussed in the March 2017 quarterly meeting.

ATTACHMENT 2

Response to Environmental Protection Agency Comments Submitted by Tim Frederick

Specific Comments:

Comment 1: Page B-4, Footnote 3. This footnote discusses the screening values that will be used to screen soil data. It states that within the industrial area, industrial screening values will be used. Similar site-specific recommendations are used in other areas. It is the policy of Region 4 that screening in all areas should be compared to residential soil screening values as a conservative screening to ensure that screening in protective of all potential future land uses. Please amend this section to be consistent with this policy and footnote 1 (groundwater) of this table.

Response 1: Chemicals and radionuclides of potential concern (COPCs) are determined by screening maximum detected result against child residential values. Comment was discussed during the March 2017 quarterly meeting. Footnotes will be explained more clearly that they are for early action screening, not for determining COPCs.

Comment 2: Table B.5A. EPA does not concur with the tox values provided for total chromium. See comments on Appendix A.

Response 2: Comment was discussed during the March 2017 quarterly meeting. Please see meeting minutes for revisions to the Risk Methods Document.

Comment 3: Page B-21, Notes on Table B.5. RAGS Part E is not Region 4 Guidance. This document was published by the Office of Superfund Remediation and Technology Innovation (OSRTI).

Response 3: The text, "Region 4" has been deleted. The note now reads, "The 'EPA ABS' is the dermal absorption value recommended by EPA in their guidance material, 2004 *RAGs, Part E*. The dermal absorption value is unitless."

Comment 4: Section B.2.4. This section explains that 2.5 ug/dL is the Commonwealth of Kentucky's recommended blood lead level. This answers Region 4's comment on Appendix A about the rationale for using a level of 2.5 ug/dL in the IEUBK calculations. Please add this statement to Appendix A.

Response 4: Statement has been added to Appendix A.

Comment 5: Section B.2.3 and Table B.4. Please provide the source for each of the default exposure parameters.

Response 5: Sources have been added.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

DEC 22 2016

OFFICE OF
SOLID WASTE AND
EMERGENCY RESPONSE

NOW THE
OFFICE OF LAND AND
EMERGENCY MANAGEMENT

MEMORANDUM

SUBJECT: Updated Scientific Considerations for Lead in Soil Cleanups

FROM: Mathy Stanislaus
Assistant Administrator
Office of Land and Emergency Management

TO: EPA Regional Administrators, I-X

This memorandum highlights the current science and risk assessment tools that Regions may consider when implementing the 1994 *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (Office of Solid Waste and Emergency Response [OSWER] Directive 9355.4-12).

Childhood lead poisoning is a complex, multi-media problem that is most effectively addressed through the cooperative efforts of many programs at the federal, state, tribal, and local level. The overarching public health goal is to eliminate lead hazards before children are exposed by implementing primary prevention measures in homes and public facilities.

OSWER Directive 9355.4-12, issued on July 14, 1994, established the Office of Land and Emergency Management's (OLEM's) current approach for addressing lead in soil at Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites. OLEM's risk reduction goal in the directive is "...to limit exposure to soil lead levels such that a typical (or hypothetical) child or group of similarly exposed children would have an estimated risk of no more than 5% of exceeding a 10 µg/dL blood lead level." This goal was consistent with the CDC blood lead action level at the time of the directive's issuance.

OLEM programs use response authorities to assess and, where appropriate, to clean up lead contaminated soil and, if necessary, groundwater, that present unacceptable human health and/or ecological risk. As discussed in the *Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (OSWER Directive 9200.4-27P), issued in August 1998:

> Several sources of lead-contamination, including soil, ground water, airborne particulates, lead plumbing, interior dust, and interior and exterior lead-based paint may be present at Superfund

sites [and] may contribute to elevated blood-lead levels...However, there are limitations on the Agency's statutory authority under CERCLA to abate some of these sources...When EPA's resources, or authority to respond or to expend monies under Superfund is limited, OSWER recommends that EPA Regions identify and coordinate to the greatest extent possible with other authorities and funding sources (e.g., other federal agencies and state or local programs).

Since issuing the 1998 guidance, the EPA's experience has demonstrated that lead-contaminated soil responses are more effective when they employ a multi-pathway approach.

Based on the current scientific consensus and national public health recommendations regarding lead exposure, OLEM is highlighting the following recommendations for Regions to consider when implementing OLEM soil lead policy:

- Within the framework of existing policy, consider the current scientific conclusions[1] in conjunction with the Integrated Exposure Uptake and Biokinetic (IEUBK) model to determine soil screening levels for residential cleanups. Similarly, Regions should continue to use the most current version of the Adult Lead Methodology (ALM) to determine soil screening levels for commercial and industrial cleanups. Soil screening levels are used to determine if additional site-specific risk characterization is needed at sites where lead is detected in soil. Levels of lead above the screening level neither automatically require an action nor designate a site as "contaminated."
- Consistent with existing policy, soils screening levels are generally not used as default preliminary remediation goals (PRGs) and cleanup levels. Site-specific information is generally used to determine PRGs and cleanup levels. In particular, Regions should evaluate the site-specific bioavailability of lead using the EPA's *in-vitro* bioaccessibility assay for lead (see: https://www.epa.gov/hw-sw846/validated-test-method-1340-vitro-bioaccessibility-assay-lead-soil) when determining cleanup levels. Site-specific cleanup levels that are protective of human health may be higher or lower than the screening value depending on the bioavailability of lead. For example, Regions have observed site-specific relative bioavailability levels as low as 14% and as high as 88%, which can impact the soil screening level by as much as a factor of 6.
- On a site-specific basis, Regions may wish to vary some of the internal IEUBK model parameters (e.g., ingestion rate or mass soil to dust) based on peer-reviewed literature or site-specific studies. However, Regions shall consult with the Office of Superfund Remediation and Technology Innovation (OSRTI) and the Technical Review Workgroup for Lead before modifying these parameters.
- Continue to use Superfund removal authorities to address imminent risks associated with high levels of soil lead contamination. The current Removal Management Level (RML) for lead can be found on the RML website at https://www.epa.gov/risk/regional-removal-management-levels-chemicals-rmls

[1] The current scientific literature on lead toxicology and epidemiology provides evidence that adverse health effects are associated with blood lead levels (BLLs) less than 10 µg/dL. For example, EPA's Office of Research and Development reviewed the health effects evidence for lead in the 2013 Integrated Science Assessment for Lead (ISA for Lead) and found that several studies have observed "clear evidence of cognitive function decrements (as measured by Full Scale IQ, academic performance, and executive function) in young children (4 to 11 years old) with mean or group blood Pb levels between 2 and 8 µg/dL (measured at various lifestages and time periods)." In addition, the National Toxicology Program's (2012) Monograph on Health Effects of Low-Level Lead found sufficient evidence of delayed puberty, reduced post-natal growth, and decreased hearing for children at BLLs below 10 µg/dL and adverse effects on academic achievement, IQ, other cognitive measures, attention-related behaviors, and problem behaviors at BLLs below 5 µg/dL

- Consider the *Role of Background in the CERCLA Cleanup Program* (OSWER Directive 9285.6-07P). As discussed in that guidance, the RCRA Corrective Action and Superfund programs do not normally set cleanup levels below natural or anthropogenic background levels. Consideration of the EPA's background policy can be especially important in urban areas where contributions from sources other than the release being addressed under CERCLA or RCRA cleanup authorities (e.g., historic industry releases or lead gas emissions) may result in background levels much higher than the lead soil screening level.
- Work across programs to address multiple sources of lead at contaminated sites. Children in communities located near or on contaminated sites may be exposed to sources of lead that are not being addressed using CERCLA/RCRA cleanup authorities. As such, Regions should leverage their presence in communities to make a concerted effort to collaborate with federal, state, tribal and local partner agencies to communicate best practices to reduce exposure to lead.
- Prioritize resources for investigation and assessment of lead contamination at CERCLA and RCRA Corrective Action sites using a risk-based prioritization approach and in collaboration with state, local and federal public health agencies.

Regions should summarize the application of these recommendations, including the basis for the derived screening level, PRG, and final cleanup level, how site-specific bioavailability was considered, any variation of default parameters to the IEUBK model, and a description of how the region is prioritizing their resources to address sites with the highest risk, during a consultation with the OSRTI before finalizing any cleanup decision documents. OSRTI shall develop a compendium of application of these recommendations.

The EPA is undertaking a unified, cross-Agency approach to addressing lead. As part of that effort, OLEM is evaluating whether updated policy recommendations are needed to incorporate the current scientific consensus and national public health recommendations regarding lead exposure into land cleanup programs. Until that cross-Agency policy work is complete, OLEM's current policy, along with these recommendations, remain in effect.

If your staff have questions regarding these interim recommendations, please contact Michael Scozzafava (Chief, OSRTI Science Policy Branch) at (703) 603-8833.

Cc:
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Risk Assessment Working Group
Meeting Minutes—June 7, 2017

✓Gaye Brewer
✓Nathan Garner
✓Mike Guffey
✓Jeri Higginbotham
✓Jerri Martin
✓Tim Frederick
✓Rich Bonczek
✓Martin Clauberg
✓LeAnne Garner
✓Bobette Nourse
✓Joe Towarnicky

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

Revised agenda sent 6/7/2017. Changes in the revised agenda were pointed out during the meeting.

2. Fiscal Year (FY) 2017 Schedule/Work Plan (Remaining)

Quarterly Meeting (June)	6/7/2017
Submit Human Health (HH) Risk Methods Document (RMD) to FFA Managers (DOE/LX/07-0107&D2/R8/V1)	6/20/2017
FFA Managers acknowledge receipt of HH RMD	7/17/2017
Quarterly Meeting (September)	9/13/2017

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

Rich Bonczek noted during the meeting that the 6/20/2017 submittal date might be in jeopardy due to the scope of the EPA comments and the subsequent DOE management and legal review changes in response to them would require.

3. Discussion of Comments received from Kentucky Division of Waste Management (KDWM), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE)

KDWM Comment 1: <u>Table A.4. Soil/Sediment No Action Levels for Significant COPCs at PGDP</u>. The values for cobalt (rather than for total chromium) were deleted on pages A-33, A-36.
Response: *Table has been corrected.*

KDWM Comment 2: <u>Table B.4. Default Exposure Parameters Used in Calculation of RME</u>. Why are there no values for averaging time for recreational users exposed to vapors and particulates from soil/sediment?
Response: *Table has been revised. There are no conforming changes necessary.*

EPA General Comment 1: The Risk Methods document should be updated to discuss the handling of cumulative risk when environmental media are divided into separate OUs. For example, if groundwater is being addressed as a separate OU, what are the procedures in place to ensure that cumulative risks from all environmental media at a given site will be addressed.
Response: *The RMD states that cumulative risk assessments will be performed (Section 2.1). Details of the OU investigations are included in regulator-approved work plans. A sentence or 2 about when the cumulative risk characterization will be performed, or point to document [such as the Site Management Plan (SMP)] where those decisions has been made. Text has been pulled from the SMP regarding the comprehensive site operable unit. See also Section 3.3.6.2. Proposed text will be sent out as redline page(s) to the group.*

EPA General Comment 2. Similarly, the vapor intrusion discussion in the document should be expanded. Vapor intrusion should be added to the list of identified exposure pathways in Section 3.3.4.2. Section 3.3.4.4 should be expanded to discuss evaluation of sites where the groundwater is a separate operable unit. Where volatiles are present in the groundwater at such sites, the risks may be significantly underestimated if vapor intrusion evaluation is deferred.
Response: *Additional discussion on vapor intrusion will be added to the list of updates for the 2018 RMD.*

EPA Comment 1: **Section 2** – This section should include discussion of the specific PRGs that will be used to screen the data and identify COPCs (i.e., residential, etc). Footnotes in table (B-1) in Appendix (B) and Exhibit 3.2 should be elevated to the main text for clarity.
Response: *The information from footnotes has been added to Section 2. Additionally, minor clarification has been made to the footnotes in Tables B.1 and B.2.*

EPA Comment 2: **Figures 2.3 and 2.4**. The term "guidance values" is not defined. If ARARs are intended, the text in the appropriate boxes should be changed for clarity. If something else is intended, then screening against appropriate ARAR's should be added to the figures.
Response: *Footnote has been added to figures to define "guidance values" by referencing Table A.14.*

EPA Comment 3: **Section 2.2**. The text states, "No further action can be selected for those sites where it can be demonstrated that no contamination is present that exceeds no-action levels". This may not be appropriate if a sufficiently conservative (i.e., residential) exposure pathway was not evaluated.
Response: *Reference has been added to the text to see Figures 2.1 – 2.5. See also response to EPA Comment 1.*

EPA Comment 4: **Section 3.1.3**. The text refers to a comparison of concentrations and activities of analytes in environmental samples with health-based standards (i.e., PRGs, ARARs, etc.). For clarity, ARARs are standards that may or may not be health based. PRGs are not standards but are health-based.
Response: *Text has been revised to "…risk-based screening values (e.g., NALs and ALs, chemical-specific ARARs, etc.)"*

EPA Comment 5: **Section 3.2**. This section describes the scoping, collection, and evaluation of data completeness to support the RI/FS. Discussion of vapor intrusion should be added to this section, since the pathway may need to be evaluated for the RI/FS. This step should be included whether or not groundwater is part of the OU in question. This section also describes several screening tables that will be used to determine the adequacy of sampling for determining nature and extent after initial sampling. It is not clear how data tables are sufficient to determine adequacy of nature and extent sampling. It is recommended that a spatial evaluation of the data should be included in this step of the evaluation.
Response: *The data tables are presented only for providing example screening tables to be presented in RI/FS work plans. Adequacy of sampling for determining nature and extent of sampling is determined in the RI/FS work plans. Screening values for groundwater use for the resident for direct contact are less than values calculated by vapor intrusion modeling (e.g., TCE groundwater NAL for the child resident is 0.282 µg/L; the TCE vapor intrusion screening level target groundwater concentration is 1.2 µg/L). Additional screening is not necessary.*

The text states currently that a spatial plane view presentation of the data also should be provided.

EPA Comment 6: **Section 3.3.1.1**. The guidance citation *Human Health Evaluation Manual, Supplemental Guidance: "Standard Default Exposure Factors"* (EPA 1991d) has been superseded by: https://www.epa.gov/risk/update-standard-default-exposure-factors (which is included in the references further down the list). The Guidance citation *Exposure Factors Handbook*, EPA 600/P-

95/002Fa,b,c (EPA 1997b) has been superseded by:
https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252 The following guidance should also be added to the list: https://semspub.epa.gov/work/HQ/100000133.pdf.
Response: *References and citations have been updated, as suggested.*

EPA Comment 7: Section 3.3.2. This section gets at the purpose of the RMD and should be expanded. The document does not exist only to reconcile differences between KY and EPA guidance. The document also serves to address site-specific issues where guidance may be lacking and/or to document site-specific agreements between the three parties that have evolved over time. EPA recommends expanding this section accordingly.
Response: *Additional text has been added, as suggested. Similar text is in the Preface to the RMD.*

EPA Comment 8: Section 3.3.3.2. This section includes discussion of the use of "survey" data, such as XRF data. Region 4 has been developing field procedures for XRF that could help future sample collection meet the requirements for data of known and sufficient quality. This comment is meant only as a placeholder for future conversation on this topic if needed.
Response: *Upon receipt of Region 4 field procedures, additional text will be added to future RMDs.*

EPA Comment 9: Section 3.3.4.1 (Page 3-24). The text states, "Note that for units or areas outside the industrialized area at PGDP, exposure at the industrialized area will not be considered because it is not necessary for remedial decisions." Please clarify what this statement means.
Response: *Text has been clarified.*

EPA Comment 10: Appendix A. This appendix discusses inclusion of dilution attenuation factors (DAFs) of 20 and 58 for sensitivity analysis. Readers are directed to Appendix E of the document for derivation of the DAF = 58 value. The derivation of this value may be limited to a specific area of PGDP or outdated based upon more recent information that would change the model inputs. The only discussion of DAFs that occurs in the main text is in Table 3.2 which says, "if site-specific DAF values are used, then need to justify these values." It is recommended that the main text should discuss DAFs explicitly and discuss the steps to developing a site-specific DAF.
Response: *Derivation of site-specific DAFs is not part of the scope of the Risk Assessment Working Group. A reference for developing a site-specific DAF (e.g., the Soil Screening Guidance) may be added to the 2018 RMD. Table footnote has been revised to "…SSL 58 is a project-specific soil screening level calculated for a DAF of 58. The appropriate DAF is calculated on a project-specific basis…." This text also has been added to Page A-3 and A-4, Item (6).*

DOE Comment 1: Appendix A, p A-4 Item 7. It is not clear that the RMD is using the referenced regulatory values in the manner prescribed by the regulations. The drinking water regulations generally apply to public water systems. MCL are enforceable standards for drinking water and are measured at the entry point to the distribution system. MCLGs are non-enforceable health-based goals that are established at levels at which no known or anticipated adverse effects occur. SMCLs are nonenforceable guidelines to assist public water systems in managing drinking water for aesthetic considerations and are typically measured at the tap. MCL and non-zero MCLG can be relevant and appropriate for groundwater that may be used for drinking water depending on the circumstances of the release based on factors in 300.400(g)(2). See NCP 300.430(e)(2)(i)(B). Kentucky water supply water quality (Domestic Water Supply from surface water sources) is applicable at the point of withdrawal. See 401 KAR 10:031 (5). Unable to determine what regulation "federal combined WQC for surface water" is referring to. If it is referring to water quality criteria under CWA 304(a), they are recommendations. States may use these criteria or use them as guidance in developing their own. Water quality criteria under 304 0r 303 of CWA may be relevant and appropriate where groundwater may impact surface water and based on factors in NCP 300.400(g)(2).

Response: *Additional text has been added to state that the referenced regulatory values may not be applicable to conditions at PGDP.*

DOE Comment 2: <u>Appendix A, p A-69 Table A.14, "State Water Supply" column heading</u>. In Kentucky this is titled "Domestic Water Supply". It is applicable at the point of withdrawal.
Response: *Column heading has been revised.*

DOE Comment 5: <u>Appendix A, p A-69 Table A.14, "Primary MCLGs" column heading</u>. Delete "Primary".
Response: *Column heading has been revised.*

DOE Comment 6: <u>Appendix A, p A-70 Table A.14</u>. Inclusion of radionuclides raises some potential concerns. The table includes surface water criteria under the CWA. Source, special nuclear, and byproduct material are not regulated under the CWA. Currently the table is not populated for the listed radionuclides but there is nothing that prevents this from happening in the future. Also, the table implies there is a specific MCL for all the listed radionuclide isotopes. The SDWA establishes MCLs for combined radium-226 and 228, gross alpha, and beta particle and photo radioactivity.
Response: *The footnote has been revised to state no criteria are available from the reference if the entry is blank. Additionally, the footnote has been revised to state that only the PGDP COPCs are listed.*

DOE Comment 7: <u>Appendix E, p E-384, December 5, 2012 Meeting Minutes</u>. General: This appendix includes minutes from past meetings of the Risk Assessment Working Group. The minutes have red line changes even through some of these discussions occurred over 5 years ago. Need to verify that these red line changes accurately reflect the discussions at the meeting. Also, it is not clear why draft minutes are included instead of final minutes.
Response: *"Draft" has been removed from historic meeting minutes headings. Red font is not meant to indicate redline changes.*

DOE Comment (additional). Additional comments have been made internally by DOE and may require small changes. These will be sent as redline pages to the group.

4. For Next RMD Revision:

- Outcomes/updates need to be made from discussions (above) in Item 3 (e.g., vapor intrusion, cumulative risk, XRF procedures).
- Updates need to be made for the child and adult resident body surface area in water values.
- Additional PRG/VISL values (below) in Item 6.

5. FY 2018 DRAFT Schedule/Work Plan

Beginning work on FY 2018 schedule, expect it to be similar to FY 2017 schedule. Please note that DOE's deactivation contract will be changing in October 2017. A draft schedule/work plan will be sent before the September 2017 meeting.

6. PRG/VISL Values for Vapor Intrusion Discussions Related to Project Action Levels to Support Analytical Results with respect to Selecting COPCs

Draft values were shown on screen during the RAWG meeting and are attached. The chronic inhalation reference concentration (RfC) value for *trans*-1,2-dichloroethene was discussed. The

source for the RfC was stated to be "PPRTV" (i.e., U.S. EPA Provisional Peer Reviewed Toxicity Values). PPRTVs are available online. Table E.8 will be updated and expanded to include all PGDP VOC and BTEX COPCs (Table 2.1 of RMD) for the FY 2018 RMD.

Rich highlighted that the residential and industrial/commercial VISL and inhalation risk-based values were similar and that this meant that the VISL values could be used for PALs, when project data were going to be used to complete a risk assessment/risk evaluation. Rich also noted that industrial/commercial VISLs exceeded residential risk-based values meaning that use of industrial/commercial VISLs as PALs would result in data that was not suitable to complete a risk assessment for residential use.

7. Watch Topics:

- New definitions for volatile organics are being used in RAIS. This needs to be watched to see if there are any impacts (especially for PCBs and PAHs).

- **Derivation of Risk-based Surface Water Effluent Limits**
  Burial Grounds Operable Unit Solid Waste Management Units 2, 3, 7, and 30 FS and Waste Disposal Alternative RI/FS has been in formal dispute. There has been an update to this status. Oak Ridge is working with EPA Region 4 to determine limits.

- **Status of EPA's Policy for Lead in Blood**
  Tim provided EPA's Directive for "Recommendations for Sieving Soil and Dust Samples at Lead Sites for Assessment of Incidental Ingestion" after last quarter's meeting.
  EPA also has Lead in Blood guidance that states not to use 10 µg/dl. New guidance does not suggest new value.

8. Poll RAWG Members/Open Discussion

The remaining FY 2017 schedule (submittal of RMD to FFA Managers) may be pushed back.

Volatile Analyte	Abbreviation	CAS#	Molar Mass (g/mole)	Industrial Worker (ug/m3) PRG TR=1E-6	Excavation Worker (ug/m3) PRG TR=1E-6	Deactivation Worker (ug/m3) PRG TR=1E-6	Commercial VISL Value (ug/m3) TR=1E-6	Industrial Worker (ug/m3) PRG THQ=0.1	Excavation Worker (ug/m3) PRG THQ=0.1	Deactivation Worker (ug/m3) PRG THQ=0.1	Commercial VISL Value (ug/m3) THQ=1
1,1-Dichloroethane*	1,1-DCA	75-34-3	98.96	7.67E+00	5.18E+01	1.92E+02	7.7E+00	2.19E+02	2.96E+02	2.19E+02	
1,2-Dichloroethane	1,2-DCA	107-06-2	98.96	4.72E-01	3.19E+00	1.18E+01	4.7E-01	3.07E+00	4.14E+00	3.07E+00	3.1E+01
1,1-Dichloroethylene	1,1-DCE	75-35-4	96.95	NA	NA	NA		8.76E+01	1.18E+02	8.76E+01	8.8E+02
1,2-Dichloroethylene (mixture)	1,2-DCE (mix)	540-59-0	96.95	NA	NA	NA		NA	NA	NA	
cis-1,2-Dichloroethylene	cis-1,2-DCE	156-59-2	96.95	NA	NA	NA		NA	NA	NA	
trans-1,2-Dichlorothylene	trans-1,2-DCE	156-60-5	96.95	NA	NA	NA		2.63E+01	3.55E+01	2.63E+01	
1,4-Dioxane	1,4-Dioxane	123-91-1	88.11	2.45E+00	1.66E+01	6.13E+01	2.5E+00	1.31E+01	1.78E+01	1.31E+01	1.3E+02
1,1,1-Trichloroethane	1,1,1-TCA	71-55-6	133.40	NA	NA	NA		2.19E+03	2.96E+03	2.19E+03	2.2E+04
1,1,2-Trichloroethane	1,1,2-TCA	79-00-5	133.40	7.67E-01	5.18E+00	1.92E+01	7.7E-01	8.76E-02	1.18E-01	8.76E-02	8.8E-01
Trichloroethylene	TCE	79-01-6	131.38	2.99E+00	2.02E+01	7.48E+01	3.0E+00	8.76E-01	1.18E+00	8.76E-01	8.8E+00
Vinyl Chloride	VC	75-01-4	62.50	2.79E+00	1.88E+01	6.97E+01	2.8E+00	4.38E+01	5.92E+01	4.38E+01	4.4E+02

Risk Assessment Information System (RAIS) Web Site (https://rais.ornl.gov/) accessed on 6/1/2017.

VISL Version 3.5.1 (using May 2016 RSLs) was accessed on 6/2/2017.

TR=Target Risk; THQ=Target Hazard Quotient; PRG = Preliminary Remediation Goal; VISL = Vapor Intrusion Sceening Level; and NA = No available toxicity value . A blank cell represents no VISL value was provided.

Industrial Worker is defined here with ED = 25 yrs; EF = 250 days/yr; ET = 8 hrs/day. [Note: 250 x 8 = 2000, and ED cancels for HQ calculations.]

Excavation Worker is defined here with ED = 5 yrs; EF = 185 days/yr; ET = 8 hrs/day.

Deactivation Worker is defined here with ED = 1 yr; EF = 200 days/yr; ET = 10 hrs/day. [Note: 200 x 10 = 2000, and ED cancels for HQ calculations.]

Note that chronic RfC values were used in the PRG and VISL calculations.

* A provisional HEAST RfC was used to calculate PRGs (for THQ) for 1,1-DCA.

Volatile Analyte	Abbreviation	CAS#	Molar Mass (g/mole)	Residential PRG (ug/m3) TR=1E-6	Residential VISL Value (ug/m3) TR=1E-6	Residential PRG (ug/m3) THQ=0.1	Residential VISL Value (ug/m3) THQ=1
1,1-Dichloroethane*	1,1-DCA	75-34-3	98.96	1.75E+00	1.8E+00	5.21E+01	
1,2-Dichloroethane	1,2-DCA	107-06-2	98.96	1.08E-01	1.1E-01	7.30E-01	7.3E+00
1,1-Dichloroethylene	1,1-DCE	75-35-4	96.95	NA		2.09E+01	2.1E+02
1,2-Dichloroethylene (mixture)	1,2-DCE (mix)	540-59-0	96.95	NA		NA	
cis-1,2-Dichloroethylene	cis-1,2-DCE	156-59-2	96.95	NA		NA	
trans-1,2-Dichlorothylene	trans-1,2-DCE	156-60-5	96.95	NA		6.26E+00	
1,4-Dioxane	1,4-Dioxane	123-91-1	88.11	5.62E-01	5.6E-01	3.13E+00	3.1E+01
1,1,1-Trichloroethane	1,1,1-TCA	71-55-6	133.40	NA		5.21E+02	5.2E+03
1,1,2-Trichloroethane	1,1,2-TCA	79-00-5	133.40	1.75E-01	1.8E-01	2.09E-02	2.1E-01
Trichloroethylene	TCE	79-01-6	131.38	4.78E-01	4.8E-01	2.09E-01	2.1E+00
Vinyl Chloride	VC	75-01-4	62.50	1.68E-01	1.7E-01	1.04E+01	1.0E+02

Risk Assessment Information System (RAIS) Web Site (https://rais.ornl.gov/) accessed on 6/6/2017.

VISL Version 3.5.1 (using May 2016 RSLs) was accessed on 6/2/2017.

TR=Target Risk; THQ=Target Hazard Quotient; PRG = Preliminary Remediation Goal; VISL = Vapor Intrusion Sceening Level; and NA = No available toxicity value. A blank cell represents no VISL value was provided.

Resident is defined here with ED = 26 yrs; EF = 350 days/yr; ET = 24 hrs/day.

Note that chronic RfC value was used in the PRG and VISL calculations.

* A provisional HEAST RfC was used to calculate PRGs (for THQ) for 1,1-DCA.

Risk Assessment Working Group
Meeting Minutes—September 29, 2017

Brian Begley✓	Tim Frederick✓	Rich Bonczek✓
Mike Guffey✓	Jon Richards✓	Martin Clauberg✓
Chris Jung✓		LeAnne Garner ✓
Jerri Martin✓		Bobette Nourse✓
		Joe Towarnicky✓

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

EPA comments added to agenda as Item 4.
Updates from FFA Manager's meeting/Groundwater Modeling Working Group (MWG)
It was noted that Four Rivers Nuclear Partnership will be the Paducah Deactivation and Remediation contractor, transitioning in October 2017.

2. Proposed FY 2018 Schedule/Work Plan

Submit Work Plan (i.e., this schedule)	9/13/2017
RAWG concurs with Work Plan	10/13/2017
Suggested revisions/corrections to Human Health (HH) RMD text should be sent to LeAnne	11/2/2017
Submit HH Appendix A [i.e., Preliminary Remediation Goals (PRGs)] to RAWG for review	11/14/2017
Quarterly Meeting (December)	12/6/2017
Submit revised HH Main Text and HH Appendix B and D to RAWG for review	12/12/2017
Comments due for HH Appendix A	1/12/2018
RAWG Concur with HH Appendix A	2/13/2018
Comments due for HH Main Text and HH Appendix B and D	2/13/2018
Quarterly Meeting (March)	3/7/2018
RAWG concur with HH Main Text and HH Appendix B and D	4/10/2018
Submit Entire Revised HH RMD to RAWG for Review	4/17/2018
Comments due for entire revised HH RMD	5/15/2018
Quarterly Meeting (June)	6/6/2018
Submit HH RMD to FFA Managers (DOE/LX/07-0107&D2/R8/V1)	6/20/2018
FFA Managers acknowledge receipt of HH RMD	7/17/2018
Quarterly Meeting (September)	9/12/2018

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

3. Discussion for Next RMD Revision:

a. Include additional discussion on vapor intrusion.

Based on EPA's comment to the 2017 RMD: "…the vapor intrusion discussion in the document should be expanded. Vapor intrusion should be added to the list of identified exposure pathways in Section 3.3.4.2. Section 3.3.4.4 should be expanded to discuss evaluation of sites where the groundwater is a separate operable unit. Where volatiles are present in the groundwater at such sites, the risks may be significantly underestimated if vapor intrusion evaluation is deferred."

More robust language is needed to describe what the projects should do, beyond only referencing guidance. LeAnne will work with Tim and Jeri H. on draft language to include in the 2018 RMD.

b. Add a reference for developing a site-specific DAF (e.g., the Soil Screening Guidance).

Based on EPA's comment to the 2017 RMD: "This appendix [Appendix A] discusses inclusion of dilution attenuation factors (DAFs) of 20 and 58 for sensitivity analysis. Readers are directed to Appendix E of the document for derivation of the DAF = 58 value. The derivation of this value may be limited to a specific area of PGDP or outdated based upon more recent information that would change the model inputs. The only discussion of DAFs that occurs in the main text is in Table 3.2 which says, 'if site-specific DAF values are used, then need to justify these values.' It is recommended that the main text should discuss DAFs explicitly and discuss the steps to developing a site-specific DAF."

DOE responded that Derivation of site-specific DAFs is not part of the scope of the Risk Assessment Working Group, but a reference for developing a site-specific DAF (e.g., the Soil Screening Guidance) may be added to the 2018 RMD….

MWG is to provide input, develop guidance on how to develop site-specific SSLs. It was discussed and agreed that the guidance will not provide a specific explanation or prescription of a numeric DAF other than 1 used for default screening (e.g. for a site-specific DAF of 58). For the 2018 RMD, we will take out the column with SSLs based on DAF of 58.

c. Make updates for the child and adult resident surface area in water values.

Based on revisions to EPA exposure factors, child and adult surface area values are 6,365 and 19,652, respectively, here: https://www.epa.gov/sites/production/files/2015-11/documents/oswer_directive_9200.1-120_exposurefactors_corrected2.pdf.

Table B.4 currently lists 6,378 and 20,900, respectively, from an earlier revision of the memo with EPA exposure factors.

Tim will confirm correct values to put in Table B.4 to update for the 2018 RMD.

d. Update and expand Table E.8 Human Health Information for the Paducah Vapor Intrusion Evaluation to include all PGDP volatile organic compound (VOC) and benzene, toluene, ethylbenzene, and xylene (BTEX) significant chemicals and radionuclides of potential concern (COPCs) at PGDP (Table 2.1 of RMD).

Information from the C-400 Work Plan, VOCs in the C-400 Vapor Intrusion Work Plan, and BTEX compounds from Table 2.1 (i.e., benzene, ethylbenzene, and xylenes)[1] will be added to Table E.8 in the 2018 RMD. If additional project-specific VOC information becomes available, it also will be added.

[1] Toluene is not a significant COPC at PGDP listed in Table 2.1 of the RMD.

e. Define approach to total, trivalent, and hexavalent chromium.

Based on EPA's comment to the 2017 RMD: "EPA requests additional discussion on the chromium screening values presented in these tables, especially regarding the basis for deriving total chromium screening values. The method described is not consistent with EPA recommendations for screening total chromium concentrations. ..."

The ideal solution with respect to an approach to dealing with chromium is to have the projects analyze for Chromium-6 and -3, especially if Chromium-6 is an issue.
Some minor chromium-6 results have been found at Paducah. Some total chromium results are above the MCL (i.e., 100 µg/L).
For the 2018 RMD, chromium screening values will be footnoted that the project should select the chromium screening value appropriate for project use.

f. Benzo[a]pyrene toxicity values change affects all carcinogenic polycyclic aromatic hydrocarbon (PAH) PRGs.

EPA's Integrated Risk Information System (IRIS) values were revised to reflect a better understanding that lowered the toxicological uncertainty factors. The revision will increase the screening values by an order of magnitude. New assessment in IRIS is worth looking at (https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=136).
The 2018 revision of the RMD will catch up to RSLs already revised for this toxicity change. Appendix E has a white paper re: PAHs at Paducah. LeAnne will check to see if this change impacts that paper.

g. Include provision for mutagenic toxicants.

Based on EPA's comment to the Soils OU RI, SWMU 1 Addendum: "Contaminants of potential concern (COPCs) at SWMU 1 such as benzo(a)pyrene and hexavalent chromium (if present) act via the mutagenic mode of action (MMOA). Based on review of the HHRA, it is unclear if adjustments to the toxicity of these COPCs were not made in the evaluation of early-life exposures. Please revise the HHRA to evaluate MMOA for all applicable COPCs consistent with U.S. EPA's *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (2005)."

Text was added for the 2017 revision of the RMD. This text may also be included as a footnote to the equations in Appendix D for the 2018 RMD. The risk assessment scoping should consider whether the mutagenic effects are significant and whether additional calculation is necessary. When doing a risk assessment, may include accounting for the mutagenic effects in the uncertainty section of the risk assessment report. The 2018 RMD will add a footnote or asterisk to Table 2.1 to denote mutagens (consistent with Table B.5).

h. Include discussion of exposure unit size of 0.5 acre for a recreational scenario.

Based on KY's comment to the Soils OU RI, SWMU 1 Addendum: "It is stated in this section that 'Hunters are assumed primarily to be teens and adults, and direct contact to soils for these receptors is assumed to be limited because repeated contact with contaminated media at sites less than 0.5 acre would be unlikely for hunting activities.' This is similar to the original logic behind the 'two men and a backhoe' application for construction/excavation workers, which has been abandoned as a viable method. Specifically, this assumes that the receptor in question is exposed

to one area of a certain size for a unit-specific period of time and then is never exposed again. Over a long period of time the number of contaminated areas that a future recreational user may come into contact with cannot be predicted with reasonable certainty. At a large facility like the Paducah Site, it cannot be assumed that a future recreational user will only hunt/recreate within a single SWMU over the course of their life. Please offer a reasonable hunter scenario which takes into consideration that a hunter may come in contact with multiple SWMUs over a lifetime of hunting and recreation."

Consideration of exposure unit size was a similar problem at Oak Ridge for a future maintenance worker scenario. It was concluded in Oak Ridge that assuming the receptor is only in one exposure unit was more protective than assuming the receptor was in more than one exposure unit for less time, respectively.

The residential scenario that provides for the receptor to be at one exposure unit for the total exposure duration, does not account for wild game being in multiple exposure units while bioaccumulating contaminants, then being ingested by hunter. Quantifying this risk to this hunter is uncertain.
Jerri will send out some information or suggestions on how to address.
The 2018 RMD may need to include a discussion regarding provision for the recreational user in cleanup goals.

i. The EPA Region 4 Field Operating Guide for XRF was sent by Tim.

The XRF procedure from EPA indicates more readings are taken by XRF than typically is taken by a fixed-base lab. Multiple shots of the bags can give better reproducibility, but peer error also needs to be considered when collecting these values; a statistician should be consulted.
LeAnne will compare FPDP's XRF procedure with EPA's.
If XRF data is to be used for risk assessments, procedures need to be in place to ensure data is of sufficient quality for making decisions. Bobette will pass this information to the programmatic Quality Assurance Project Plan (pQAPP). The pQAPP includes information for collecting XRF data. Additionally, data quality objectives (DQOs) should be discussed whenever using XRF data.

j. Include additional direction for PCB test kits and XRF field measurements.

Based on EPA's comments to the Soils OU RI, SWMU 1 Addendum and additional discussion regarding the field data and fixed-base laboratory data being used together in the risk assessment: "Section B.3.2 (PCBs) presents a comparison of field test kit data to paired test kit/laboratory data for polychlorinated biphenyls (PCBs). The table shows that neither analytical methodology resulted in any detection of PCBs at the SWMU 1. However, paired data was provided for only six samples that were sent to the laboratory, and it was noted that the detection limit for the field test kits was 5 milligrams per kilogram (mg/kg), compared to approximately 0.02 mg/kg for the laboratory results. The PCB test kits reporting limit of 5 mg/kg exceeds the Industrial worker NAL of 0.295 mg/kg. As such, it is unclear how use of the PCB test kits meets the DQOs for the project. Please revise the RI Addendum Report to state how the investigation at the SWMU 1 using primarily PCB test kits is adequate for identifying the nature and extent of contamination and subsequent risk evaluations."

Bobette will pass this information to the pQAPP.

k. Link to EPA's RSL and PRG online calculators (https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search and https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search) will be included in the 2018 RMD.

l. Bioaccumulation Factors will be moved from Table B.5 to Appendix E in the 2018 RMD.

m. For the biennial review and revision of Appendix E, items were considered that can be removed and referenced to previous RMDs.

A link to Kentucky Guidance was sent by Jerri Martin during the meeting (http://waste.ky.gov/SFB/Documents/KY%20Risk%20Assessment%20Guidance%20_Final_.pdf). That link will be used in Appendix E in place of the reproduced guidance.

4. EPA's Comments to the RMD (Dated 9/6/2017)

LeAnne will set up a separate call to discuss comments related to radionuclides. Dose information may be deleted from the 2018 RMD. Use of negative values will need to be decided—for calculation of exposure point concentrations (EPCs) (i.e., EPCs for risk assessments vs. EPCs used for dose assessments)

a. The RMD does not include reference to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements to maintain risk within the 1E-04 to 1E-06 risk upper bound excess lifetime cancer risk (ELCR). The following sections in the RMD reference the use of DOE Order 458.1 dose limits of 25 mrem/yr and 100 mrem/yr:

— Section 2.1, Analyses Supporting Action Prior to RI/FS, Page 2-10: The last paragraph in this section includes a dose assessment discussion which references the DOE Order 458.1, Radiation Protection of the Public and Environment Total Effective Dose limit of 25 millirem per year (mrem/yr)

— Appendix A, Screening Levels, Item G, Page A-5: Item G identifies the following dose-based radionuclide screening levels used in the RMD:

- 1 mrem/year (from NRCRP Report No. 116, Section 17, Negligible Individual Dose and ANSI/HPS standard N13.12)
- 12 mrem/year (from "Radiation Risk Assessment at CERCLA Sites: Q & A" OSWER No. 9200.4-40, June 13, 2014)
- 25 mrem/year (derived from the public dose limit of 100 mrem/year limit in DOE Order 458.1 and considering ALARA principles)
- 100 mrem/year (DOE Order 458.1)

In accordance with the National Contingency Plan (NCP) 40 CFR Section 300.430 and CERCLA, acceptable exposure levels are generally concentration levels that represent an ELCR to an individual of between l0E-04 and l0E-06 using information on the relationship between dose and response. In addition, a 10E-06 risk level should be used as the point of departure for determining remediation goals for alternatives when Applicable or Relevant and Appropriate Requirements (ARARs) are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure.

Since, according to the EPA guidance document OSWER No. 9285.6-20 and OSWER 9200.4-40 "Radiation Risk Assessment at CERCLA Sites: Q & A" dated June 13, 2014, a dose of 12

mrem/yr, equivalent to 3E-04 risk is a protective dose-based limit, use of screening levels such as 25 mrem/yr and 100 mrem/yr obtained from DOE Order 458.1 are not protective and therefore do not meet the statutory requirements of the NCP and CERCLA.

Section 2.1 of the RMD, Appendix A, and any other references to the use of the 25 mrem/yr and 100 mrem/yr dose limits in the RMD will require revision in the next update to the RMD to include a requirement to meet CERCLA requirements in all CERCLA evaluations, planning, and action decisions.

This topic is postponed to the separate call; to be held in October 2017.

b. Appendix B, Derivation of Preliminary Remediation Goals, Table B.4. Default Exposure Parameters Used in Calculation of RME [Reasonable Maximum Exposure] includes exposure factors such as consumption of fish, homegrown vegetables, meat and dairy products that were obtained from the Exposure Factors Handbook, EPA/600/8-89/043, dated 1989 rather than the more recent Exposure Factors Handbook: 2011 Edition, EPA/600/R-090/052F, dated 2011. The 2011 Edition incorporates data available since 1997, up to July 2011 and also reflects the revisions made to the Child-Specific Exposure Factors Handbook updated and published in 2008. It is therefore recommended the more recent 2011 Exposure Factors Handbook be consulted for use of consumption of fish, homegrown vegetables, meat and dairy products. *Please ensure that the next update of the RMD incorporate revisions published in the 2011 Edition of the Exposure Factors Handbook.*

Tim will provide these values that need to be updated in Table B.4 of the 2018 RMD.

c. Specific Comment 1: **Section 3.3.3.2, Procedures to screen or evaluate data to determine COPCs, Step 2: Evaluation of Sampling and Analytical Methods, Pages 3-16, 3-17**: The first paragraph on this page states that data for non-radionuclides that are not generated using EPA-approved methods will not be used quantitatively, but may be used qualitatively. This section also states that methods for radionuclides will be evaluated during the data quality objective (DQO) process to ensure data quality requirements can be met; however, this section does not specify how radionuclide data which does not meet data quality requirements will be assessed or used *Please revise Section 3.3.3.2 accordingly to clarify the DQOs for radionuclides in the next update to the RMD.*

This topic is postponed to the separate call; to be held in October 2017.

d. Specific Comment 2: **Section 3.3.3.2, Procedures to screen or evaluate data to determine COPCs, Step 3, Evaluation of Sample Quantitation Limits, Page 3-19**: This section does not appear to properly take into account the uncertainty inherent in the statistically-based accounting of radionuclide processes and analyses. For example, radionuclide data will have a counting uncertainty associated with the instrument's detection of light or electrical pulses used to approximate the amount of radioactivity present; and a total propagated uncertainty associated with each result that accounts for the sample collection and preparation errors in addition to the counting error. As such, results are reported from the laboratory as a value, with a plus or minus error/uncertainty. As an example, a result of 3 picoCuries per gram (pCi/g) may have an uncertainty of +/- 1 pCi/g. The uncertainty value indicates the actual result may fall within a range of 2 pCi/g to 4 pCi/g at a certain level of confidence. In this case, if the Minimum Detectable Concentration (MDC) for this instrument is 2 pCi/g, there is uncertainty as to whether the reported result is actually a detection or not and therefore may impact the value included in the EPC calculation. It is recommended that the next update to the RMD address the reporting of

the uncertainty associated with radionuclide data. *The RMD should clearly discuss how this uncertainty will be handled in the reporting and use of such data. Please also include an explanation of whether radionuclide results reported with an uncertainty that indicates the result could fall below the MDC will be· reported as detections or non-detects, or otherwise flagged in the data verification/validation and assessment process indicating the detected result is tentative.*

This topic is postponed to the separate call; to be held in October 2017.

e. Specific Comment 3: **Section 3.3.3.2, Procedures to screen or evaluate data to determine COPCs, Step 3, Evaluation of Sample Quantitation Limits, Page 3-19**: This section states "[F]or radionuclides, all reported values, including negative values, will be used to derive the EPCs [exposure point concentrations] under current conditions." A footnote associated with this statement indicates that the negative value may arise from the subtraction of the instrument background value. While it is true that the subtraction of the instrument background may result in a negative value, it is unclear why a negative value would not be considered a non-detect and why it is deemed appropriate to include a negative number in the EPC calculation which may bias the EPC low. It is requested that EPC calculations be performed without using negative values for radionuclides so as to avoid biasing the EPC result low. *Please incorporate this change in the next revision of the RMD.*

This topic is postponed to the separate call; to be held in October 2017.

f. Specific Comment 4: **Section 3.3.3.2, Procedures to screen or evaluate data to determine COPCs, Step 4, Evaluation of Data Qualifiers and Codes, Page 3-19**: The text states evaluation of radionuclide data will follow rules agreed upon by the Commonwealth of Kentucky Radiation Health Branch [formerly the Kentucky Radiation Health and Toxic Agents Branch (KYRHTAB)] and DOE, and includes qualifiers for the following conditions:

— KYRHTAB-50: KYRHTAB has performed an independent data assessment and the radiation counting uncertainty is greater than 50% of the analytical results.
— KYRHTAB-ER: KYRHT AB has performed an independent data assessment and the data present error problems (i.e., no counting uncertainty or zero counting uncertainty).

The text in this section does not, however, specify how data with a counting uncertainty greater than 50% of the result, or for which a counting uncertainty is not reported or reported as '0' will be used in assessing the nature and extent of contamination and in risk assessments. *It is therefore requested that the data evaluation and associated rules specifying how such data will be used be specified in the next update to the RMD for the cases where an uncertainty greater than 50% is reported, or for which uncertainty is not available or reported as '0'.*

This topic is postponed to the separate call; to be held in October 2017.

5. Watch Topics:

- New definitions for volatile organics are being used in RAIS. This needs to be watched to see if there are any impacts (especially for PCBs and PAHs).

- **Derivation of Risk-based Surface Water Effluent Limits**
  Burial Grounds Operable Unit Solid Waste Management Units 2, 3, 7, and 30 FS and Waste Disposal Alternative RI/FS has been in formal dispute. There has been an update to this status.

Oak Ridge is working with EPA Region 4 to determine limits.
This is still being worked.

- **Status of EPA's Policy for Lead in Blood**
  EPA has Lead in Blood guidance that states not to use 10 µg/dl. New guidance does not suggest new value. Where lead is a driver, risk from lead will need to be addressed.
  New screening levels may be less than what they currently are (i.e., less than 400 mg/kg for the resident). Screening value should be footnoted to look for updated changes. Additionally, a new IEUBK will be coming out over the course of this RMD revision. The new IEUBK should also be footnoted in RMD 2018.

  Tim previously shared sieving guidance; projects also need to keep this in mind.

6. Poll RAWG Members/Open Discussion

LeAnne will send out meeting invitation to discuss rad in October 2017.

Risk Assessment Working Group
Meeting Minutes—October 27, 2017
(Items Remaining from September 29, 2017 Meeting)

Gaye Brewer✓	Julie Corkran✓	Rich Bonczek✓
Nathan Garner✓	Jana Dawson✓	Martin Clauberg✓
Chris Jung✓	Jon Richards✓	LeAnne Garner ✓
Jerri Martin✓		Bobette Nourse✓
		Joe Towarnicky✓

This separate call was set up to discuss comments related to radionuclides. Before discussing the comments, Rich Bonczek began with an introduction as to why the dose information is presented in the Risk Methods Document (RMD). Dose information was added to the RMD in approximately 2000 to address concerns from Kentucky. Dose limits generally were consistent with U.S. Nuclear Regulatory Commission and U.S. Department of Energy (DOE) orders, later U.S. Environmental Protection Agency (EPA) dose screening limits were added.

4. EPA's Comments to the RMD (Dated 9/6/2017)

Dose information may be deleted from the 2018 RMD. Use of negative values will need to be decided—for calculation of exposure point concentrations (EPCs) (i.e., EPCs for risk assessments vs. EPCs used for dose assessments)

a. The RMD does not include reference to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements to maintain risk within the 1E-04 to 1E-06 risk upper bound excess lifetime cancer risk (ELCR). The following sections in the RMD reference the use of DOE Order 458.1 dose limits of 25 mrem/yr and 100 mrem/yr:

— Section 2.1, Analyses Supporting Action Prior to RI/FS, Page 2-10: The last paragraph in this section includes a dose assessment discussion which references the DOE Order 458.1, Radiation Protection of the Public and Environment Total Effective Dose limit of 25 millirem per year (mrem/yr)

— Appendix A, Screening Levels, Item G, Page A-5: Item G identifies the following dose-based radionuclide screening levels used in the RMD:

- 1 mrem/year (from NRCRP Report No. 116, Section 17, Negligible Individual Dose and ANSI/HPS standard N13.12)
- 12 mrem/year (from "Radiation Risk Assessment at CERCLA Sites: Q & A" OSWER No. 9200.4-40, June 13, 2014)
- 25 mrem/year (derived from the public dose limit of 100 mrem/year limit in DOE Order 458.1 and considering ALARA principles)
- 100 mrem/year (DOE Order 458.1)

In accordance with the National Contingency Plan (NCP) 40 CFR Section 300.430 and CERCLA, acceptable exposure levels are generally concentration levels that represent an ELCR to an individual of between l0E-04 and l0E-06 using information on the relationship between dose and response. In addition, a 10E-06 risk level should be used as the point of departure for determining remediation goals for alternatives when Applicable or Relevant and Appropriate Requirements (ARARs) are not available or are not sufficiently protective

because of the presence of multiple contaminants at a site or multiple pathways of exposure.

Since, according to the EPA guidance document OSWER No. 9285.6-20 and OSWER 9200.4-40 "Radiation Risk Assessment at CERCLA Sites: Q & A" dated June 13, 2014, a dose of 12 mrem/yr, equivalent to 3E-04 risk is a protective dose-based limit, use of screening levels such as 25 mrem/yr and 100 mrem/yr obtained from DOE Order 458.1 are not protective and therefore do not meet the statutory requirements of the NCP and CERCLA.

Section 2.1 of the RMD, Appendix A, and any other references to the use of the 25 mrem/yr and 100 mrem/yr dose limits in the RMD will require revision in the next update to the RMD to include a requirement to meet CERCLA requirements in all CERCLA evaluations, planning, and action decisions.

Appendix A information noted in the 2nd bullet, above, will be added to the footnote in Section 2.1.

Cleanup values are risk-based, not dose-based. The RMD needs to be completely clear that dose is not used for cleanup values, risk values are used for CERCLA cleanup. PGDP follows the FFA; therefore, a paragraph can be added to the Executive Summary citing the FFA.

EPA will look at specific additional language that may need to be added regarding cleanup goal calculations and send to LeAnne by December 1, 2017.
LeAnne will look into whether a footnote is needed regarding ROD cleanup goals in Section 4.

Negative values previously have been included in EPC calculations for radionuclides.

b. (See September 29, 2017 Meeting Minutes; Tim Frederick is following up on updated exposure factors.)

c. Specific Comment 1: **Section 3.3.3.2, Procedures to screen or evaluate data to determine COPCs, Step 2: Evaluation of Sampling and Analytical Methods, Pages 3-16, 3-17**: The first paragraph on this page states that data for non-radionuclides that are not generated using EPA-approved methods will not be used quantitatively, but may be used qualitatively. This section also states that methods for radionuclides will be evaluated during the data quality objective (DQO) process to ensure data quality requirements can be met; however, this section does not specify how radionuclide data which does not meet data quality requirements will be assessed or used *Please revise Section 3.3.3.2 accordingly to clarify the DQOs for radionuclides in the next update to the RMD.*

The group discussed use of radionuclide screening data (such as gamma walkover surveys) and that type data are used according to the agreed-upon and all agencies-approved work plans.

EPA will look at specific additional language that may need to be added for clarity regarding DQOs for radionuclides and send to LeAnne by December 1, 2017.

d. Specific Comment 2: **Section 3.3.3.2, Procedures to screen or evaluate data to determine COPCs, Step 3, Evaluation of Sample Quantitation Limits, Page 3-19**: This section does not appear to properly take into account the uncertainty inherent in the statistically-based accounting of radionuclide processes and analyses. For example, radionuclide data will have a counting uncertainty associated with the instrument's

detection of light or electrical pulses used to approximate the amount of radioactivity present; and a total propagated uncertainty associated with each result that accounts for the sample collection and preparation errors in addition to the counting error. As such, results are reported from the laboratory as a value, with a plus or minus error/uncertainty. As an example, a result of 3 picoCuries per gram (pCi/g) may have an uncertainty of +/- 1 pCi/g. The uncertainty value indicates the actual result may fall within a range of 2 pCi/g to 4 pCi/g at a certain level of confidence. In this case, if the Minimum Detectable Concentration (MDC) for this instrument is 2 pCi/g, there is uncertainty as to whether the reported result is actually a detection or not and therefore may impact the value included in the EPC calculation. It is recommended that the next update to the RMD address the reporting of the uncertainty associated with radionuclide data. *The RMD should clearly discuss how this uncertainty will be handled in the reporting and use of such data. Please also include an explanation of whether radionuclide results reported with an uncertainty that indicates the result could fall below the MDC will be· reported as detections or non-detects, or otherwise flagged in the data verification/validation and assessment process indicating the detected result is tentative.*

Regarding radionuclide reporting error/uncertainty, this uncertainty is not taken into account during the risk assessment. Data are validated and assessed according to contractor procedures. For newly generated data, quantitation limits generally are low enough that the radionuclide reporting error/uncertainty is not an issue. The quantitation limits will be defined in the quality assurance project plans.

A footnote will be developed from the italicized text above and added to the RMD to clearly discuss how radionuclides are handled in the DQOs.

e. Specific Comment 3: **Section 3.3.3.2, Procedures to screen or evaluate data to determine COPCs, Step 3, Evaluation of Sample Quantitation Limits, Page 3-19**: This section states "[F]or radionuclides, all reported values, including negative values, will be used to derive the EPCs [exposure point concentrations] under current conditions." A footnote associated with this statement indicates that the negative value may arise from the subtraction of the instrument background value. While it is true that the subtraction of the instrument background may result in a negative value, it is unclear why a negative value would not be considered a non-detect and why it is deemed appropriate to include a negative number in the EPC calculation which may bias the EPC low. It is requested that EPC calculations be performed without using negative values for radionuclides so as to avoid biasing the EPC result low. *Please incorporate this change in the next revision of the RMD.*

ProUCL accounts for negative radiological values (if nondetects) for certain statistical methods. ProUCL also recommends the EPC value, based on the appropriate statistical method.

Rich asked Nathan if he thought negative values should be used. Nathan felt that if the data were of sufficient quality, then the results should be used as reported, even if they are negative.

f. Specific Comment 4: **Section 3.3.3.2, Procedures to screen or evaluate data to determine COPCs, Step 4, Evaluation of Data Qualifiers and Codes, Page 3-19**: The text states evaluation of radionuclide data will follow rules agreed upon by the Commonwealth of Kentucky Radiation Health Branch [formerly the Kentucky Radiation Health and Toxic Agents Branch (KYRHTAB)] and DOE, and includes qualifiers for the following conditions:

— KYRHTAB-50: KYRHTAB has performed an independent data assessment and the radiation counting uncertainty is greater than 50% of the analytical results.
— KYRHTAB-ER: KYRHT AB has performed an independent data assessment and the data present error problems (i.e., no counting uncertainty or zero counting uncertainty).

The text in this section does not, however, specify how data with a counting uncertainty greater than 50% of the result, or for which a counting uncertainty is not reported or reported as '0' will be used in assessing the nature and extent of contamination and in risk assessments. *It is therefore requested that the data evaluation and associated rules specifying how such data will be used be specified in the next update to the RMD for the cases where an uncertainty greater than 50% is reported, or for which uncertainty is not available or reported as '0'.*

Radionuclide data were historically qualified to highlight data uncertainty.
To clarify this, a footnote will be added to the bullet regarding use of historical data in Section 3.3.7.1 in the RMD. The footnote will clarify that this uncertainty includes use of historical data with the above codes.

A follow-up RAWG may be needed to discuss EPA's suggested revisions. That meeting will be planned, based on RAWG member availability.

Paducah Risk Assessment Working Group
Meeting Summary—December 6, 2017

Stephanie Brock✓	Julie Corkran✓	Rich Bonczek✓
Nathan Garner✓	Jana Dawson✓	Martin Clauberg✓
Mike Guffey✓	Tim Frederick✓	LeAnne Garner ✓
Jeri Higginbotham✓		Bobette Nourse✓
Jerri Martin✓		

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

- EPA's Regional Screening Levels (RSLs) and the RSL calculator web-based interface have been updated. Several changes have been made to the on-line calculator to provide more functionality. https://www.epa.gov/risk/regional-screening-levels-rsls-whats-new-november-2017
  Toxicity values for these RSLs were updated based on updated ATSDR and PPRTV values, but no changes in IRIS toxicity values. The updated toxicity values did not include Paducah Site-significant COPCs.

- As a result of the October call, text has been added to the Executive Summary to help clarify that risk values (not dose) are used for CERCLA cleanup. The added text was extracted from the SMP and FFA. A footnote was added to update historical terminology from the FFA. It was agreed that the RAWG members will review and, as necessary, comment upon the inserted text and footnote in the draft HH Main Text RMD that will be sent out December 12, 2017.

2. Remaining FY 2018 Schedule/Work Plan

Quarterly Meeting (December)	12/6/2017
Submit revised HH Main Text and HH Appendix B, D, and E to RAWG for review	12/12/2017
Comments due for HH Appendix A	1/12/2018
RAWG Concur with HH Appendix A	2/13/2018
Comments due for HH Main Text and HH Appendix B. D, and E	2/13/2018
Quarterly Meeting (March)	3/7/2018
RAWG concur with HH Main Text and HH Appendix B, D, and E	4/10/2018
Submit Entire Revised HH RMD to RAWG for Review	4/17/2018
Comments due for entire revised HH RMD	5/15/2018
Quarterly Meeting (June)	6/6/2018
Submit HH RMD to FFA Managers (DOE/LX/07-0107&D2/R8/V1)	6/20/2018
FFA Managers acknowledge receipt of HH RMD	7/17/2018
Quarterly Meeting (September)	9/12/2018

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

3. Discussion for 2018 RMD Revision:

a. Include additional discussion on vapor intrusion (Section 3.3.4.4, Consideration of vapor intrusion).

More robust language is needed to describe what the projects should do, beyond referencing only guidance. Text will be added, based on EPA comments and/or EPA Region 4 Supplemental Guidance when it is available.

It was noted that based on the September 2017 RAWG Meeting, additional VOCs were added to Table E.8, "Human Health Information for the Paducah Vapor Intrusion Evaluation."

b. Add a reference for developing a site-specific dilution attenuation factor (DAF) (e.g., the Soil Screening Guidance).

   Groundwater Modeling Working Group (MWG) is scheduled to meet on December 13, 2017, to initiate development of a White Paper that will address the use of site-specific parameters in the determination of site-specific DAFs and site screening levels (SSLs). Once the MWG has finalized the White Paper, it will be added to Appendix E of the RMD.

   Meeting announcement will be sent to RAWG participants, as well as to the MWG.

c. Include provision for mutagenic toxicants.

   In the September meeting, it was discussed that a footnote be included with the equations in Appendix D for the 2018 RMD. After looking at the document, a table row for age-dependent adjustment factors has been added instead to Table B.4.

   A footnote also is being placed on site-specific COPCs in Table 2.1 to denote mutagens.

d. The EPA Region 4 Field Operating Guide for XRF was sent by Tim and forwarded to the RAWG on September 25, 2017.

   The XRF procedure from EPA indicates more readings are taken by XRF than typically are taken by a fixed-base lab. Multiple shots of the bags can give better reproducibility, but pure error also needs to be considered when collecting these values; a statistician should be consulted.
   LeAnne will compare FRNP's XRF procedure with EPA's.

   If XRF data is to be used for risk assessments, procedures need to be in place to ensure data is of sufficient quality for making decisions. Bobette will pass this information to the programmatic Quality Assurance Project Plan (pQAPP). The pQAPP includes information for collecting XRF data. Additionally, data quality objectives (DQOs) should be discussed when using XRF data.

e. EPA will look at specific additional language that may need to be added regarding cleanup goal calculations and send it as comments on minutes and/or main text to include language. (DOE clarified that this issue was in regard to rad dose assessment.)

f. Values that need to be updated in Table B.4 of the 2018 RMD include "Consumption of Homegrown Vegetables." Various combinations of fraction injected and daily consumption rate were discussed, including consideration of site-specific inputs from the McCracken County and Ballard County Agriculture Extension Offices. No decision was reached, and these values will not be changed in the draft RMD. These values, (the fraction ingested and the ingestion rate) need to be looked at and commented upon in the draft copy.

4. Watch Topics:

- New definitions for volatile organics are being used in RAIS. This needs to be watched to see if there are any impacts (especially for PCBs and PAHs).

- **Derivation of Risk-based Surface Water Effluent Limits**
  DOE noted that the Burial Grounds Operable Unit (BGOU) Solid Waste Management Units (SWMUs) 2, 3, 7, and 30 FS formal dispute ended and a Memorandum of Agreement (MOA) was signed. The MOA does not provide specific guidance on surface water effluent limit derivation. DOE also noted that discussions concerning effluent limits are ongoing among EPA Region 4 and DOE Oak Ridge Operations, and EPA and DOE headquarters.
  EPA stated that the MOA provides specific language for determining effluent limits.
  Effluent limits may be included in the Risk Methods Document; EPA will propose language to be included in their comments to the Risk Methods Document and these minutes.
  Following the meeting, EPA provided the following:
  1) EPA Action Item: Establishment of Surface Water Effluent Limits, attached to these minutes.
  2) 2017 05 BGOU 2 3 7 30 D2 FS DRC MOA, available at the following location: http://paducaheic.com/Search.aspx?accession=ENV 1.A-01377.
  3) 2017 02 WDA Rad Effluent PPPO-02-4036918-17, available at the following location: http://paducaheic.com/Search.aspx?accession=ENV 1.A-01301.

- **Status of EPA's Policy for Lead in Blood**
  EPA has Lead in Blood guidance that states not to use 10 µg/dl. New guidance does not suggest new value. Where lead is a driver, risk from lead will need to be addressed.
  New screening levels may be lower than what they currently are (i.e., lower than 400 mg/kg for the resident). Screening value should be footnoted to look for updated changes. Additionally, a new IEUBK will be coming out over the course of this RMD revision. The new IEUBK also should be footnoted in RMD 2018.

  Tim previously shared sieving guidance; projects also need to keep this in mind.

5. Poll RAWG Members/Open Discussion

Exposure area text in regard to the recreational user exposure pathways has been added to the RMD. Please see Section 3.3.4.2 of draft document and comment on added text.

Risk Methods Work Group Call 12 06 2017 (Contact: J. Corkran 404-562-8547, EPA R4/12 06 2017)

Rich and Brian: I am responding to the group regarding the EPA action item noted below. After review of the HHRMD, I believe that the parties need only reach agreement on an elimination, or revision, of bullet 2 under Task 4 - Watch Topics. Let me know what you think. Thanks, Julie

HH RMD - 2016-2017.....EPA Action Item: Establishment of Surface Water Effluent Limits -

(i) representation in the HH RMD and
(ii) the RMD Work Group "Item 4 - Watch Topics"

given SEC Formal Dispute Resolution for the potential future CERCLA Cell (Memorandum of Agreement effective date 02-03 2017) and the DRC BGOU SWMUs 2/3/7/30 FS Formal Dispute Resolution (Memorandum of Agreement Effective Date 05-16-2017) regarding tri-party expectations for establishment of radiological effluent discharge limits to surface water at the PGPD Superfund Site.

(i) representation in the HH RMD
Search term: effluent

Pg 26/244: The surface water screening values selected are a location-specific decision. For all areas along effluent ditches or along creeks carrying effluent, the industrial worker screening values are appropriate.

Pg 44/244: Environmental Radiological Effluent Monitoring and Environmental Surveillance, DOE-HDBK-1216-2015 (DOE 2015b)

Pg 92/244: DOE 2015b. Environmental Radiological Effluent Monitoring and Environmental Surveillance, DOE-HDBK-1216-2015, U.S. Department of Energy, Washington, DC.

Pg 170/244: Table B.1. Footnote 3. The surface water screening values selected are a location-specific decision. For all areas along effluent ditches or along creeks carrying
effluent, the industrial worker screening values are appropriate. Additionally, at areas outside the industrialized areas, use of the recreator values are appropriate, etc.

Search term: discharge

No matches were found.

Conclusion: The 2016-2017 HH RMD does not address the establishment of radionuclide effluent limits for discharges of treated water to surface water.

Extended Conclusion: No action is necessary at this time to amend the HH RMD to reflect the outcomes of the two MOAs discussed below unless agreement cannot be reached on item (ii), below, regarding the Watch Topic entry - Bullet 2.

Note: I also looked quickly at the ECO RMD (2015, which seems to be the last update on the FFS Paducah document library web page). Industrial discharge language was noted, so there may be a need to look more closely at the Eco RMD. What is the schedule for the next update? Let's discuss.

(ii) **the RMD Work Group "Item 4 - Watch Topics" 2nd bullet entry** (L. Garner - Paducah Risk Assessment Working Group Proposed Agenda—December 6, 2017, as discussed on 12/6/2017) reads as follows:

"Derivation of Risk-based Surface Water Effluent Limits
Burial Grounds Operable Unit Solid Waste Management Units 2, 3, 7, and 30 FS and Waste Disposal Alternative RI/FS has been in formal dispute. There has been an update to this status. Oak Ridge is working with EPA Region 4 to determine limits. This is still being worked."

The PGDP radionuclide effluent discharge limit formal dispute was resolved for the Waste Disposal Alternatives RI/FS (February 2017) and the BGOU SWMUS 2/3/7/30 (May 2017) many months ago and are enforceable modifications to the PGDP Federal Facility Agreement (FFA). The resolution contemplates both risk-based and technology-based approaches: the MOAs are provided as Attachments to this Action Item response for purpose of reference.

Regardless of any dispute or set of disputes that may be ongoing or contemplated for any DOE-ORR FFA project (*"Oak Ridge is working with EPA Region 4 to determine limits"*), CERCLA remedy selection and risk management decisions are project specific. The DOE-PGDP proposal to bring a future formal dispute resolution between DOE-TDEC-EPA to the PGDP risk methods work group for discussion is not supported: neither a DOE ORR-TDEC-EPA agreement nor the PGDP risk methods work group, has the authority to override the DOE PGDP-KDEP-EPA MOA enforceable modifications to the FFA for the PGDP cleanup. (The author notes that the risk methods work group attempted in 2015 to provide a *recommendation* to the FFA Managers and Tri-Party Senior Managers in support of resolving the WDA Formal Dispute rad effluent discharge limit dispute, and was not successful at that time.)

Conclusion: The Watch Topic Bullet 2 entry as currently written is factually incorrect and incomplete (re: formal dispute MOAs) and represents a path forward contemplated only by DOE (ORR resolution will be applied to PGDP and, further, will be applied by the PGDP risk methods work group).

Extended Conclusion: Allowing this entry in the DOE PGPD record to stand as written is inconsistent with the PGDP FFA.

Recommendation Options for discusson:

(i) Redline the entirety of Bullet 2. Add a statement that the parties have agreed to eliminate the bullet since the stated issue has been resolved through PGDP Formal Dispute Resolution MOAs for WDA RI/FS (February 2017) and BGOU SWMUs 2/3/7/30 RI/FS (May 2017). Add a statement that neither the WDA or BGOU is scheduled to move forward between now and 2027; however, the risk methods work group may be asked in the future to provide recommendations to the FFA Managers regarding effluent discharge limits for radionuclides and other hazardous substances for other PGDP FFA projects.

(ii) KDEP recommended option...

(iii) DOE recommended option...

Attachments (2)

1. 2017 02 WDA Rad Effluent PPPO-02-4036918-17
2. 2017 05 BGOU 2 3 7 30 D2 FS DRC MOA

ATTACHMENT E1

1995 QUESTIONAIRE 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

94355L05.doc

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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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.

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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.

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