APPENDIX E

ADDITIONAL INFORMATION

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CONTENTS

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-238, 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 2013 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 December 2013.

- 8,333 population (as of 2012)
- 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 December 2013.

- 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: 39814 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 2013 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 December 2013.

- 65,549 population (as of 2012)

- 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 December 2013.

- 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: 9160 harvested acres

- All wheat for grain: 3899 harvested acres
- Soybeans for beans: 37579 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, published in June 2009. The information is available at the following Web sites, accessed December 12, 2013:

- http://www.nass.usda.gov/Statistics_by_State/Kentucky/Publications/State_Census_Summaries/Historical_Ag_Statistics/BALLARD.pdf
- http://www.nass.usda.gov/Statistics_by_State/Kentucky/Publications/State_Census_Summaries/Historical_Ag_Statistics/MCCRACKEN.pdf

	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

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 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 Risk Assessment Working Group 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.

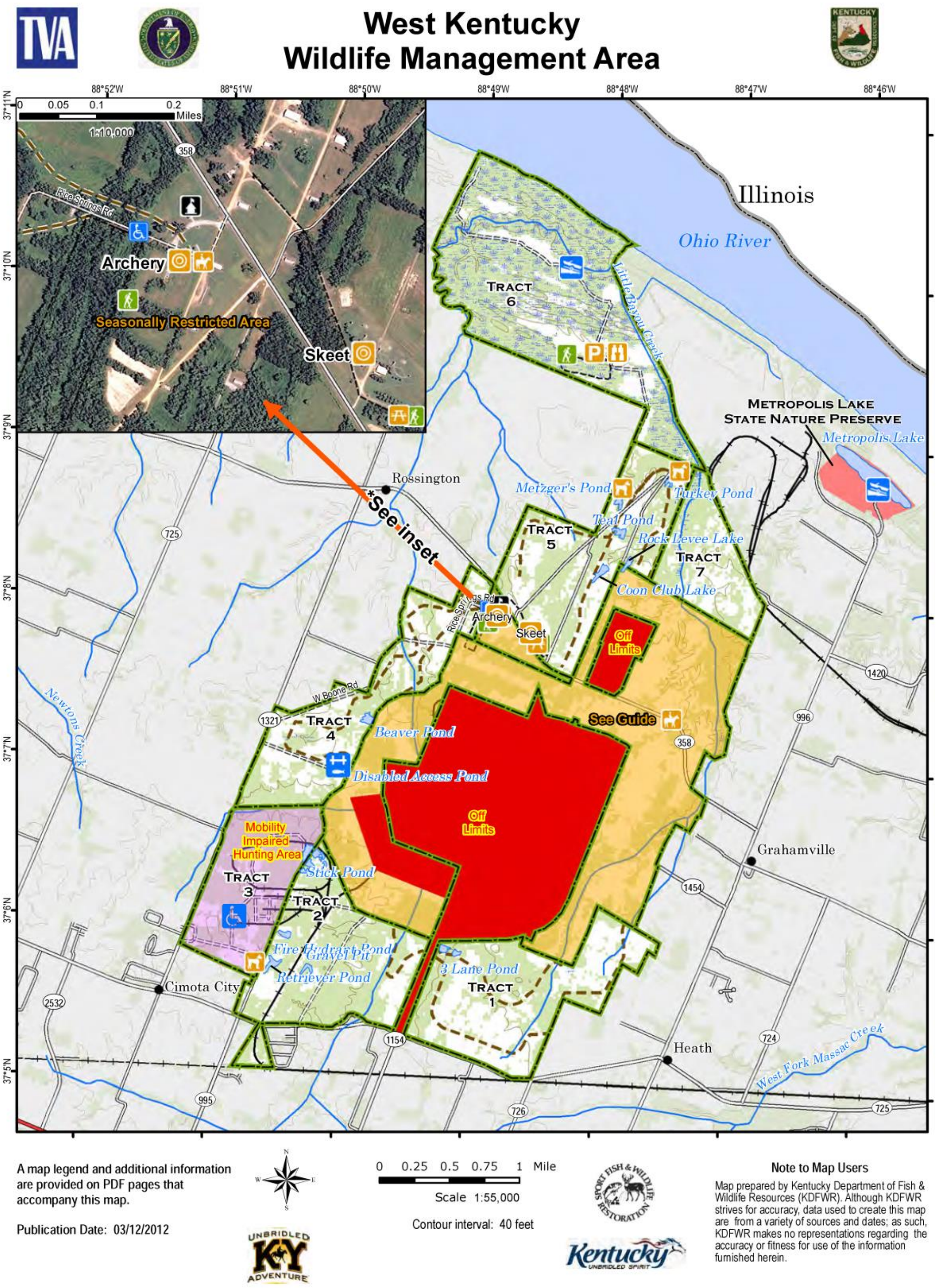
8. Is there a harvestable fish population in Little Bayou? If there is. is there enough to support subsistence fishing (i .e., 0.284 kilograms of meat flesh/meal) for one person to eat 128 meals a year? If not, how much fish, and how often could a person best expect to harvest a meal for consumption?

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, DEER, GEESE, AND DUCKS IN MCCRACKEN AND BALLARD COUNTIES, KENTUCKY

PGDP is surrounded by the WKWMA (Figure E.1). Additionally, several solid waste management units (SWMUs) (currently listed as no further action) are located in the Ballard Wildlife Management Area (Figure E.2). Figure E.3 provides a legend for features in the wildlife management areas. 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.4 and Table E.2 and Figure E.5 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 Wildlife Management Area during the 2010/2011 and 2011/2012 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 2013.



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

Publication Date: 03/12/2012

Note to Map Users

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

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

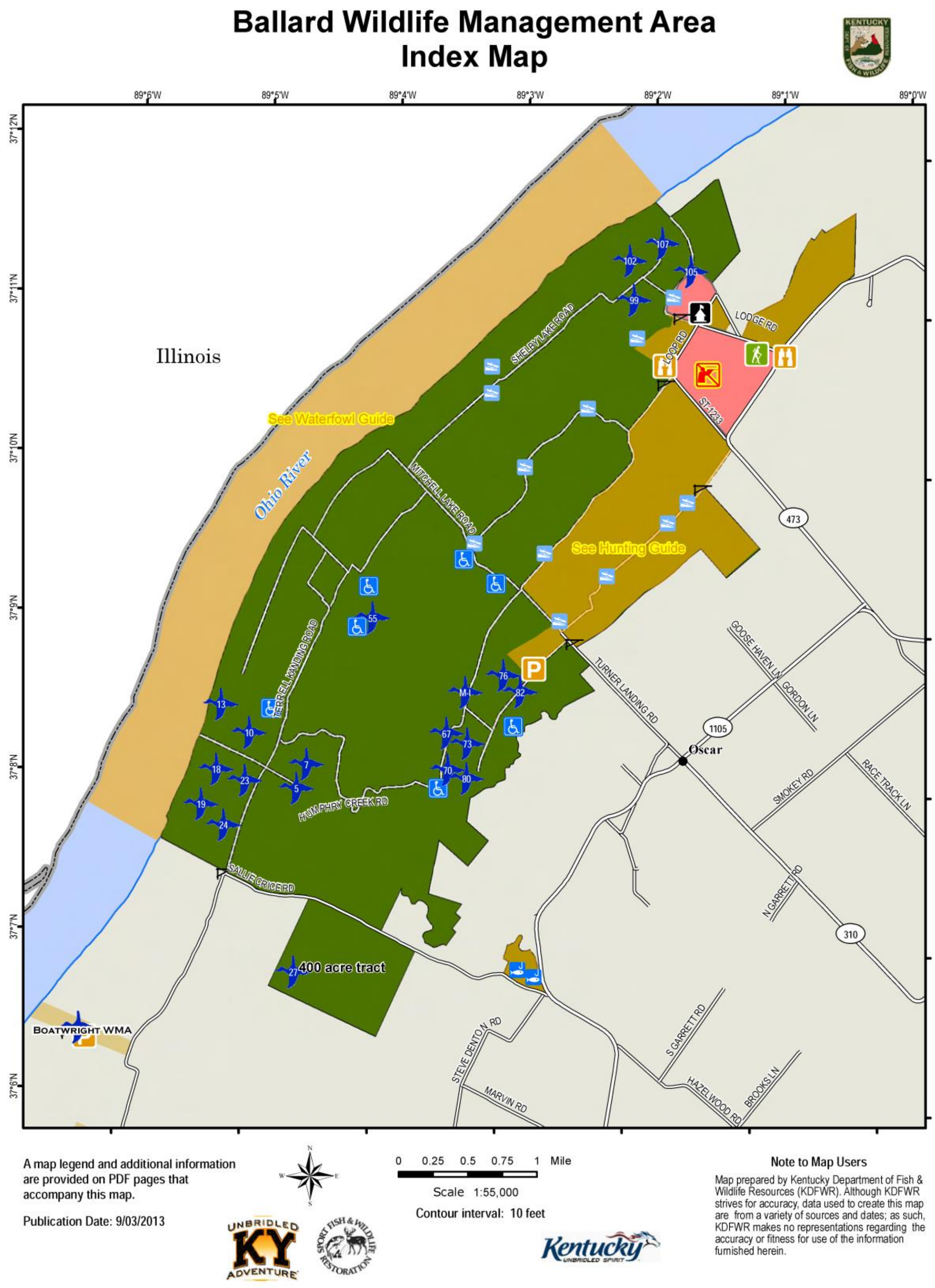


Figure E.2. Map of Ballard Wildlife Management Area

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 Blind
- Trailhead
- Horseback Trailhead
- P Parking Lot
- Picnic Area
- Restrooms
- Wildlife Viewing Site
- Interpretive Site
- Retriever Training Site
- Gate
- Campground
- Cemetery
- Corps of Engineers Office
- Waterfowl Blind
- Shooting Range
- Established Bank Access
- Fishing Pier
- Carrydown Launch
- Small Boat Ramp
- Large Boat Ramp
- State Park Office

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

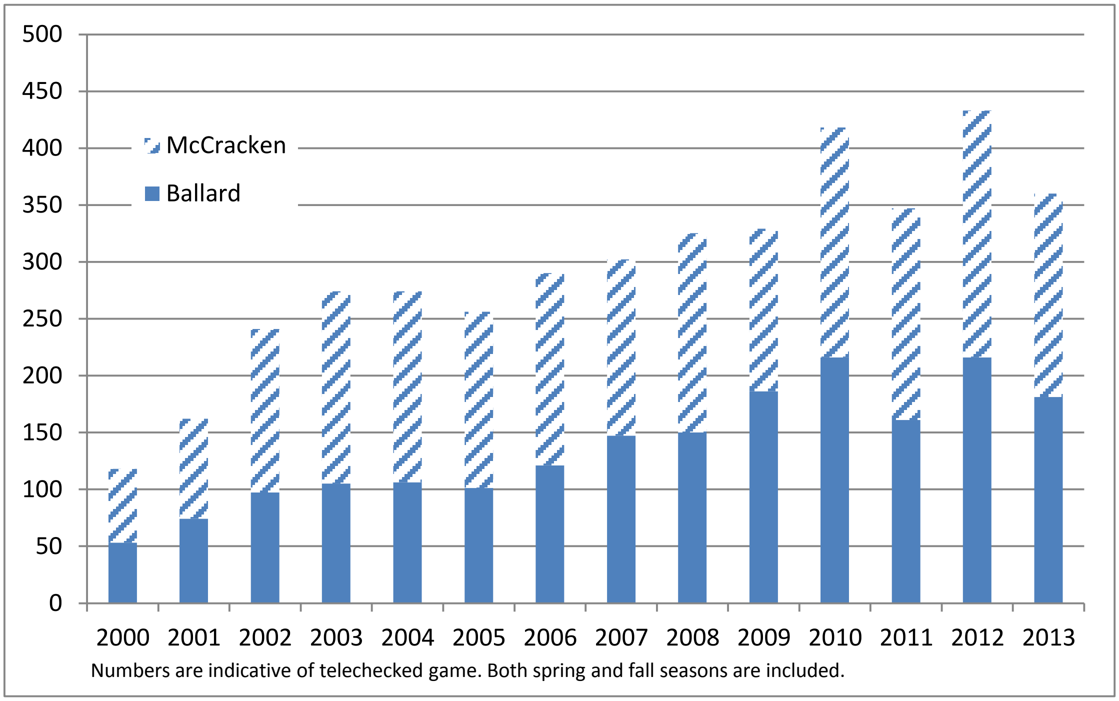
- ● Populated Place
- Kentucky Boundary
- 75 Interstate Highway
- Kentucky Parkway
- 60 U.S. Highway
- 169 State Highway
- Named Road Local Road
- 4596 Forest Service Road
- Active Railroad
- Abandoned Railroad
- Federal Recreation Trail
- WMA Road
- WMA Foot Trail
- WMA Horse Trail
- Gas Pipeline
-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

Figure E.3. Wildlife Management Area Map Legend

Table E.1 Turkey Harvested on Public Land in Western Kentucky in 2013[a]

Public Land	Male	Female	Total	Archery	Firearm	Muzzleloader	Crossbow
Ballard WMA	15	0	15	0	15	0	0
Beechy Creek WMA	2	0	2	0	2	0	0
Boatwright WMA	2	0	2	0	2	0	0
Clarks River NWR	19	2	21	0	20	1	0
Coil Estate WMA	3	0	3	0	3	0	0
Doug Travis WMA	9	0	9	0	9	0	0
Jones-Keeney WMA	2	0	2	0	2	0	0
Kaler Bottoms WMA	3	0	3	0	3	0	0
Kentucky Lake WMA	4	0	4	1	2	1	0
Lake Barkley WMA	16	0	16	1	15	0	0
Land Between The Lakes NRA	56	2	58	3	55	0	0
Livingston County WMA and SNA	2	1	3	0	3	0	0
Obion Creek WMA	1	0	1	0	1	0	0
Ohio River Islands WMA	0	0	0	0	0	0	0
Pennyrile State Forest	31	1	32	0	32	0	0
Reelfoot NWR	3	0	3	0	3	0	0
Tradewater WMA	2	0	2	0	2	0	0
West Kentucky WMA	18	2	20	2	18	0	0
Winford WMA	0	0	0	0	0	0	0
Totals	188	8	196	7	187	2	0

[a] Numbers are indicative of telechecked game (http://app.fw.ky.gov/harvestweb/TurkeyPublicLandRegion.aspx accessed 5/23/2014). Both spring and fall hunting seasons are included.



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

Figure E.4. Total Turkey Harvest in Ballard and McCracken Counties 2000–2013

Table E.2 Deer Harvested on Public Land in Western Kentucky in 2013[a]

Public Land	Male	Female	Quota	Total	Archery	Firearm	Muzzleloader	Crossbow
Ballard WMA	21	30	35[b]	86	16	30	5	0
Beechy Creek WMA	6	11	not available	17	3	11	3	0
Boatwright WMA	24	36	not available	60	7	43	8	2
Clarks River NWR	62	65	not available	127	16	105	5	1
Coil Estate WMA	1	1	not available	2	0	1	1	0
Doug Travis WMA	18	17	not available	35	3	26	6	0
Jones-Keeney WMA	7	4	not available	11	1	7	3	0
Kaler Bottoms WMA	19	17	not available	36	7	29	0	0
Kentucky Lake WMA	27	23	not available	50	4	39	4	3
Lake Barkley WMA	41	39	not available	80	21	57	1	1
Land Between The Lakes NRA	129	102	not available	231	183	27	4	17
Livingston County WMA and SNA	30	21	not available	51	7	7	37	0
Obion Creek WMA	24	16	not available	40	4	36	0	0
Ohio River Islands WMA	3	0	not available	3	0	3	0	0
Pennyrile State Forest	23	22	not available	45	26	15	0	4
Reelfoot NWR	0	0	not available	0	0	0	0	0
Tradewater WMA	3	2	not available	5	2	1	2	0
West Kentucky WMA	18	28	28[b]	74	36	2	0	8
Winford WMA	4	3	not available	7	2	3	2	0
Totals	**460**	**437**	**63[b]**	**897**	**338**	**442**	**81**	**36**

[a] Numbers are indicative of telechecked game (http://app.fw.ky.gov/harvestweb/deerpubliclandregion.aspx accessed 5/23/2014).

[b] Quota deer hunt numbers from Kentucky Department of Fish and Wildlife Resources (KDWFR) 5/23/2014.

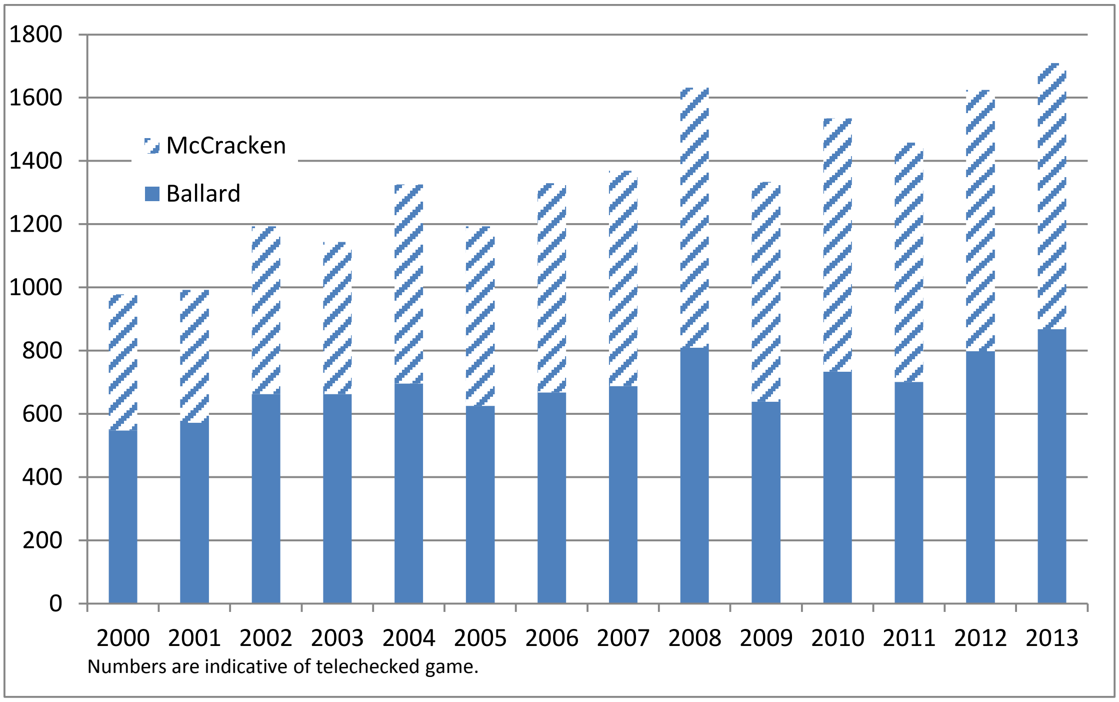


Figure E.5. Total Deer Harvest in Ballard and McCracken Counties 2000–2013

Table E.3 Waterfowl Counts in Ballard Wildlife Management Area

Date	Population Count		Harvest		
	Ducks	Geese	Ducks	Canadas	Other
12/8/2010	57,000	3000	34	0	0
12/9/2010	57,000	3000	19	0	0
12/10/2010	57,000	3000	36	0	0
12/11/2010	57,000	3000	139	1	0
12/12/2010	57,000	3000	172	4	0
12/15/2010	57,000	3000	67	0	0
12/16/2010	57,000	3000	105	1	0
12/17/2010	57,000	3000	33	0	0
12/18/2010	107,700	4800	31	3	1
12/19/2010	107,700	4800	23	5	2
12/22/2010	107,700	4800	96	2	1
12/23/2010	107,700	4800	68		0
12/24/2010	107,700	4800	63	3	1
12/25/2010	NA	NA	NA	NA	NA
12/26/2010	54,000	14000	234	5	16
12/29/2010	54,000	14,000	68	0	3
12/30/2010	54,000	14,000	71	0	1
12/31/2010	54,000	14,000	49	1	0
1/1/2011	58,000	52,000			
1/2/2011	58,000	52,000	54	7	3
1/5/2011	58,000	52,000	88	5	53
1/6/2011	58,000	52,000	62	4	2
1/7/2011	58,000	52,000	32	3	4
1/8/2011	58,000	52,000	75	3	3
1/9/2011	81,000	11,000	19	1	3
1/12/2011	81,000	11,000	46	2	20
1/13/2011	81,000	11,000	4	0	0
1/14/2011	81,000	11,000	11	4	12
1/15/2011	81,000	11,000	16	0	2
1/16/2011	58,000	12,500	13	0	0
1/19/2011	58,000	12,500	97	0	10
1/20/2011	58,000	12,500	112	2	9
1/21/2011	58,000	12,500	14	0	2
1/22/2011	58,000	12,500	34	1	5
1/23/2011	65,155	3,105	32	3	0
1/26/2011	65,155	3105	122	4	5
1/27/2011	65,155	3105	108	2	4
1/28/2011	65,155	3105	98	0	1
1/29/2011	65,155	3105	88	4	3
1/30/2011	44,500	3,000	113	2	10

Date	Population Count		Harvest		
	Ducks	Geese	Ducks	Canadas	Other
12/7/2011	21,000	100	Ballard closed due to flooding		
12/8/2011	21,000	100	Ballard closed due to flooding		
12/9/2011	21,000	100	Ballard closed due to flooding		
12/10/2011	21,000	100	Ballard closed due to flooding		
12/11/2011	21,000	100	Ballard closed due to flooding		
12/14/2011	16,000	100	Ballard closed due to flooding		
12/15/2011	16,000	100	Ballard closed due to flooding		
12/16/2011	16,000	100	Ballard closed due to flooding		
12/17/2011	16,000	100	Ballard closed due to flooding		
12/18/2011	16,000	100	Ballard closed due to flooding		
12/21/2011	52,000	1,000	112	0	0
12/22/2011	52,000	1,000	72	0	0
12/23/2011	52,000	1,000	56	0	0
12/24/2011	52,000	1,000	56	0	0
12/25/2011	52,000	1,000	Ballard closed for Christmas		
12/28/2011	20,000	500	58	0	0
12/29/2011	20,000	500	38	0	1
12/29/2011	43,000	200	44	0	0
12/30/2011	23,000	500	59	0	0
12/31/2011	23,000	5,000	20	0	0
1/1/2012	Closed		Closed		
1/4/2012	23,000	100	58	0	1
1/5/2012	23,000	100	32	0	0
1/6/2012	23,000	100	7	0	0
1/7/2012	32,000	200	33	0	0
1/8/2012	32,000	200	8	0	1
1/11/2012	32,000	100	77	0	3
1/12/2012	32,000	100	123	0	2
1/13/2012	32,000	100	26	1	2
1/14/2012	79,000	300	31	2	3
1/15/2012	79,000	300	10	0	1
1/18/2012	79,000	1,000	81	1	3
1/19/2012	79,000	1,000	52	0	0
1/20/2012	79,000	1,000	47	0	1
1/21/2012	79,000	1,000	65	0	0
1/22/2012	41,000	500	59	0	2
1/25/2012	41,000	500	78	0	1
1/26/2012	41,000	500	71	0	3
1/27/2012	41,000	500	50	0	1
1/28/2012	43,000	200	75	0	1

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

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

PLANNING ISSUES FOR SUPERFUND SITE REMEDIATION

Randall T. Ryti
Dean Neptune

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

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

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

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

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

Site history

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

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

Phase 1

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

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

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

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

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

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

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

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

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

The main goal of Phase 1 is to define the list of COCs for the site and estimate the risk posed to the public. To address these goals, some information on the spatial distribution of the contaminants must be collected. Based on the historical use of the site and aerial photos, the site was divided into three areas: administration, operations and storage; PCB contamination was expected to be lowest in administration, intermediate in storage, and highest in operations. This stratification should lead to a more precise estimate of the average PCB concentration on the site. The lis COCs was confirmed on a subse 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 e positive or false negative errors. e positive is where the actual risk posed by the site is *less than* 1 in 1,000,000 addi-

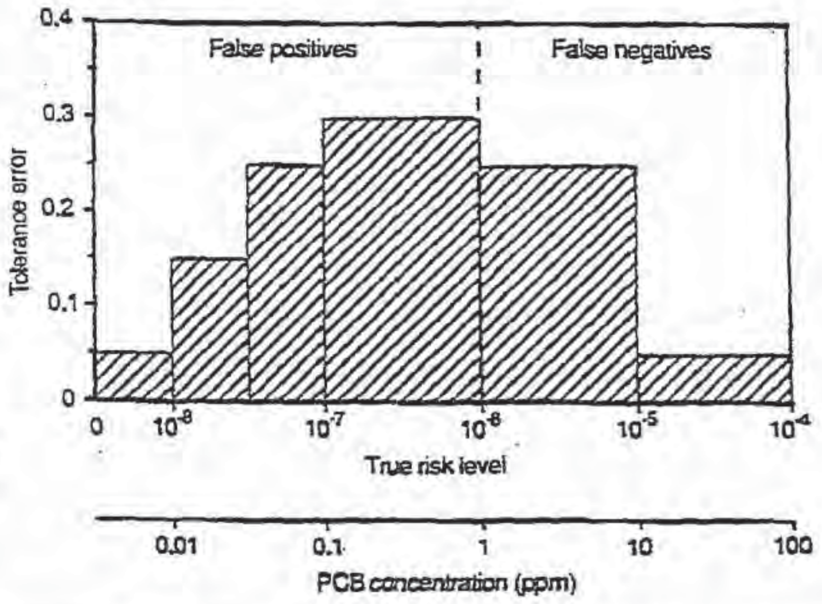
TABLE 1

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.

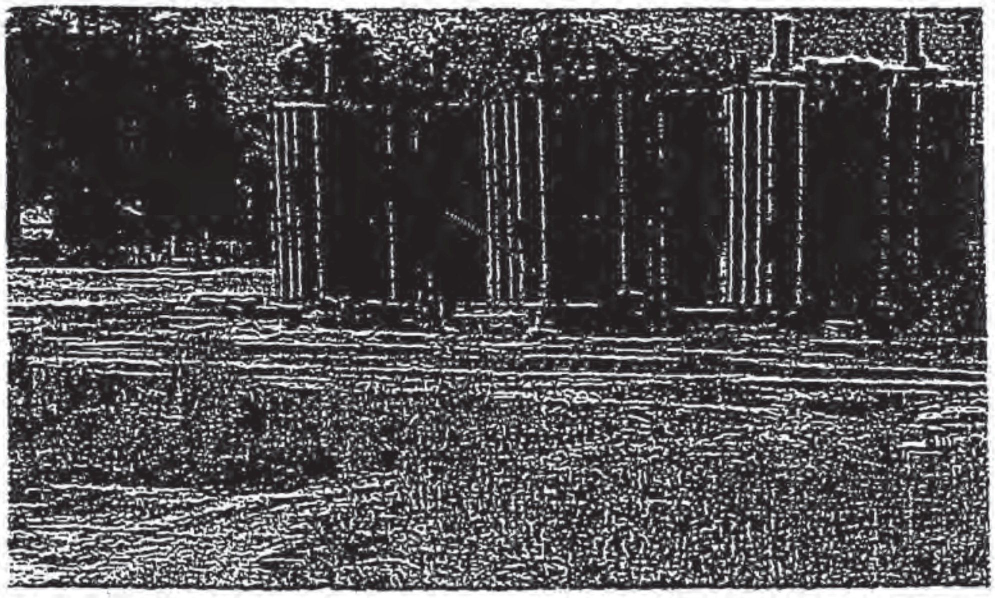
TABLE 2
Results of the pilot survey

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

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

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

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



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 surfac 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 outlie

Discussion

The goal of Superfund program is to

remediate sites that pose an unacceptable health hazard. Because resources nited, 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 esate the volume of soil that was contaminated. In this way they could balance the importance of these main questions in the Phase 2 survey.

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

Conclusions

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

TABLE 3

Results of Phase 2 survey

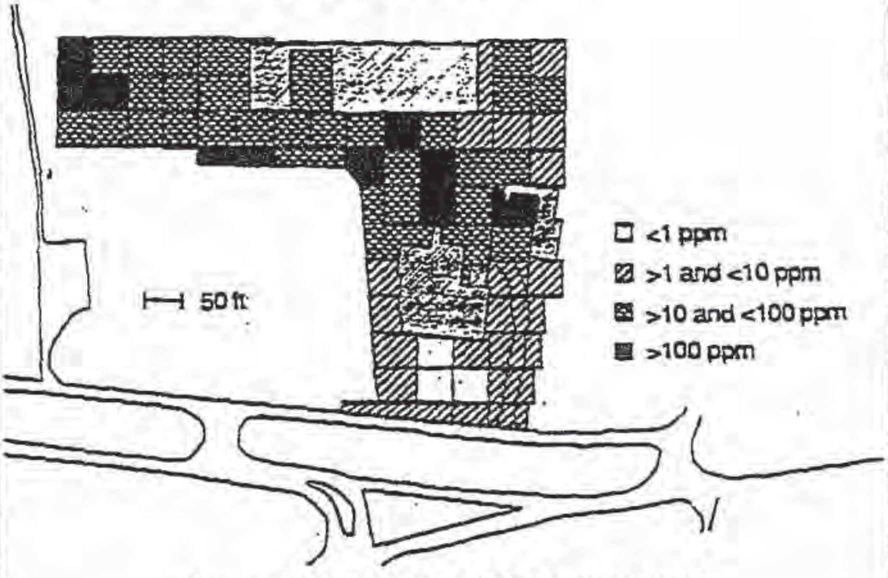
		Range		Number of RUs	
Soil layer	Median	low	high	<1 ppm	<10 ppm
0–2"[1]	21	0.4	2500	3	21
8–10"[2]	7.25	0.2	1100	18	36

[1] n=62

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

FIGURE 2

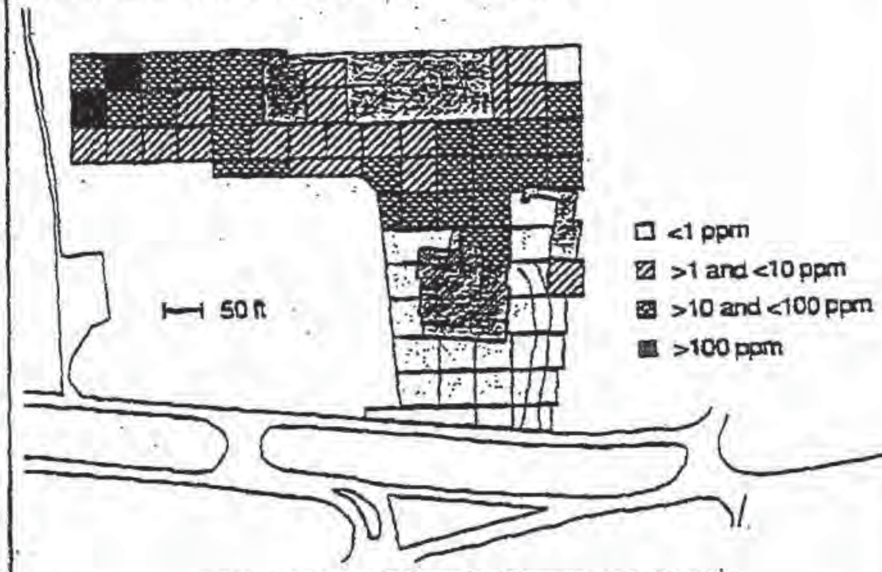
PCB concentrations in 0–2 in. soil layer



Hatched areas represent buildings or concrete pads

FIGURE 3

PCB concentrations in 8–10 in. soil layer



Hatched areas indicate buildings or concrete pads

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TABLE 4

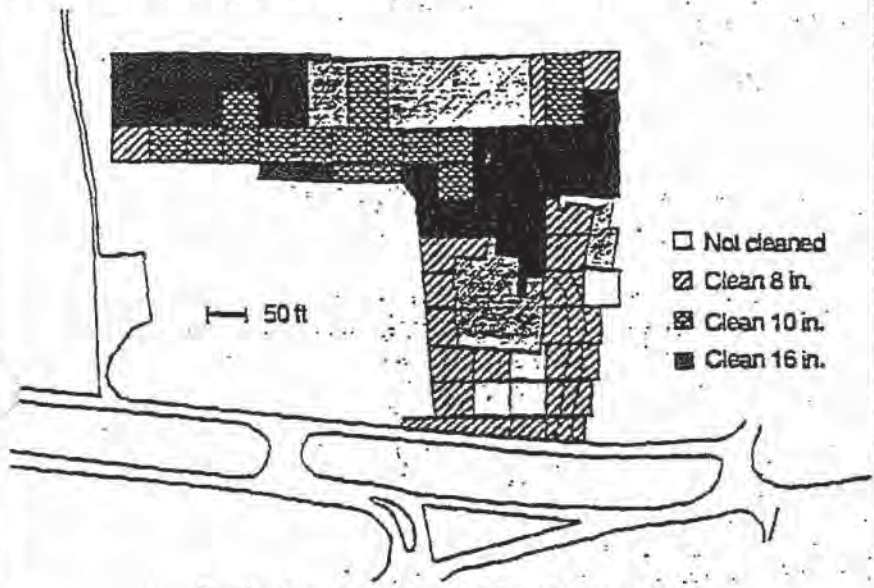
mmary of cleanup strategy

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

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Quantitative Decision Making in Superfund:

A Data Quality Objectives CASE STUDY

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

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

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

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

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

Problem statement

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

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

Decisions and decision elements

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

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

Domain and logic statement

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

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

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

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

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

Data quality objectives

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

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

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

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

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

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

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

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

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

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

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

Constraints on uncertainty

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

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

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

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

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

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

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

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

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

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

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

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

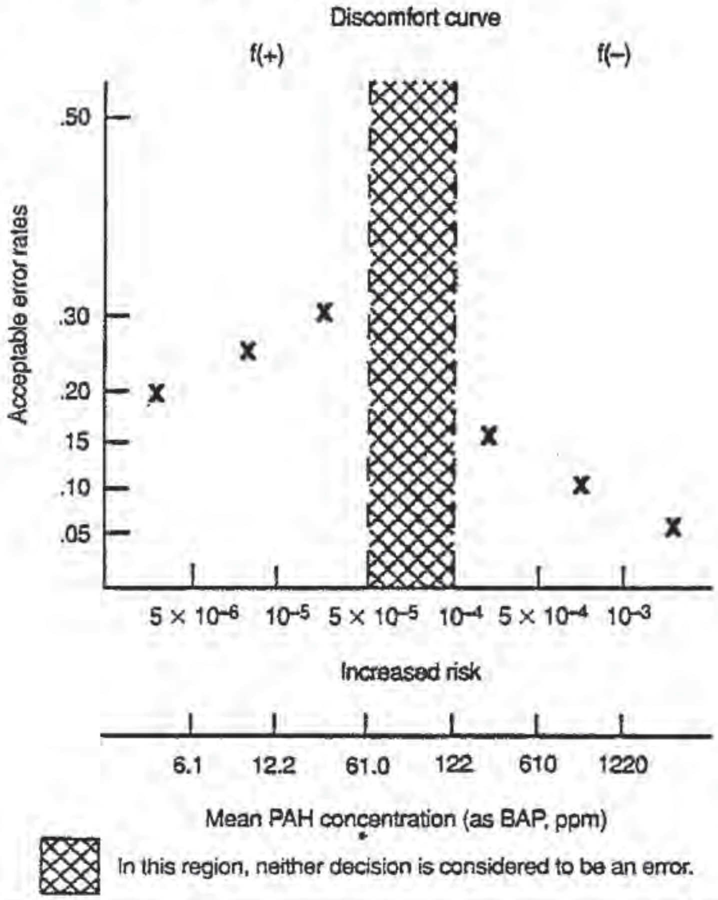
Design and optimization

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

One concern the statistician noted was

FIGURE 1

Acceptable limits for decision error



DQOs for case study

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

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

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

Uncertainty constraints

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

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

Workers collect soil samples at the Superfund site

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

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

Since prior data on average PAHs across half-acre units were not available, the statistician used prior data from ran-

FIGURE 2

Frequency distribution of soil PAH concentrations

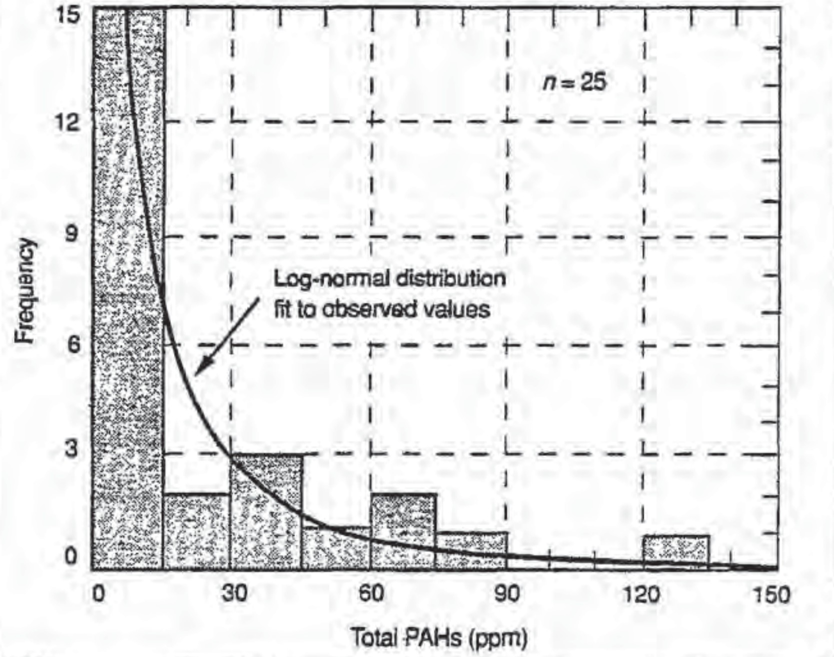


TABLE 1

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.

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 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

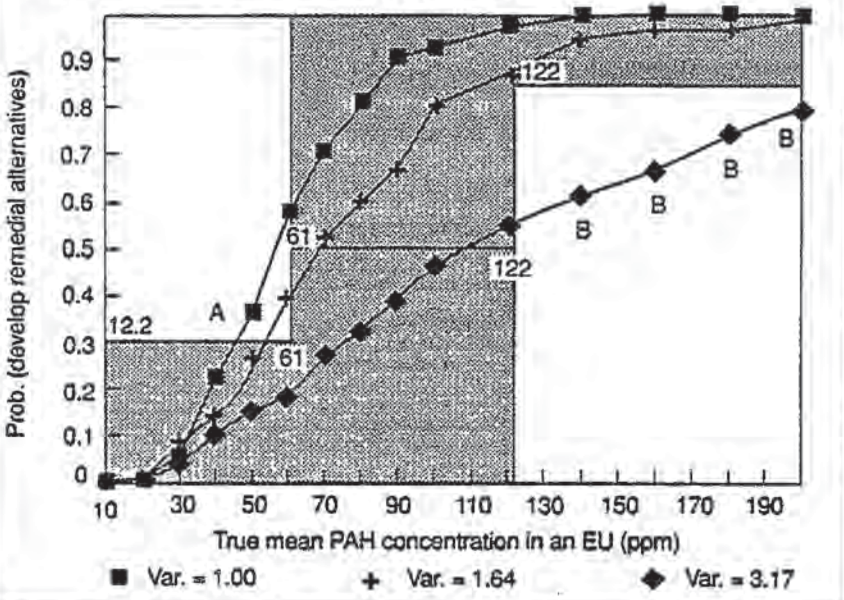
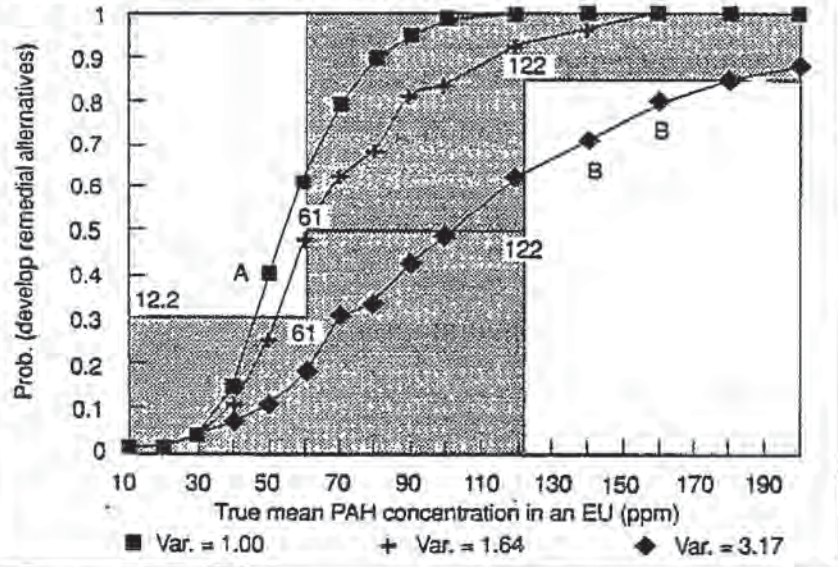


FIGURE 4

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

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

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

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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

The following copies of regulatory guidance are presented in this chapter.

- Kentucky Risk Assessment Guidance, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, June 8, 2002.

- Kentucky Guidance for Ambient Background Assessment, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, January 8, 2004.

- Kentucky Guidance for Groundwater Assessment Screening, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, January 15 2004.

- Trichloroethylene Environmental Levels of Concern, Risk Assessment Branch, Department of Environmental Protection, Commonwealth of Kentucky, April 2004.

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Kentucky Risk Assessment Guidance

June 8, 2002

Natural Resources and
Environmental Protection Cabinet

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Section 1. Introduction

Risk assessment is a formalized process for evaluating the potential human health and ecological impacts based on the concentration of, exposure to, and toxicity of environmental contaminants. Risk assessment has been used in environmental decision-making since the process was outlined in a publication by the National Research Council – National Academy of Sciences (1983) Red Book. The United States Environmental Protection Agency (U.S. EPA) produced several guidance documents to assist in assessing risks (U.S. EPA, 1989; 1991).

Human health risk assessment, as outlined, is a four-part process. The first step, Data Collection and Evaluation, assesses the available data and identifies chemicals of potential concern (COPCs). The next part, Exposure Assessment, identifies potential receptors and calculates their exposure to the COPCs. Toxicity Assessment, the third process, quantifies the toxicity of the COPCs for carcinogenic and noncarcinogenic effects. The final step, Risk Characterization, is the calculation of the potential effects on the receptors identified in the Exposure Assessment, based on the toxicity of the chemicals identified in the Data Collection and Evaluation step.

Risk assessment procedures are used in several stages of site assessment and closure. During site scoping Preliminary Remediation Goals may be used to determine preferred detection limits and to screen initial data to focus on areas of concern. Data from Site Characterization are often screened against target risk-based concentrations (Preliminary Remediation Goals) to identify whether a baseline risk assessment or further evaluation is needed and, if so, which chemicals should be further assessed. Risk assessment is also used in setting remedial goals, and as an exit criterion for closure of remediation activities. Risk assessment is used as part of activities related to the Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Clean Water Act, and Clean Air Act.

This document details the application of risk assessment to environmental remediation. The document can be used to determine if site conditions are protective of human health and the environment, or that risks are reduced to acceptable levels through removal of contaminants or management. The risk-based procedures for the program are based on a tiered approach allowing for screening against default risk-based screening values in lower tiers and incorporating more site-related data in the higher tiers.

This document outlines the procedures for:

1. Comparing site data against risk-based screening values.
2. Preparing a baseline risk assessment to determine protectiveness of human health and the environment.
3. Evaluating when an ecological assessment is necessary
4. Evaluating when to compare site soil data to Soil Screening Levels for protection of groundwater.
5. Selecting remedial cleanup goals.

The following sections describe the process of evaluating the site data that were collected during the site characterization. The data must be representative and complete. If statistical procedures are used, a sufficient number of samples should be collected to meet the needs of those statistical tests. Human health risk assessment is described in Section 2.0. The subsections within Section 2.0 describe the application of risk assessment to the processes of environmental assessment and remediation including: tiered risk assessment, groundwater evaluation, risk management, selection of remedial goals, and presenting the results of the two tiers of risk assessment. Section 3.0 details the ecological risk assessment procedures.

Section 2. Human Health Risk Assessment

This section provides methods for screening environmental data to identify Contaminants of Concern, performing screening and baseline risk assessment, evaluating groundwater, managing risks, and selecting remedial goals. Figures 1 and 2 outline the process for risk-based procedures for residential and commercial/industrial scenarios in environmental remediation. The remedial options listed in Figures 1 and 2 are those listed in KRS 224.01-400 (18)-(21).

Figure 1. Flowchart for Residential Cleanup Options

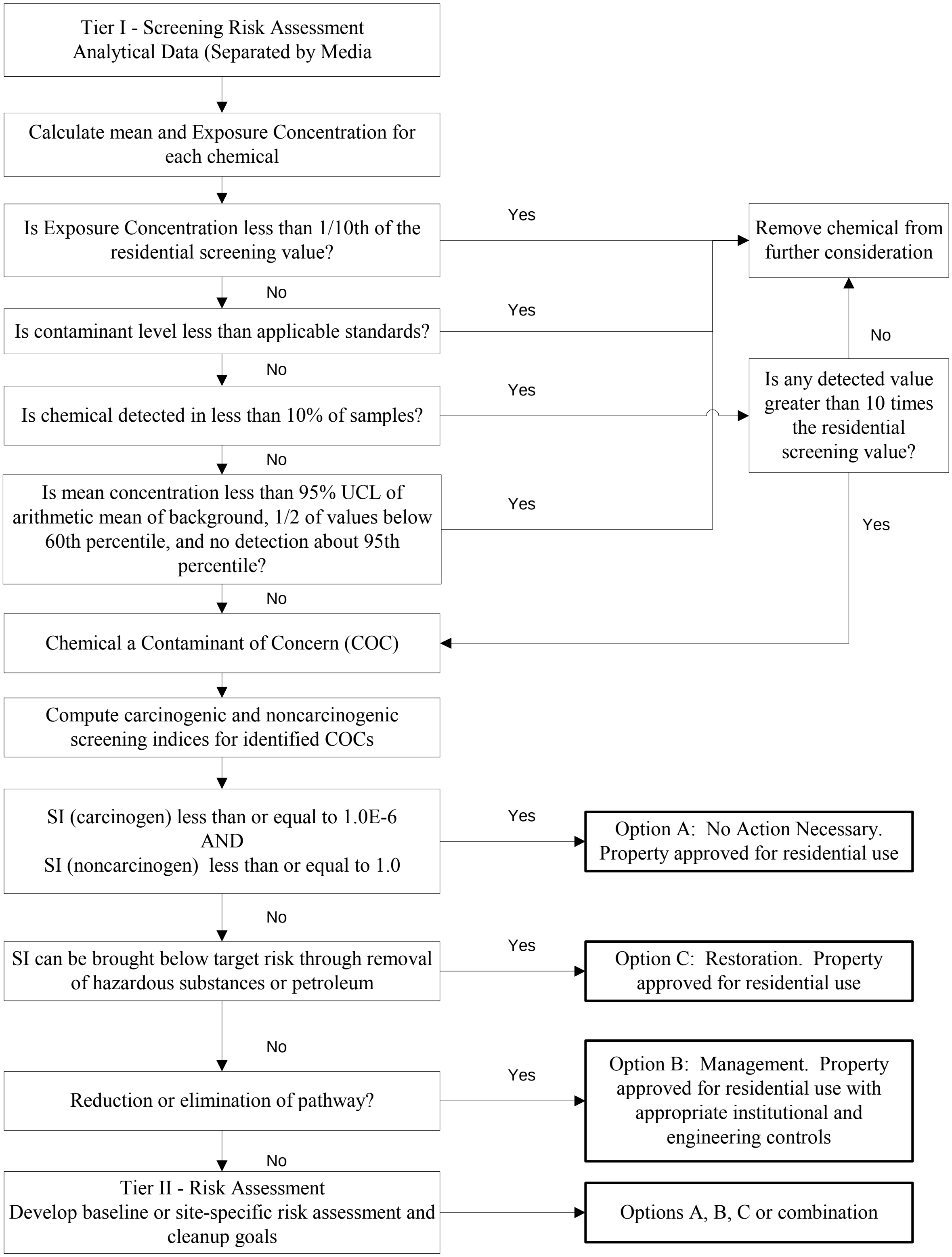
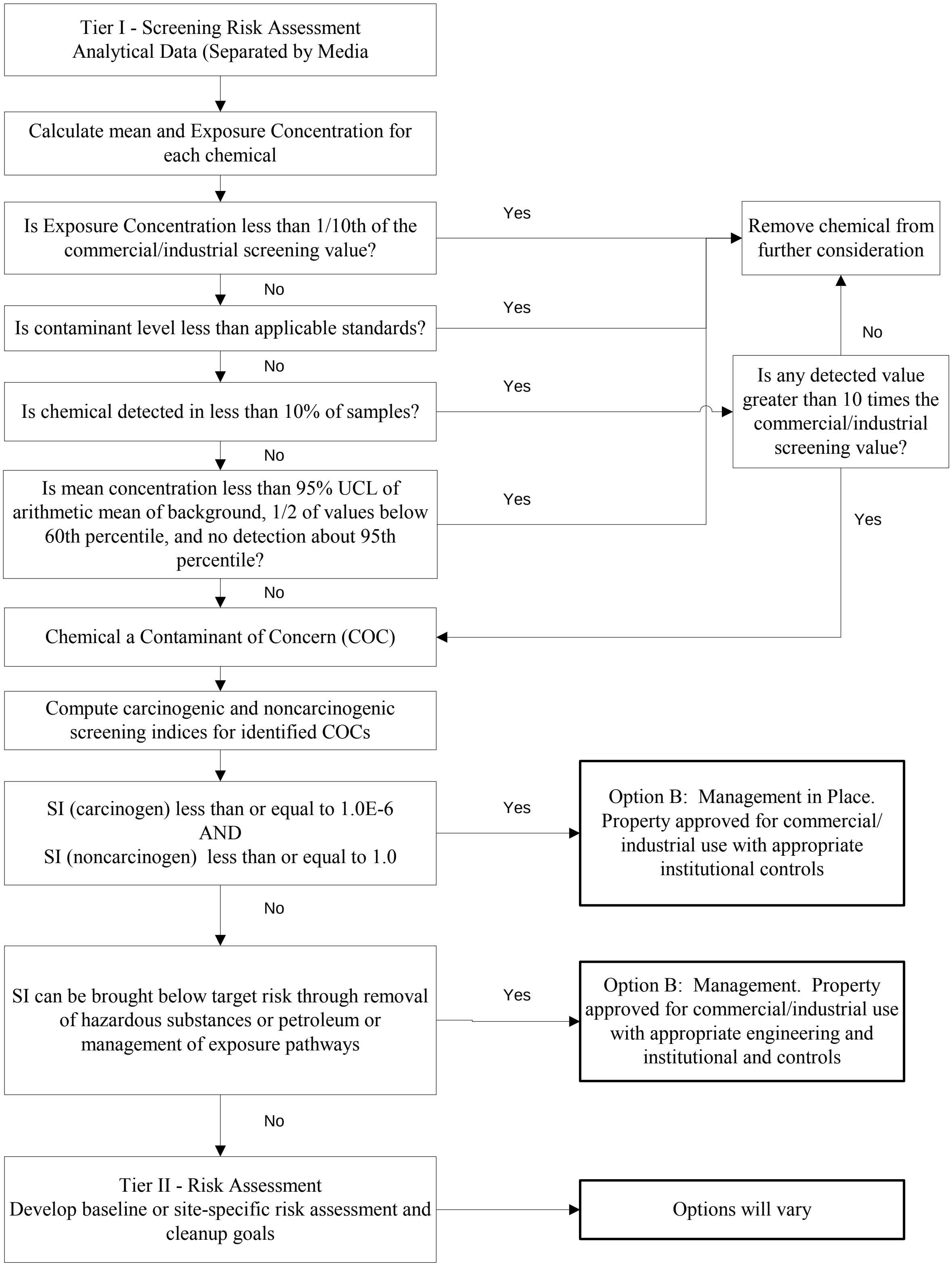


Figure 2. Flowchart for Commerical/Industrial Cleanup Options



Section 2.1. Tier I. Human Health Risk-Based Screening

This initial tier identifies which contaminants contribute significantly to the risks associated with the property and calculates the cumulative risk for all Contaminants of Concern (COCs). For this guidance, hazardous substance or petroleum shall have the meaning as defined in KRS 224.01-512. The screening-level risk assessment should be completed for residential land use as a baseline, and commercial or industrial land use if commercial or industrial use is part of the management plan. The following steps should be followed when completing a screening-level risk assessment for human health.

1. Segregate analytical data by medium. Further segregate soil data into surface (0-1 foot depth) and subsurface (greater than one foot depth).
2. Calculate 95% Upper Confidence Limit (UCL) of the arithmetic mean as described in U.S. EPA, 1992 (Supplemental Guidance to RAGS: Calculating the Concentration Term). Use all samples of the property and site(s). Use one-half of the detection limit for non-detect sample results. The Exposure Concentration shall be the lower of the 95% UCL of the arithmetic mean and the maximum detected value for that medium (and horizon, for soil). Calculate the mean of the site data for inorganic compounds in addition to the 95% UCL.
3. Compare the Exposure Concentration to 1/10th of the residential or commercial/industrial screening value, as appropriate. When screening, use the Total Chromium value for chromium, use carcinogenic effects for arsenic, and use Toxicity Equivalency Factors (TEFs) to calculate a Toxicity Equivalency Quotient (TEQ) for dioxins. Instead of 1/10th of the screening value for lead, use the Kentucky Lead Action Level of 50 mg/kg for soils for residential, and 400 mg/kg for commercial/industrial soils. Appendix E contains the KY Radiological Risk-Based Preliminary Remediation Goals, if applicable. Compare the Exposure Concentration to the following standards when applicable: Maximum Contaminant Levels (MCLs) for surface and ground water (401 KAR 8:250, 401 KAR 8:300, 401 KAR 8:400, 401 KAR 8:420), National Ambient Air Quality Standards (NAAQS) for air, and Surface Water Standards (401 KAR 5:031) for surface water.
4. Calculate the frequency of detection of the hazardous substance or petroleum constituent. Identify those compounds that are detected in at least 10 percent of the samples. If there is any detection above ten times the residential or commercial/industrial screening value, as

appropriate, then the hazardous substance or petroleum should remain a Contaminant of Concern (COC) regardless of the frequency of detection.

5. Compare the mean of the site data to the 95% UCL of background for inorganics. The background value shall be the generic statewide background number listed on Table G-2 in Appendix G, or site-specific background may be determined using the methods described in 401 KAR 100:100 Section 7 (6). In addition to the site mean being less that the 95% UCL of background, at least half of the samples should fall below the 60th percentile on Table G-2 or site-specific background, and no sample should exceed the 95th percentile listed on Table G-2 or site-specific background. The cabinet may approve other statistical methods proposed by the VERP applicant or party.

6. Produce a summary table that lists each hazardous substance or petroleum, site mean, Exposure Concentration, 1/10th of the screening value, frequency of detection (as a fraction), and, for inorganics, 95% UCL of the arithmetic mean of background. Include MCLs, Surface Water Standards, and NAAQS, if applicable. Identify those compounds as Contaminants of Concern (COCs) that exceeds the values in all applicable screens (i.e., is not eliminated by any screen). Highlight or denote with bold text the screen that eliminates the COPC from further evaluation, if applicable. Table 1 is an example of the summary table for soil.

Table 1. Summary of Results of Tier I Screening

Hazardous Substance	Mean	Exposure Concentration	1/10th Screening Value	Frequency of Detection	95% UCL of Background	COC?
Benzene	--	0.8 mg/kg	0.03 mg/kg	(8/30)	---	Yes
Arsenic	7.9 mg/kg	9.3 mg/kg	0.019 mg/kg	(24/30)	**9.4**	No

7. Segregate the COCs into carcinogens and noncarcinogens as described in the Preliminary Remediation Goals table in Appendix C. Radionuclides should be evaluated in the Tier I Screen using the screening values in Appendix E, if applicable. Calculate a Screening Index for all COCs by dividing the Exposure Concentration by the chemical-specific Preliminary Remediation Goal from Appendix C and summing the carcinogens and noncarcinogens:

$$\text{Screening Index (SI)} = \sum \frac{\text{Exposure Concentration x}}{\text{Screening Value x}} + \frac{\text{Exposure Concentration y}}{\text{Screening Value y}} + \frac{\text{Exposure Concentration z}}{\text{Screening Value z}} + etc.$$

For noncarcinogens, a Screening Index of less than 1.0 indicates that exposure to all noncarcinogenic contaminants, when summed, do not exceed a HQ of 1.0. Likewise the carcinogenic constituents should also use the SI approach and multiply the result by 10^{-6} to determine the additive risk in the media. This approach should be used for all applicable media at a site and then summing the indices of the individual media. The VERP applicant or party may calculate a site-specific PRG for a Tier I risk assessment screen.

8. Present the results of the Screening Index in the risk assessment report (Section 2.6).
9. If the cumulative Screening Index (SI) exceeds 1.0 for noncarcinogens or 1×10^{-6} for carcinogens, a VERP Applicant or party should select the next course of action. They may select to complete a risk management plan (Section 2.4), initiate remedial action(s) (Section 2.5), or evaluate the risks further through a baseline risk assessment (Section 2.2).

Section 2.2. Tier II. Baseline Human Health Risk Assessment.

1. Based on the COCs that were identified in Tier I (Risk-Based Screening), conduct a baseline risk assessment.
2. Risk assessment guidance documents from the United States Environmental Protection Agency should be used in preparing the risk assessment. Primary guidance is the "Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual. (Part A)" (RAGS Part A) and RAGS Part B (U.S. EPA, 1989; 1991), the "Soil Screening Guidance: Technical Background Document" (U.S. EPA, 1996a), the "Soil Screening Guidance: Users Guide" (U.S. EPA, 1996b), the "Soil Screening Guidance for Radionuclides: Users Guide" (U.S. EPA, 2000), and the Supplemental Guidance to RAGS: Region 4 Bulletins (U.S. EPA, 2001c). Other supporting guidance documents should be used as needed.
3. Describe the collection of sampling data and the procedures used to evaluate the data that are included in the risk assessment. Evaluation is completed as described in RAGS Part A (U.S. EPA, 1989) and involves evaluating analytical methods, quality of data, quantitation limits, data qualifiers, and blanks.
4. Identify and calculate exposure to current and future receptors. Potential land uses should be identified including, but not limited to: residential, industrial, recreational, commercial, or

agricultural. The baseline risk assessment should address all current and potential future receptors including trespassers and residents. Exposure factors for common receptors are listed in Appendix A. Site-specific factors may be used, subject to cabinet approval. The factors and the rationale for their use should be documented in the risk assessment report.

5. Describe the toxicity of the COCs that were identified in Section 2.1. List the toxicity values that are associated with the COCs. The hierarchy for sources of toxicity values is: (1) U.S. EPA's Integrated Risk Information System (IRIS), (2) U.S. EPA's Health Effects Assessment Summary Tables (HEAST), (3) provisional values from U.S. EPA's National Center for Environmental Assessment (NCEA), and (4) Other sources. Other sources may include Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles, World Health Organization (WHO) documents, publications in the primary toxicological literature, or values withdrawn from IRIS or HEAST, with cabinet approval.
6. Calculate the risks associated with the receptors that were identified in Step 4.
7. Identify and describe the uncertainties associated with the risk assessment. Potential sources of uncertainty include COC selection, range of values for exposure parameters, characterization of the site, and interaction between chemicals (additivity, synergism). Uncertainty analysis is further discussed in RAGS Part A (U.S. EPA, 1989).

Section 2.3. Groundwater Evaluation.

Groundwater data from monitoring wells are evaluated in Tier I and II risk evaluations. Recoverable water from soil borings can also be evaluated with groundwater numbers (Preliminary Remediation Goals, MCLs) as described in Section 2.1 and 2.2. If no groundwater monitoring data are available, or data are not adequate, then compare Exposure Concentration(s) for soil to the Soil Screening Level(s) from the Preliminary Remediation Goals table in Appendix C as described in 401 KAR 100:100 Section 5 (5). Radionuclides should be evaluated using the Soil Screening Levels in Appendix E, if applicable.

If the bottom two sampling intervals in the soil boring do not exceed the SSL, modified SSL, site-specific SSL, or subsurface background, then further groundwater evaluation of soil as a potential source for groundwater contamination is not necessary. If soil concentrations in the bottom two sampling intervals of the soil boring do exceed the Soil Screening Level, Modified SSLs, or site-specific SSLs for protection of groundwater resources, and subsurface background, then this indicates a need to manage for migration of contaminants to groundwater or for a groundwater investigation. Submit a plan to assess and protect groundwater or provide site-specific information that contamination doesn't pose a threat to groundwater.

Identify if the site is in an area where contamination of a karst aquifer is possible, or the contaminant(s) could result in a dense non-aqueous phase liquid (DNAPL) layer, or any other circumstances exist that would indicate a higher potential for contamination of groundwater. If such conditions exist, submit a plan for groundwater assessment and protection.

Section 2.4. Management of Risks.

1. Property Use. Management of risks can be accomplished by ensuring that a property is only used by a certain receptor. For example, a property that meets criteria for commercial or industrial use, but not residential, must remain commercial or industrial. Alternate land uses can be evaluated by using commercial/industrial screening values in place of the residential screening values that were used in Section 2.1, or in a baseline risk assessment.
2. Physical and Institutional Controls. Management of risks can be accomplished if exposure to contaminated media is controlled using a combination of soil cover, restrictive covenants, dig restrictions, fencing, or other approved methods.
3. Submit Corrective Action Plan for approval as described in 401 KAR 100:100 Section 8.

Section 2.5. Selection of Remedial Goals.

1. The primary goals of remediation is protection of human health at the hazard index of 1.0 and the carcinogenic risk of 1×10^{-6} at the point of exposure, and protection of ecological health. Ecological risks are addressed in Section 3.0.
2. The primary goals of remediation do not excuse compliance with other applicable standards, such as the National Ambient Air Quality Standards and the surface water standards.
3. The intended use must be ensured through physical and institutional controls and described in the Corrective Action Plan. The risk-based Preliminary Remediation Goals are found in the Appendix C table or derived based on approved receptor-specific values. Remedial goals

for radionuclides will be developed on a site-specific basis in consultation with the Kentucky Cabinet for Health Services. Generic inorganic background values are listed in Appendix G or may be derived using the guidance in 401 KAR 100:100 Section 7 (6).

4. The applicable risk-based remedial goals for surface soils are the residential and commercial/industrial soil numbers in the Appendix C Preliminary Remediation Goals table or those calculated based on approved receptor-specific values. Appendix E contains the risk-based concentrations for radionuclides, if applicable. The remedial goal for certain organic chemicals may be based on site-specific concentrations if it can be demonstrated to the cabinet that concentrations are the result of natural sources or are a by-product of combustion of fuels and not the result of activities on the property or site. For subsurface soils, a VERP applicant or party may select ten times the surface soil risk-based concentrations as an initial remedial goal with implementation of the institutional and physical controls and should not be a source of groundwater contamination. If contaminants are in the surface soil horizon, this can be attained through the use of cover (6 inches of pavement (e.g., asphalt or concrete), 12 inches of soil, or other approved method). For example, if the commercial/industrial soil number is 1.3 mg/kg on the risk-based PRGs table in Appendix C, and the contamination is more than a foot below the surface or is covered with a foot of clean soil, then the concentration that is left in place can be 13 mg/kg and the use of the site would need to be restricted to commercial or industrial use with the soil cover maintained in place.

Section 2.6. Human Health Risk Assessment Report Format.

The risk assessment results should be presented as part of the environmental remediation process wherever risk assessment is used for environmental decision-making. This may be included as part of the site characterization report, corrective action completion report, in an appendix to those reports, or as a separate document.

1. Screening. The screening report should consist of a brief description of the property, site characterization activities, a summary of the analytical data along with the statistical calculations of the 95% UCL, the summary table as described in Section 2.1 6., and results of the Screening Index.

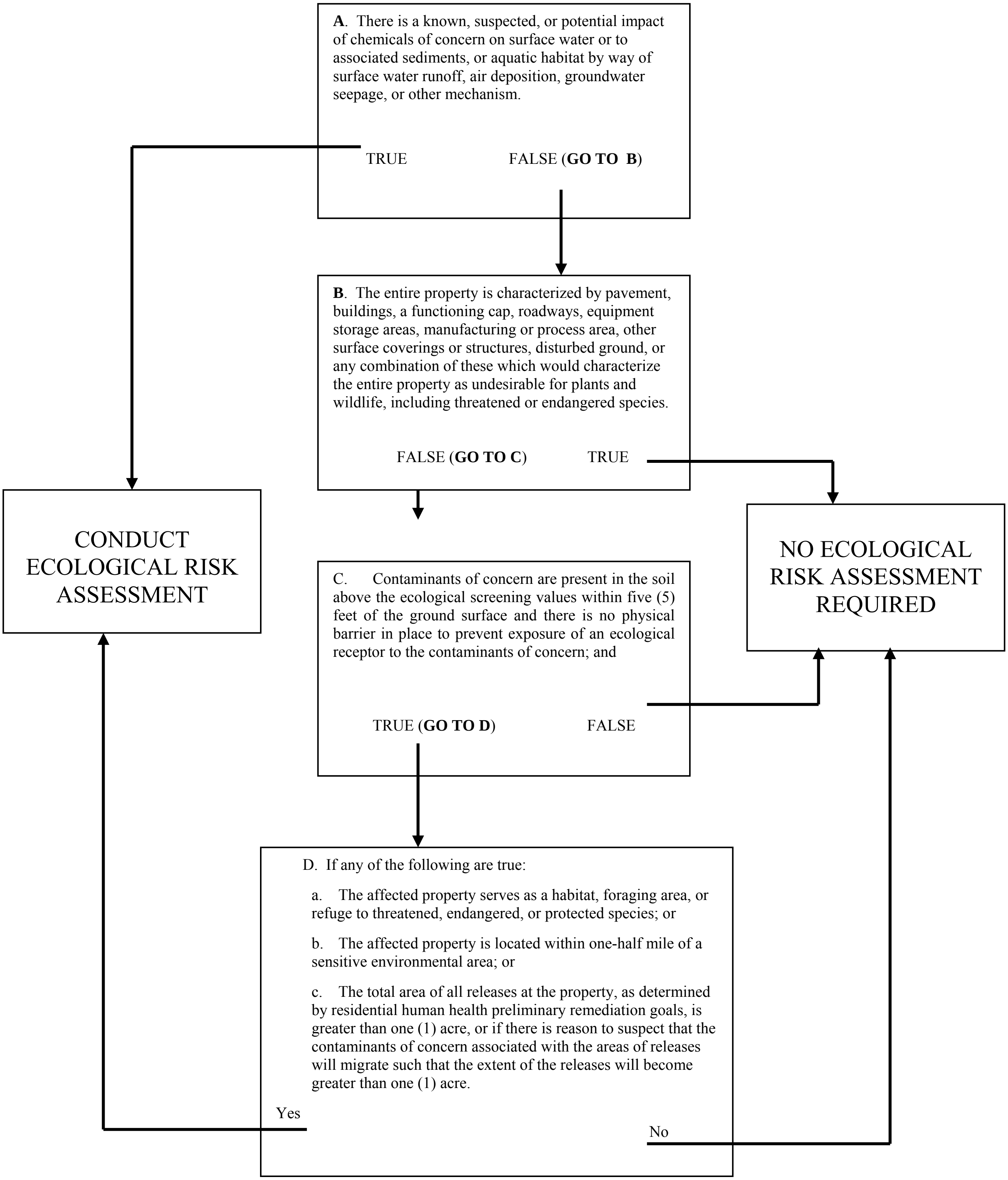
2. Baseline Risk Assessment. The baseline risk assessment report should follow the general outline shown in Appendix B. A copy of the screening risk assessment may be included with the baseline risk assessment to provide information that was used in the baseline risk assessment (selection of COCs, calculation of 95% UCL).

Section 3.0 Ecological Risk Assessment

If it has been determined that an Ecological Risk Assessment (ERA) needs to be conducted (401 KAR 100:100 Section 5 (8)), this document provides the outline for that process. The flowchart in Figure 3 is the process for determining if an ERA needs to be conducted. The checklist in Appendix F can be used to identify features of the environmental setting that are related to ecological receptors.

The phrase "ecological risk assessment" refers to a qualitative and/or quantitative appraisal of the actual or potential impacts from a hazardous compound or physical stressor on plants and animals. Documents from various federal programs (Simini et. al., 2000; USEPA 1993; USEPA 1997a; USEPA 1998) were consulted in the process of developing this document and the procedures used in calculating risk-based concentrations. Figure 4 outlines the process of the ERA.

Figure 3. Flowchart For Determining An Ecological Risk Assessment



A. There is a known, suspected, or potential impact of chemicals of concern on surface water or to associated sediments, or aquatic habitat by way of surface water runoff, air deposition, groundwater seepage, or other mechanism.

TRUE

FALSE (**GO TO B**)

B. The entire property is characterized by pavement, buildings, a functioning cap, roadways, equipment storage areas, manufacturing or process area, other surface coverings or structures, disturbed ground, or any combination of these which would characterize the entire property as undesirable for plants and wildlife, including threatened or endangered species.

FALSE (**GO TO C**)

TRUE

C. Contaminants of concern are present in the soil above the ecological screening values within five (5) feet of the ground surface and there is no physical barrier in place to prevent exposure of an ecological receptor to the contaminants of concern; and

TRUE (**GO TO D**)

FALSE

D. If any of the following are true:

a. The affected property serves as a habitat, foraging area, or refuge to threatened, endangered, or protected species; or

b. The affected property is located within one-half mile of a sensitive environmental area; or

c. The total area of all releases at the property, as determined by residential human health preliminary remediation goals, is greater than one (1) acre, or if there is reason to suspect that the contaminants of concern associated with the areas of releases will migrate such that the extent of the releases will become greater than one (1) acre.

Yes

No

CONDUCT ECOLOGICAL RISK ASSESSMENT

NO ECOLOGICAL RISK ASSESSMENT REQUIRED

The ERA process is based on two major elements: characterization of effects and characterization of exposure. These provide the focus for conducting the phases of risk assessment: planning, problem formulation, analysis, risk characterization, and risk management.

a) Planning – The Planning phase involves the determination of level-of-effort necessary for the ERA. ERA management goals and objectives are determined (i.e., what plant, animal, or ecosystem is at risk and might need protection), the focus of the ERA is laid out, and the time frame for the assessment is set.

b) Problem Formulation – The overall strategy for estimating risk at a site is developed in Problem Formulation. During this phase, the Conceptual Site Model (CSM) is created, the receptors potentially at risk are defined, and a plan is written that describes the data to be analyzed and the process to be used to calculate risk.

c) Analysis – This component of the ERA consists of data collection, the technical evaluation of the data, the calculation of the existing and potential exposures, and corresponding ecological effects.

d) Risk Characterization – The likelihood and severity of the risk is evaluated for the assessment endpoints, and the ERA's uncertainty is described in the Risk Characterization. A good description of the risk, including the level of adverse effects, is important for interpreting the risk results.

e) Risk Management – In this component, the results of the ERA are integrated with other considerations to make and justify remedial decisions. In a screening level ERA, the risk management decision is whether a baseline ERA is needed.

Section 3.1. Tier 1. Screening-Level Ecological Risk Assessment.

The purpose of the screening-level risk assessment is to evaluate whether existing data justify a decision that site contaminants do not pose a risk to ecological receptors or whether additional evaluation is necessary. If no potential for risk is identified in a screening-level risk assessment, then risk managers can confidently conclude that no further action is required at the site. Tier 1 of ERA consists of two steps:

Step 1. Screening-Level Problem Formulation and Ecological Effects Evaluation.

Step 2. Screening-Level Preliminary Exposure Estimate and Risk Calculation.

Steps 1 and 2 of the ERA process contain the following elements:

- Site visit
- Screening-level problem formulation (preliminary Conceptual Site Model)
- Exposure pathways and endpoints
- Screening-level effects evaluation (toxicity threshold benchmarks)
- Screening-level exposure estimate (site concentration data)
- Screening-level risk calculation (site concentration data screens)
- Documentation

a) Preliminary Conceptual Site Model (CSM). As part of Tier 1, Step 1 of the ERA, use available information to develop a preliminary CSM. Available information may include observations made during site visits, historical documents, existing data, and professional judgement of technical experts who are familiar with the site. The preliminary CSM should describe the environmental setting of the individual site, the site's immediate surroundings, and the contaminants known to exist at the site. The preliminary CSM should identify fate and transport mechanisms of contaminants potentially moving off-site, and briefly discuss the ways that site contaminants act on likely receptors.

b) Exposure Pathways and Endpoints. Based on the preliminary CSM, the ecological risk assessor should identify the potentially complete exposure pathways and endpoints for the screening assessment. The exposure pathways and endpoints for the site specify which ecological effects data are required. The screening-level effects data are screening-level benchmarks and concentrations of substances in the abiotic media (e.g., soil, air or water). If groundwater potentially discharges to surface water, groundwater concentrations are compared to surface water screening benchmarks.

c) Identify Chemicals of Potential Concern. As part of Tier 1, Step 2, determine (COPCs) by eliminating COPCs from further evaluation:

- Background Comparisons**.** Compare the mean concentration for inorganic constituents on-site against the 95% UCL of the mean concentrations of background for inorganic constituents. At least ½ of the data points should be less than the 60th percentile, and no data point above the 95th percentile. Generic inorganic background values are listed in Appendix G or may be derived in accordance with 401 KAR 100:100 Section 7 (6).

- Screening Table Comparison. Compare the lesser of the maximum concentration or 95% UCL on site for substances in a given exposure medium to the screening-level benchmarks (Appendix D) for those substances. Compare site concentrations to screening-level benchmarks for surface soil, sediment, surface water, and groundwater (if site conditions will potentially result in exposure to ecological receptors).

d) Retaining Chemicals of Concern. If any constituent in an abiotic medium to which organisms are potentially exposed is present at a concentration exceeding screening-level benchmark and ambient background or if there is not a screening-level benchmark, then further evaluation of the potential risk will be required. Chemicals with known synergistic effects or that bioaccumulate will be retained as COPCs. If existing data does not have adequate detection limits (i.e., detection limits above screening benchmarks) new data must be collected to replace it.

e) Documentation. The documentation of Steps 1 and 2 should include the following:
- Brief habitat description, and map;
- Preliminary CSM;
- Tables of screening results;
- List of wildlife species actually or potentially occurring at the site, including threatened and endangered plant and animal species;
- Discussion of uncertainties. The discussion of the uncertainties should identify constituents for which there are no screening-level benchmarks or analytical chemistry data.

At the end of Tier 1, the decision whether to collect additional data for screening, to proceed with the ERA, or to take no further action can be documented in the report.

Section 3.2. Tier 2 Baseline Ecological Risk Assessment

The baseline ecological risk assessment is a continuation of the screening ERA. It consists of 6 steps:

Step 3. Baseline Risk Assessment Problem Formulation
Step 4. Study Design and Data Quality Objectives
Step 5. Field Verification of Sampling Design
Step 6. Site Investigation and Analysis of Exposure and Effects
Step 7. Risk Characterization
Step 8. Risk Management

a) Step 3. Baseline Risk Assessment Problem Formulation. The Baseline Risk Assessment Problem Formulation should provide sufficient information to support a risk management decision concerning the need for additional evaluation of ecological risk. Further evaluation may mean site-specific ecological investigation at the site. This will require a work plan, documenting Step 4 of the process, and describing how the data will be used in Step 7 to make a remedial decision for the site. Important inputs to this decision are:

- Site concentration data;
- Conceptual Site Model;
- Habitat Description;
- Preliminary Hazard Quotients. The Hazard Quotient should be calculated for COPCs using toxicity values from current literature and intake factors from the Wildlife Exposure Factors Handbook (USEPA 1993) for the species listed below. A Hazard Quotient is calculated by dividing the site concentration (the lessor of the 95% UCL of the mean or maximum) by the No-Observed Adverse Effect Level (NOAEL). If the Hazard Quotient is above 1.0, that compound continues through the baseline ERA.

  For terrestrial habitats, receptors must include (1) earthworm (Lumbricus terrestris), (2) short-tailed shrew (Blarina brevicauda), (3) long-tailed weasel (Mustela frenata), (4) meadow vole (Microtus pennsylvanicus) or prairie vole (Microtus ochrogaster), and (5) American woodcock (Scolopax minor). For aquatic habitats, receptors must include; mink (Mustela vison) little brown bat (Myotis lucifugus), and belted kingfisher (Cerlye alcyon). The above list of species should not be considered exclusive. If there are other species on site that exposure factors, intake rates, and toxicity values are known, those species should be included in the ERA. Species that are on the Federal and/or State Threatened or Endangered Species List and either known to have been on or in the vicinity of the site or if the site contains habitat known to support those species, then they should also be included in the ERA.

- The identification of COPCs that warrant further evaluation.
- An understanding of the effects of COPCs on ecological receptors (including toxicity reference values).
- The identification of complete exposure pathways by which COPCs are brought into contact with ecological receptors (include bioaccumulation factors and ingestion rates for wildlife receptors).
- The identification of assessment endpoints (e.g., protection of fish eating birds from eggshell thinning due to DDT exposure) and measurement endpoints (e.g., natural population structure, feeding, resting, and reproductive cycles).
- Discussion of uncertainties should include the lack of site concentration or toxicity data for COPCs.

b) In Step 4, the process identifies the study design and data quality objectives (DQOs) for the site investigation. The work plan (WP) and the sampling and analysis plan (SAP) are the primary products of Step 4. The WP and SAP must specify the study design in sufficient detail to evaluate its adequacy for collecting the data necessary to answer the risk questions.

The WP or SAP should include the following:

- The number and location of samples of each medium for each purpose
- The comparison of analytical detection limits and threshold concentrations
- The full description of toxicity tests and population/community study designs
- A description of how the results of site investigations will be used in the risk characterization (Step 7) to answer risk questions.

c) In Step 5, the Verification of Field Sampling Design process evaluates the probability of successfully completing the study as designed. The WP or SAP should describe the methods for verifying the study design. The verification process and any remaining uncertainties about the study design should be discussed when the results of the site investigation are reported.

d) Step 6, the Site Investigation and Data Analysis, is the implementation of the site investigation designed in Step 4 and verified in Step 5. Approved alterations in the work plan should be documented in the report containing the risk characterization (i.e., the baseline risk report).

e) Risk Characterization (Step 7) is conducted after data collected during the site investigation have been analyzed. The risk characterization evaluates the exposure and effects data to assess the risk to the assessment endpoints (risk estimation). The risk characterization also presents information necessary to interpret the risk assessment and to decide upon adverse effect thresholds for the assessment endpoints (risk description). This presentation should include a qualitative and quantitative summary of risk results and uncertainties.

   In risk estimation, the lines of evidence, for which data were collected in the site investigation, are integrated in the risk characterization to support a conclusion about the significance of ecological risk. The different possible lines of evidence could be tissue concentration data, toxicity test results, and/or population/community data.

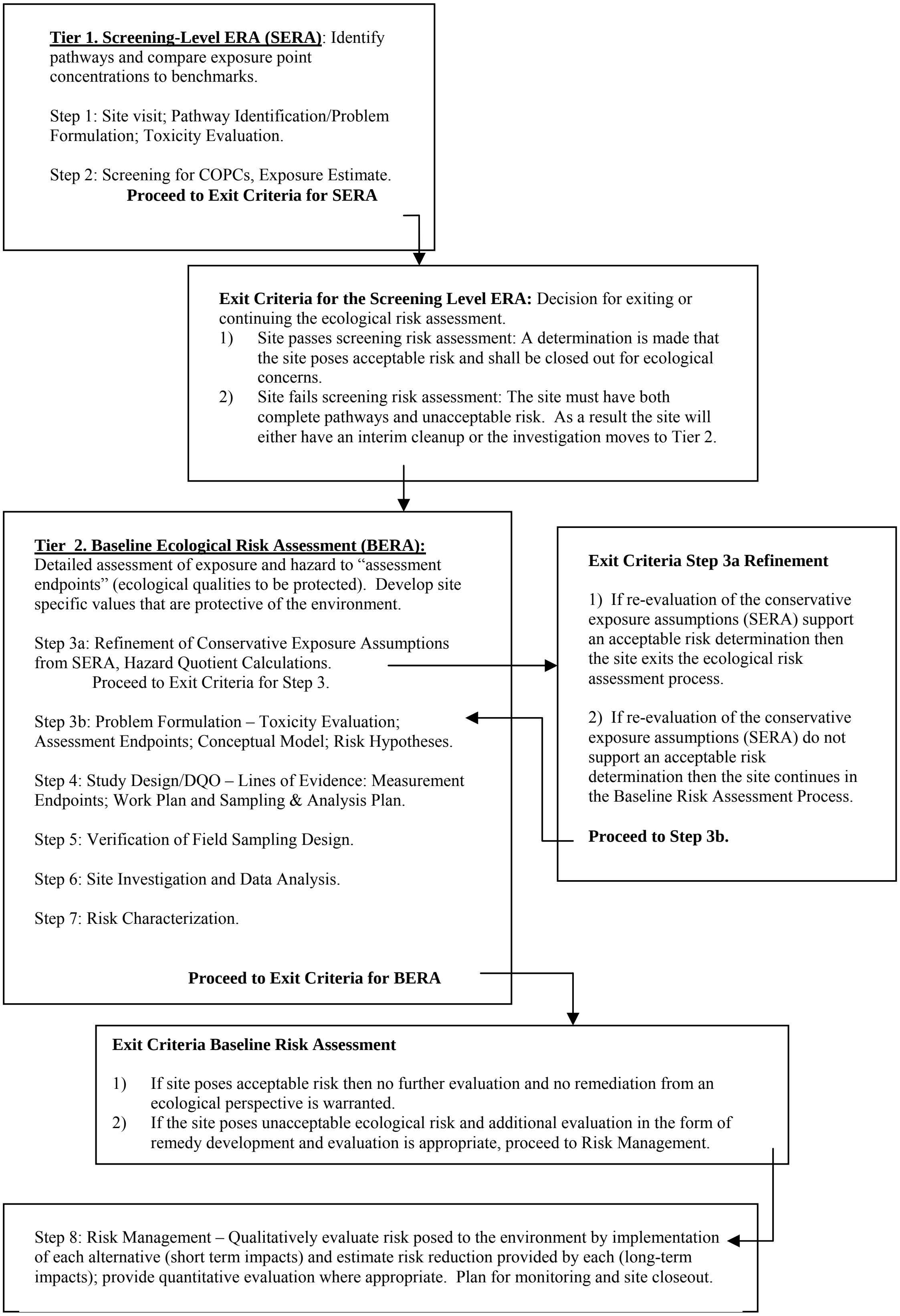
   If site-specific tissue concentration data are available from the site investigation, HQs for wildlife receptors preying on those tissues are calculated. These HQs are calculated using appropriate exposure estimates and toxicity reference values.

   In the ERA, the risk characterization should put the level of risk at the site in context. The risk description should identify threshold concentrations in source or exposure media for effects on the assessment endpoint. All site-specific parameter values used to calculate HQs must be described and the source of the values identified.

   At Step 7, the uncertainty about the risk posed by a substance should have been reduced to a level that allows risk managers to make a technically defensible remedial decision. The risk characterization provides information to judge the ecological significance of the estimated risk to assessment endpoints in the absence of any remedial action.

f) Step 8 of the ERA is Risk Management. The role of ecological risk assessors is to advise the risk managers during the final actions. If the risk characterization concludes there is a risk to ecological receptors, the risk management decision is whether to remediate the site or to leave the constituents of concern in place with controls on exposure and monitoring.

Figure 4. Ecological Risk Assessment Flow Chart



Tier 1. Screening-Level ERA (SERA): Identify pathways and compare exposure point concentrations to benchmarks.

Step 1: Site visit; Pathway Identification/Problem Formulation; Toxicity Evaluation.

Step 2: Screening for COPCs, Exposure Estimate.

Proceed to Exit Criteria for SERA

Exit Criteria for the Screening Level ERA: Decision for exiting or continuing the ecological risk assessment.

1) Site passes screening risk assessment: A determination is made that the site poses acceptable risk and shall be closed out for ecological concerns.
2) Site fails screening risk assessment: The site must have both complete pathways and unacceptable risk. As a result the site will either have an interim cleanup or the investigation moves to Tier 2.

Tier 2. Baseline Ecological Risk Assessment (BERA): Detailed assessment of exposure and hazard to "assessment endpoints" (ecological qualities to be protected). Develop site specific values that are protective of the environment.

Step 3a: Refinement of Conservative Exposure Assumptions from SERA, Hazard Quotient Calculations.

Proceed to Exit Criteria for Step 3.

Step 3b: Problem Formulation – Toxicity Evaluation; Assessment Endpoints; Conceptual Model; Risk Hypotheses.

Step 4: Study Design/DQO – Lines of Evidence: Measurement Endpoints; Work Plan and Sampling & Analysis Plan.

Step 5: Verification of Field Sampling Design.

Step 6: Site Investigation and Data Analysis.

Step 7: Risk Characterization.

Proceed to Exit Criteria for BERA

Exit Criteria Step 3a Refinement

1) If re-evaluation of the conservative exposure assumptions (SERA) support an acceptable risk determination then the site exits the ecological risk assessment process.

2) If re-evaluation of the conservative exposure assumptions (SERA) do not support an acceptable risk determination then the site continues in the Baseline Risk Assessment Process.

Proceed to Step 3b.

Exit Criteria Baseline Risk Assessment

1) If site poses acceptable risk then no further evaluation and no remediation from an ecological perspective is warranted.
2) If the site poses unacceptable ecological risk and additional evaluation in the form of remedy development and evaluation is appropriate, proceed to Risk Management.

Step 8: Risk Management – Qualitatively evaluate risk posed to the environment by implementation of each alternative (short term impacts) and estimate risk reduction provided by each (long-term impacts); provide quantitative evaluation where appropriate. Plan for monitoring and site closeout.

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Appendix A
Exposure Factors

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Table 1 Incidental Soil Ingestion Pathway.

Parameter	Value
Chemical Concentration in Soil	95 % UCL of the mean or maximum
Ingestion Rate:	
Child less that 7 years	200 mg/day
Child 7 through 18 years, and Adult	100 mg/day
Adult Worker (8 hour work day)	50 mg/day
Outdoor Adult (landscaping, construction, Rural outdoor activities, tilling and gardening)	480 mg/day
Exposure Frequency:	
Resident	350 days/year
General Workers	250 days/year
Adult Outdoors (urban)	52 days/year
Adult Outdoors (rural)	104 days/year
Outdoor Worker	185 days/year
Child Outdoors (recreational or trespasser)	140 days/year
Fraction of Soil from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adult	12 years
Residential Rural Adult	22 years
Adult Worker	25 years
Ingestion Absorption Factor	1.0 (unitless) or chemical-specific
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adult	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 2 Dermal Contact with Stressors in Soil Pathway.

Parameter	Value
Chemical Concentration in Soil	95 % UCL of the mean or maximum
Skin Surface Area:	
Child less than 7 years	2800 cm^2/day (face, forearms, hands, lower legs, and feet)
Child 7 through 18 years	7500 cm^2/day (arms, hands, legs, and feet)
Residential Adult	5700 cm^2 (face, hands, forearms, and lower legs)
Adult (Industrial)	3300 cm^2/day (face, forearms, and hands)
Outdoor Worker	4700 cm^2/day (arms, hands, and head)
Exposure Frequency:	
Resident	350 days/year
General Workers	250 days/year
Adult Outdoors (urban)	52 days/year
Adult Outdoors (rural)	104 days/year
Outdoor Worker	185 days/year
Child Outdoors (recreational or trespasser)	140 days/year
Fraction of Soil from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adult	12 years
Residential Rural Adult	22 years
Adult Worker	25 years
Dermal Absorption Factor	0.25 Volatile Organics (unitless) 0.1 Semivolatiles (unitless) 0.05 Inorganics (unitless)
Skin Contact Time (fraction of day soil remains on skin):	
Residential	12 hours/24 hours (0.5 unitless)
Worker	8 hours/24 hours (0.33 unitless)
Recreational or Trespasser	12 hours/24 hours (0.5 unitless)
Soil to Skin Adherence Factor	1.0 mg/cm^2
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adult	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 3 Inhalation of Particulate-phase Stressors from Soil Pathway.

Parameter	Value
Chemical Concentration in Soil	95 % UCL of the mean or maximum
Inhalation Rate:	
Resident (Children and Adults)	20 m^3/day (0.833m^3/hour, 24 hr/day)
Trespasser	20 m^3/day (2.5 m^3/hour, 8 hr/day)
Worker (Indoor and Outdoor)	12.5 m^3/day (2.5 m^3/hour, 5 hr/day)
Exposure Frequency:	
Resident	350 days/year
General Worker	250 days/year
Adult Outdoors (urban)	52 days/year
Adult Outdoors (rural)	104 days/year
Outdoor Worker	185 days/year
Child Outdoors (recreational or trespasser)	140 days/year
Fraction of Soil from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adults	12 years
Residential Rural Adults	22 years
Adult Worker	25 years
Inhalation Absorption Factor	1.0 (unitless) or chemical-specific
Particulate Emission Factor:	
Residential	9.3 x 10^8 m^3/kg or site-specific
Commercial/Industrial	6.2 x 10^8 m^3/kg or site-specific
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adults	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 4 Inhalation of Airborne (Vapor Phase) Stressors from Soil Pathway.

Parameter	Value
Chemical Concentration in Soil	95 % UCL of the mean or maximum
Inhalation Rate:	
Resident (Children and Adults)	20 m^3/day (0.833 m^3/hour, 24 hr/day)
Trespasser	20 m^3/day (2.5 m^3/hour, 8 hr/day)
Worker (Indoor and Outdoor)	12.5 m^3/day (2.5 m^3/hour, 5 hr/day)
Exposure Frequency:	
Resident	350 days/year
General Worker	250 days/year
Adult Outdoors (urban)	52 days/year
Adult Outdoors (rural)	104 days/year
Outdoor Worker	185 days/year
Child Outdoors (recreational or trespasser)	140 days/year
Fraction of Soil from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adult	12 years
Residential Rural Adult	22 years
Adult Worker	25 years
Inhalation Absorption Factor	1.0 (unitless) or chemical-specific
Volatilization Factor	Derived using Equation 8 of the Soil Screening Level Guidance User's Guide (U.S. EPA 1996b)
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adult	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 5 Ingestion of Stressors from Water Pathway.

Parameter	Value
Chemical Concentration in Water	95 % UCL of the mean or maximum
Ingestion Rate:	
Child less than 3 years old	1.0 liter/day
Child 3 through 18 years and Adult	2.0 liters/day
Adult Worker (up to an 8 hour work day)	1.0 liter/day
Exposure Frequency:	
Resident	350 days/year
General Worker	250 days/year
Fraction of Soil from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adult	12 years
Residential Rural Adult	22 years
Adult Worker	25 years
Ingestion Absorption Factor	1.0 (unitless) or chemical-specific
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adult	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 6 Ingestion of Stressors in Surface Water While Swimming Pathway.

Parameter	Value
Chemical Concentration in Water	95 % UCL of the mean or maximum
Ingestion Rate:	50 milliliters/hour
Exposure Time:	2.6 hours/day
Exposure Frequency:	45 days/year
Fraction of Water from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adult	12 years
Residential Rural Adult	22 years
Ingestion Absorption Factor	1.0 (unitless) or chemical-specific
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adults	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 7 Dermal Contact with Stressors in Water while Swimming or Wading Pathway.

Parameter	Value
Chemical Concentration in Water	95 % UCL of the mean or maximum
Skin Surface Area:	
Child swimmer 3 through 6 years	0.6500 m^2/day
Child swimmer 7 through 18 years	1.3100 m^2/day
Adult swimmer	1.8150 m^2/day
Child wader 1 through 6 years	0.3300 m^2/day (arms, hands. legs and feet)
Child wader 7 through 18 years	0.7500 m^2/day (arms, hands. legs and feet)
Adult wader	1.0600 m^2/day (arms, hands. legs and feet)
Exposure Time	2.6 hours/day
Dermal Permeability factor (Kp)	Use RAGS Part E (U.S. EPA 2001b) Appendix B. If measured K_ps are available, then those should be used instead of the modeled values for those chemicals.
Exposure Frequency:	
Swimming	45 days/year
Child and Adolescent Wading	140 days/year
Adult Wading	52 days/year
Fraction of Water from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adult	12 years
Residential Rural Adult	22 years
Dermal Absorbed Dose per Event (DA_{event})	Calculated using RAGS Part E (U.S. EPA, 2001b)
Ingestion Absorption Factor	1.0 (unitless) or chemical-specific
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adult	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 8 Dermal Contact with Stressors in Water during Showering or Bathing Pathway.

Parameter	Value
Chemical Concentration in Water	95 % UCL of the mean or maximum
Skin Surface Area:	
Child 3 through 6 years	0.6500 m^2/day
Child 7 through 18 years	1.3100 m^2/day
Adult	1.8150 m^2/day
Exposure Time	0.2 hours/day
Dermal Permeability factor (Kp)	Use RAGS Part E (U.S. EPA 2001b) Appendix B. If measured K_ps are available, then those should be used instead of the modeled values for those chemicals.
Exposure Frequency:	
Residents	350 days/year
Workers in the work place	250 days/year
Fraction of Water from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adult	12 years
Residential Rural Adult	22 years
Adult Worker	25 years
Dermal Absorbed Dose per Event (DA_{event})	Calculated using RAGS Part E (U.S. EPA, 2001b)
Ingestion Absorption Factor	1.0 (unitless) or chemical-specific
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adult	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 9 Inhalation of Airborne (Vapor Phase) Stressors in Water during Showering Pathway

Parameter	Value
Chemical Concentration in Water	95 % UCL of the mean or maximum
Concentration of Stressor in Air	Use Schaum, et al., 1994, Showering Exposure
Inhalation Rate	0.833 m^3/day
Exposure Time	0.2 hours/day (12 minutes/day)
Exposure Frequency:	
Residents	350 days/year
Workers in the work place	250 days/year
Fraction of Water from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adults	12 years
Residential Rural Adults	22 years
Adult Worker	25 years
Inhalation Absorption Factor	1.0 (unitless) or chemical-specific
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adults	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Table 10 Inhalation of Airborne (Vapor Phase) Stressors in Water during General Home Use Pathway.

Parameter	Value
Chemical Concentration in Water	95 % UCL of the mean or maximum
Concentration of Stressor in Air	Use Schaum et al., 1994, Whole House Model
Inhalation Rate	20 m^3/day
Water Flow Rate	890 L/day
House Volume	450 m^3
Air Exchange Rate	10 changes/day
Fraction Volatilized	0.5 (unitless)
Mixing Coefficient (how well mixed in the home)	0.5 (unitless)
Exposure Frequency:	
Resident	350 days/year
Fraction of Water from a Source Impacted by a Release	1.0 (unitless)
Exposure Duration:	
Child less than 7 years	6 years
Child 7 through 18 years	12 years
Residential Urban Adult	12 years
Residential Rural Adult	22 years
Inhalation Absorption Factor	1.0 (unitless) or chemical-specific
Body Weight:	
Child less than 7 years	15 kg
Child 7 through 18 years	43 kg
Adults	70 kg
Exposure Averaging Time	25,550 days for carcinogens Exposure Duration (years) x 365 days/year for noncarcinogens

Other Pathways. Other pathways may be used at sites that have current or potential future pathways that are not listed in this Appendix. Examples include: consumption of contaminated fish, produce, and livestock. Exposure factors should be based on site-specific conditions and may be obtained from U.S. EPA documents including Exposure Factors Handbook, Risk Assessment Guidance for Superfund (Part A), and Risk Assessment Guidance for Superfund (Part B).

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Appendix B

General Outline for Baseline Risk Assessment

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Outline of Components of a Human Health Baseline Risk Assessment

This is a general outline and not all components of the outline are applicable to all sites.

1.0 INTRODUCTION

- 1.1 Overview
  - 1.1.a General Problem at site
  - 1.1.b Site-specific objectives of risk assessment
- 1.2 Scope of Risk Assessment
  - 1.2.a Complexity of risk assessment and rationale
  - 1.2.b Overview of study design

2.0 IDENTIFICATION OF STRESSORS OF POTENTIAL CONCERN

- 2.1 General Site-Specific Data Collection Considerations
  - 2.1.a Preliminary identification of potential human exposure
  - 2.1.b Modeling parameter needs
- 2.2 General Site-Specific Data Evaluation Considerations
  - 2.2.a Steps used (including statistical methods used for evaluation and data selection)
  - 2.2.b Criteria employed in evaluating data
  - 2.2.c Discussion of data uncertainty
- 2.3 Stressor Analytical Data (Complete for All Media)
  - 2.3.a Listing of analytical methods used
  - 2.3.b Evaluation of chemical limits
  - 2.3.c Evaluation of qualified and coded data
  - 2.3.d Contaminants in field and laboratory blanks
  - 2.3.e Tentatively identified compounds
  - 2.3.f Further limitation of number of stressors
  - 2.3.g Uncertainties, limitations, gaps in quality of collection or analysis
- 2.4 Summary of Stressors of Potential Concern

3.0 EXPOSURE ASSESSMENT

- 3.1 Characterization of Exposure Setting
  - 3.1.a Summary of Physical Setting
  - 3.1.b Potentially Exposed Individuals, Populations, and Communities (Human)
    - 3.1.b.1 Relative locations of individuals, populations, and communities with respect to site
    - 3.1.b.2 Current land use

        3.1.b.3 Potential alternate future land uses
        3.1.b.4 Subpopulations of potential concern
    3.2 Identification of Exposure Pathways
    3.2.a Sources of the release and receiving media
    3.2.b Fate and transport in release media
    3.2.c Exposure points and exposure routes
    3.2.d Integration of sources, releases, fate and transport mechanisms, exposure points, and exposure routes into complete exposure pathways
    3.2.e Summary of exposure pathways to be quantified in this assessment
3.3 Quantification of Exposure
    3.3.a Exposure concentrations
    3.3.b Estimation of chemical intakes for individual pathways
3.4 Identification of Uncertainties
    3.4.a Current and future land-use
    3.4.b Environmental sampling and analysis
    3.4.c Exposure pathways evaluated
    3.4.d Fate and transport modeling
    3.4.e Parameter values
3.5 Summary of Exposure Assessment

4.0 TOXICITY ASSESSMENT

4.1 Toxicity Information for Noncarcinogenic Effects (Human Health)
    4.1.a Appropriate exposure periods for toxicity values
    4.1.b Up-to-date reference doses (RfDs) for all stressors
    4.1.c One-and ten-day health advisories for shorter-term oral exposures
    4.1.d Overall data base and the critical study on which the toxicity value is based (including the critical effect and the uncertainty and modifying factors used in the calculation)
    4.1.e Effects that may appear at doses higher than those required to elicit the critical effect
    4.1.f Absorption efficiency considered
4.2 Toxicity Information for Carcinogenic Effects
    4.2.a Exposure averaged over a lifetime
    4.2.b Up-to-date slope factors for all carcinogens
    4.2.c Weight-of-evidence classification for all carcinogens (Groups A, B, and C)
    4.2.d Type of cancer for Group A, B, and C carcinogens

    - 4.2.e Concentration above which the dose-response curve is no longer linear, if applicable
    - 4.3 Stressors for Which No EPA Toxicity Values are Available
    - 4.3.a Sources of values
    - 4.3.b Qualitative evaluation
    - 4.3.c Documentation or justification of any new toxicity values developed
- 4.4 Uncertainties Related to Toxicity Information
    - 4.4.a Quality of the individual studies
    - 4.4.b Completeness of the overall data base
- 4.5 Summary of Toxicity Information

5.0 RISK CHARACTERIZATION

- 5.1 Current Land-use Conditions (Human Health)
    - 5.1.a Carcinogenic risk of individual stressors in individual pathways
    - 5.1.b Chronic hazard quotient calculation (individual stressors, individual pathways)
    - 5.1.c Subchronic hazard quotient calculation (individual stressors, individual pathways)
    - 5.1.d Shorter-term hazard quotient calculation (individual stressors, individual pathways)
    - 5.1.e Noncarcinogenic hazard index (individual stressors, all pathways)
    - 5.1.f Carcinogenic risk (individual stressors, all pathways)
    - 5.2 Future Land-Use Conditions (Human Health)
    - 5.2.a Carcinogenic risk of individual stressors in individual pathways
    - 5.2.b Chronic hazard quotient calculation (individual stressors, individual pathways)
    - 5.2.c Subchronic hazard quotient calculation (individual stressors, individual pathways)
    - 5.2.d Noncarcinogenic hazard index (individual stressors, all pathways)
    - 5.2.e Carcinogenic risk (individual stressors, all pathways)
- 5.3 Uncertainties
    - 5.3.a Site-specific uncertainty factors
        - 5.3.a.1 Definition of physical setting
        - 5.3.a.2 Model applicability and assumptions
        - 5.3.a.3 Parameter values for fate or transport and exposure calculations
    - 5.3.b Summary of toxicity assessment uncertainty
        - 5.3.b.1 Uncertainty and identification of potential human health effects

- 5.3.b.2 Derivation of toxicity value including completeness of overall database
- 5.3.b.3 Potential for synergistic or antagonistic interactions
- 5.3.b.4 Uncertainty in evaluating less-than-lifetime exposures

5.4 Comparison of Risk Characterization Results to Human Studies (if available)

- 5.4.a Health assessment from the Agency for Toxic Substances and Disease Registry (ATSDR)
- 5.4.b Site-specific health studies (pilot studies or epidemiological studies)
- 5.4.c Incorporation of studies into the overall risk characterization

5.5 Summary Discussion and Tabulation of the Risk Characterization

- 5.5.a Key site-related stressors and key exposure pathways identified
- 5.5.b Types of health risk of concern
- 5.5.c Level of confidence in the quantitative information used to estimate risk
- 5.5.d Presentation of qualitative information on toxicity
- 5.5.e Confidence in the key exposure estimates for the key exposure pathways
- 5.5.f Magnitude of the carcinogenic and noncarcinogenic risk estimates
- 5.5.g Magnitude of chronic and subchronic risk estimates
- 5.5.h Major factors contributing to risk
- 5.5.i Major factors (COCs and Pathways) contributing to uncertainty
- 5.5.j Exposed population and community characteristics
- 5.5.k Comparison with site-specific health studies
- 5.5.l Comparison of chemical concentrations with natural background

6.0 SUMMARY AND CONCLUSIONS

- 6.1 Stressors of Potential Concern
- 6.2 Exposure Assessment
- 6.3 Toxicity Assessment
- 6.4 Risk Characterization
- 6.5 Uncertainties

Outline of Components of an Ecological Baseline Risk Assessment

This is a general outline and not all components of the outline are applicable to all sites.

STEP 1: SCREENING-LEVEL PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

1.1 INTRODUCTION

1.2 SCREENING-LEVEL PROBLEM FORMULATION

  1.2.1 Environmental Setting and Contaminants at the Site

  1.2.2 Contaminant Fate and Transport

  1.2.3 Ecotoxicity and Potential Receptors

  1.2.4 Complete Exposure Pathways

  1.2.5 Assessment and Measurement Endpoints

1.3 SCREENING-LEVEL ECOLOGICAL EFFECTS EVALUATION

  1.3.1 Preferred Toxicity Data

  1.3.2 Dose Conversions

  1.3.3 Uncertainty Assessment

1.4 SUMMARY

STEP 2: SCREENING-LEVEL EXPOSURE ESTIMATE AND RISK CALCULATION

2.1 INTRODUCTION

2.2 SCREENING-LEVEL EXPOSURE ESTIMATES

  2.2.1 Exposure Parameters

  2.2.2 Uncertainty Assessment

2.3 SCREENING-LEVEL RISK CALCULATION

2.4 SCIENTIFIC/MANAGEMENT DECISION POINT (SMDP)

2.5 SUMMARY

STEP 3: BASELINE RISK ASSESSMENT PROBLEM FORMULATION

3.1 THE PROBLEM-FORMULATION PROCESS

3.2 REFINEMENT OF PRELIMINARY CONTAMINANTS OF CONCERN

3.3 LITERATURE SEARCH ON KNOWN ECOLOGICAL EFFECTS

3.4 CONTAMINANT FATE AND TRANSPORT, ECOSYSTEMS POTENTIALLY AT RISK, AND COMPLETE EXPOSURE PATHWAYS

3.4.1 Contaminant Fate and Transport

3.4.2 Ecosystems Potentially at Risk

3.4.3 Complete Exposure Pathways

3.5 SELECTION OF ASSESSMENT ENDPOINTS

3.6 THE CONCEPTUAL MODEL AND RISK QUESTIONS

3.6.1 Conceptual Model

3.6.2 Risk Questions

3.7 SCIENTIFIC/MANAGEMENT DECISION POINT (SMDP)

3.8 SUMMARY

STEP 4: STUDY DESIGN AND DATA QUALITY OBJECTIVE PROCESS

4.1 ESTABLISHING MEASUREMENT ENDPOINTS

4.1.1 Species/Community/Habitat Considerations

4.1.2 Relationship of the Measurement Endpoints to the Contaminant of Concern

4.1.3 Mechanisms of Ecotoxicity

4.2 STUDY DESIGN

4.2.1 Bioaccumulation and Field Tissue Residue Studies

4.2.2 Population/Community Evaluations

4.2.3 Toxicity Testing

4.3 DATA QUALITY OBJECTIVES AND STATISTICAL CONSIDERATIONS

4.3.1 Data Quality Objectives

4.3.2 Statistical Considerations

4.4 CONTENTS OF WORK PLAN AND SAMPLING AND ANALYSIS PLAN

4.4.1 Work Plan

4.4.2 Sampling and Analysis Plan

4.4.3 Field Verification of Sampling Plan and Contingency Plans

4.5 SCIENTIFIC/MANAGEMENT DECISION POINT (SMDP)

4.6 SUMMARY

STEP 5: FIELD VERIFICATION OF SAMPLING DESIGN

5.1 PURPOSE

5.2 DETERMINING SAMPLING FEASIBILITY

5.3 SCIENTIFIC/MANAGEMENT DECISION POINT (SMDP)

5.4 SUMMARY

STEP 6: SITE INVESTIGATION AND ANALYSIS PHASE

6.1 INTRODUCTION

6.2 SITE INVESTIGATION

- 6.2.1 Changing Field Conditions
- 6.2.2 Unexpected Nature or Extent of Contamination

6.3 ANALYSIS OF ECOLOGICAL EXPOSURES AND EFFECTS

- 6.3.1 Characterizing Exposures
- 6.3.2 Characterizing Ecological Effects

6.4 SCIENTIFIC/MANAGEMENT DECISION POINT (SMDP)

6.5 SUMMARY

STEP 7: RISK CHARACTERIZATION

7.1 INTRODUCTION

7.2 RISK ESTIMATION

7.3 RISK DESCRIPTION

- 7.3.1 Threshold for Effects on Assessment Endpoints
- 7.3.2 Likelihood of Risk
- 7.3.3 Additional Risk Information

7.4 UNCERTAINTY ANALYSIS

- 7.4.1 Categories of Uncertainty
- 7.4.2 Tracking Uncertainties

7.5 SUMMARY

STEP 8: RISK MANAGEMENT

8.1 INTRODUCTION

8.2 ECOLOGICAL RISK MANAGEMENT

- 8.2.1 Other Risk Management Considerations
- 8.2.2 Ecological Impacts of Remedial Options
- 8.2.3 Monitoring

8.3 SCIENTIFIC/MANAGEMENT DECISION POINT (SMDP)

8.4 SUMMARY

Appendix C

Human Health Screening Values

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Development of Risk Based Concentrations for Environmental Remediation in Kentucky

Introduction

This appendix details the procedures used to develop risk-based concentrations that will be used for the Voluntary Environmental Remediation Program, KRS 224.01-400 and KRS 224.01-405 cleanups, and other programs where risk-based concentrations are needed. Documents from the United States Environmental Protection Agency were consulted in the process of developing this document and the procedures used in calculating risk-based concentrations.

Application

It is intended for this table to have several applications to sites undergoing environmental remediation. Applications include: preliminary screening of site contaminants, closure of small spills, determination of potential toxic conditions, and reduction and refinement of the number of Chemicals of Concern (COCs) at a site during a baseline risk assessment. The values are also one of the factors that should be considered when selecting remedial goals. The values consider the more common exposure routes but if an individual site has other exposure routes that play a major role in the site-related exposures, these values may underestimate the risk.

Calculation of Risk-Based Values

The formulae for calculating the risk-based concentrations are primarily from U.S. EPA guidance including Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A), commonly referred to as RAGS Part A (U.S. EPA, 1989), RAGS part B (U.S. EPA, 1991), Soil Screening Guidance: Users Guide (U.S. EPA, 1996c), and Soil Screening Guidance: Technical Background Document (U.S. EPA, 1996b). "Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water" (Schaum *et al.*, 1994) was used to represent the inhalation exposure to water based on the Whole House Dispersion Model. The assumptions that are used in estimating the risk-based concentrations are selected to be protective of sensitive subpopulations.

KYDEP incorporated applicable exposure routes into each medium of exposure. For residential and occupational exposure to soil; ingestion, dermal and inhalation exposure was considered. Dermal exposure to soil used default absorption values of 0.25 for volatiles, 0.1 for semivolatiles, and 0.05 for metals. Default dermal absorption factors were derived from literature reviews of dermal absorption. The Agency for Toxic Substances and Disease Registry

(ATSDR) Toxicological Profiles were a valuable source of absorption and chemical specific data. Ten compounds had chemical-specific dermal absorption rates as listed in RAGS Part E (U.S, EPA, 2000a). Inhalation of contaminants found in soil used two factors: a Volatilization Factor (VF), and a Particulate Emission Factor (PEF). Potential volatilization from soil to air was represented for volatiles by the volatilization factor that was calculated using the formula in the Soil Screening Guidance: User's Guide (U.S. EPA, 1996c). A compound was assumed to be volatile when the molecular weight was less than 200 mg/mol and the Henry's Law Constant (H) was greater than 10^{-5} atm-m^3/mol. The respective default dispersion factor for residential and commercial/industrial exposures were derived for Kentucky sites using exhibit 11 in U.S. EPA, 1996c. Climatic zone VII was used to calculate the dispersion factor term since that is the logical zone for Kentucky sites. For a residential dispersion factor, the 90% lower confidence limit was calculated for a 0.5-acre site size. A commercial/industrial value for dispersion factor was calculated based the 90% lower confidence limit of the values listed under a site size of 5 acres.

Inhalation was the route that was used for air exposures. Tap water exposure used ingestion and inhalation, the latter using the Schaum (1994) Whole House Exposure Model. The model describes the average indoor air concentration as a result of water use throughout the house. This model considers water use such as washing dishes, bathing, washing clothes, and cooking. The formula is:

$$C_a = \frac{WHF \times C_w \times f}{HV \times ER \times MC}$$

where:

Ca = concentration in air, mg/m^3

Cw = concentration in water, mg/L

WHF = water flow rate in whole house, 890 L/day

HV = house volume, 450 m^3

ER = exchange rate, 10 air changes/day

MC = mixing coefficient, 0.5 (unitless)

f = fraction of contaminant that volatilizes, 0.5 (unitless)

The default values for these parameters were selected from the text of the Schaum (1994) chapter and are listed following the description.

Formulae

The formulae for calculation of the risk-based values are the result of taking the standard exposure equations used in risk assessments and solving for the concentration term. Toxicity values were used to represent the potential toxicity of each compound. These values are obtained from several sources. The source is listed next to each toxicity value. The abbreviations in order of preference are: “i” U.S. EPA’s Integrated Risk Information System (IRIS), “h” U.S. EPA’s Health Effects Assessment Summary Tables (HEAST), “n” U.S. EPA’s National Center for Environmental Assessment (NCEA), “w” withdrawn from IRIS or HEAST, “o” other EPA documents, “r” route extrapolation, and “s” when the toxicity value of a surrogate compound was used based on physicochemical characteristics. The Risk-Based Screening Values are based on a target risk of 1 x 10^{-6} for carcinogens and a Hazard Index of 1.0 for noncarcinogens in each media. The carcinogenic risk of 1 x 10^{-6}, or one excess cancer in one million is standard practice in risk assessment for *de minimis* risk. The target Hazard Index of 1.0 indicates that the noncarcinogenic risk is below a toxicity threshold represented by the reference dose. The basis for each screening value in the table is denoted by “ca” for a carcinogenic endpoint, and “nc” for a noncarcinogenic endpoint. A soil saturation limit was derived using the formula in U.S. EPA, 1996c. A ceiling limit was set at 10^{+5} as a maximum soil concentration. If the risk-based screening value exceeded the saturation limit or the maximum, then the soil screening value was set at the saturation limit (denoted as “sat”) or the maximum ceiling limit (denoted as “max”) The following formulae were used to calculate the risk-based screening values for each media.

Noncarcinogenic Effects

Residential Soil

$$\frac{(ED\_c \times BW\_c \times 365 \times THQ)}{(IRA\_c \times (1/VF + 1/PEF\_r) \times EF\_r \times ED\_c \times 1/RfDi) + (SA\_c \times AF \times ABS \times EF\_r \times ED\_c \times 0.000001 \times 1/RfDo) + (IRS\_c \times EF\_r \times ED\_c \times 0.000001 \times 1/RfDo)}$$

Commercial/Industrial Soil

$$\frac{(ED\_a \times BW\_a \times 365 \times THQ)}{(IRA\_a \times (1/VF + 1/PEF\_o) \times EF\_o \times ED\_o \times 1/RfDi) + (SA\_i \times AF \times ABS \times EF\_o \times ED\_o \times 0.000001 \times 1/RfDo) + (IRS\_o \times EF\_o \times ED\_o \times 0.000001 \times 1/RfDo)}$$

Ambient Air

$$\frac{(ED\_c \times BW\_c \times 365 \times THQ \times RfDi \times 1000)}{(IRA\_c \times EF\_r \times ED\_c)}$$

Tap Water

$$\frac{(BW\_c \times ED\_c \times 365 \times THQ \times 1000)}{(\frac{(IRW\_c<3\times 3)+(IRW\_c>3\times 3)}{ED\_c} \times EF\_r \times ED\_c \times 1/RfDo)+(\frac{(890\times 0.5)}{(450\times 10\times 0.5)} \times IRA\_c \times EF\_r \times ED\_c \times 1/RfDi)}$$

Carcinogenic Effects

Residential Soil

$$\frac{(AT \times 365 \times TR)}{(InF\_adj \times (1/VF + 1/PEF\_r) \times EF\_r \times SFi)+(SFS\_adj \times AF \times ABS \times EF\_r \times 0.000001 \times SFo)+(IFS\_adj \times EF\_r \times 0.000001 \times SFo)}$$

Commercial/Industrial Soil

$$\frac{(AT \times BW\_a \times 365 \times TR)}{(IRA\_a \times (1/VF + 1/PEF\_o) \times EF\_o \times ED\_o \times SFi)+(SA\_i \times AF \times ABS \times EF\_o \times ED\_o \times 0.000001 \times SFo)+(IRS\_o \times EF\_o \times ED\_o \times 0.000001 \times SFo)}$$

Ambient Air

$$\frac{(AT \times 365 \times TR \times 1000)}{(InhF\_adj \times EF\_r \times SFi)}$$

Tap Water

$$\frac{(AT \times 365 \times TR \times 1000)}{(IFW\_adj \times EF\_r \times SFo)+(\frac{(890 \times 0.5)}{(450 \times 10 \times 0.5)} \times InhF\_adj \times EF\_r \times SFi)}$$

Four age adjusted factors were calculated for carcinogenic exposure calculations. The formula for each factor is shown below.

Ingestion Factor for Soil

$$\left(\frac{IRS\_c \times ED\_c}{BW\_c}\right)+\left(\frac{IRS\_a \times ED\_adol}{BW\_adol}\right)+\left(\frac{IRS\_a \times ED\_a}{BW\_a}\right)$$

Skin Contact Factor for Soil

$$\left(\frac{SA\_c \times ED\_c}{BW\_c}\right)+\left(\frac{SA\_adol \times ED\_adol}{BW\_adol}\right)+\left(\frac{SA\_a \times ED\_a}{BW\_a}\right)$$

Inhalation Factor

$$\left(\frac{IRA\_c \times ED\_c}{BW\_c}\right) + \left(\frac{IRA\_a \times ED\_adol}{BW\_adol}\right) + \left(\frac{IRA\_a \times ED\_a}{BW\_a}\right)$$

Ingestion Factor for Water

$$\left(\frac{IRW\_c < 3 \times 3}{BW\_c}\right) + \left(\frac{IRW\_a, c > 3 \times 3}{BW\_c}\right) + \left(\frac{IRW\_a, c > 3 \times ED\_adol}{BW\_adol}\right) + \left(\frac{IRW\_a, c > 3 \times ED\_a}{BW\_a}\right)$$

Table 1 summarizes the exposure factors that were used to calculate the risk-based screening values.

Table 1. Exposure Factors

Parameter (units)	**Value**	**Abbreviation**
Target Cancer Risk	1 x 10^{-6}	TR
Target Hazard Quotient	1	THQ
Body weight, age 1-6 (kg)	15	BW_c
Body weight adolescent (kg)	43	BW_adol
Body weight, adult (kg)	70	BW_a
Surface area , child (cm^2/day)	2800	SA_c
Surface area , adolescent (cm^2/day)	7500	SA_adol
Surface area , adult resident (cm^2/day)	5700	SA_a
Surface area , adult industrial (cm^2/day)	3300	SA_i
Adherence factor (mg/cm^2)	1	AF
Dermal absorption in soil (volatiles)	0.25	ABS_vol
Dermal absorption in soil (semivolatiles)	0.1	ABS_semi
Dermal absorption in soil (metals)	0.05	ABS_met
Averaging time (years)	70	AT
Inhalation rate (m^3/d)	20	IRA_a
	20	IRA_c
Drinking water ingestion (L/d)	2	IRW_a, c>3
	1	IRW_c<3
	1	IRW_o
Volatilization factor - soil (m^3/kg)	Chemical specific	VF_S
Particulate emission factor (m^3/kg)	9.3E+08	PEF_r
	6.2E+08	PEF_o
Soil ingestion - adolescent & adult resident (mg/d)	100	IRS_a
Soil ingestion - age 1-6 (mg/d)	200	IRS_c
Soil ingestion – commercial/industrial (mg/d)	50	IRS_o
Exposure frequency (d/yr)	350	EF_r
Commercial/Industrial Exposure Frequency (d/yr)	250	EF_o
Exposure duration, age 1-6 (yr)	6	ED_c
Exposure duration, age 7-18 (yr)	12	ED_adol
Exposure duration, adult (yr)	12	ED_a
Commercial/Industrial Exposure Duration (yr)	25	ED_o
Total residential duration (yr)	30	ED_total
Age-adjusted factors (for carcinogens only)		
Ingestion factor for soils ([mg*yr]/[kg*d])	125.050	IFS_adj
Skin contact factor for soils ([cm^2*yr]/[kg*d])	4190.166	SFS_adj
Inhalation factor ([m^3*yr]/[kg-d])	17.010	InhF_adj
Ingestion factor for water ([L*yr]/[kg-d])	1.501	IFW_adj

The formulae for calculating the volatilization factor (VF), particulate emission factor (PEF), and soil screening levels (SSL) are contained in the Soil Screening Guidance: Users Guide (U.S. EPA, 1996c) and are listed below. The assumptions for those calculations are listed in the Soil Screening Guidance: Users Guide. The only factors in this document that were different were the dispersion factor (Q/C) values for residential (64.177) and commercial/industrial (43.07). The Kentucky-specific values for Q/C were estimated based on the 90% Lower Confidence Level of the mean dispersion factor of Climatic Zone VII of Table 3 of the SSL Technical Background Document (U.S. EPA, 1996b). Volatilization Factors are used in the soil exposure scenario to estimate partitioning between soil and vapor in the exposure zone, and the particulate emission factor represents the concentration of respirable particulates in air. The chemical specific values of D_i in the VF calculation were obtained from the U.S. EPA Region 9 Preliminary Remediation Goals Table dated November 1, 2000. Region 9 used several sources: Superfund Exposure Assessment Manual (U.S. EPA, 1988), Subsurface Contamination Reference Guide (U.S. EPA, 1990c), Fate and Exposure Data (Howard, 1991), and the Superfund Chemical Data Matrix (U.S. EPA 1994). Some chemicals required the use of a surrogate for physicochemical data based on chemical structure and characteristics.

The Soil Screening Level uses modeling to estimate soil concentrations that are protective of human health exposure to groundwater with a Dilution and Attenuation Factor of 1. The endpoint that was chosen for the SSL was the MCL from U.S. EPA (2001b) or the risk-based tap water concentration as calculated in the table if an MCL was not available.

Volatilization Factor

$$VF(m^3/kg) = \frac{Q/C \times (3.14 \times D_A \times T)^{1/2} \times 10^{-4}(m^2/cm^2)}{2 \times \rho_b \times D_A}$$

where

$$D_A = \frac{\left(\theta_a^{10/3} \times D_i \times H' + \theta_w^{10/3} \times D_w\right)/n^2}{\rho_b \times K_d + \theta_w + \theta_a \times H'}$$

and:

Q/C = *64.177 (residential)*
43.07 (commercial/industrial)
T = *9.5E+8 seconds*
ρ_b = *1.5 g/cm3*
θ_a = *0.28* L_{air}/L_{soil}
D_i = *chemical-specific*
H' = *H x 41*
H = *Henry's Law Constant (chemical-specific)*
θ_w = *0.15* L_{water}/L_{soil}
D_w = *chemical-specific*
n = *0.43* L_{pore}/L_{soil}
K_d = *chemical-specific*

Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3600s/h}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$$

where:
Q/C = *64.177 (residential)*
43.07 (commercial/industrial)
V = *0.5 (unitless)*
U_m = *4.69 m/s*
U_t = *11.32 m/s*
F(x) = *0.194 (unitless)*

Soil Screening Level

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

where the C_w is the MCL or risk-based tap water value in mg/L from the table.

and:
K_d = *chemical-specific*
θ_w = $0.3\ L_{water}/L_{soil}$
θ_a = $0.13\ L_{air}/L_{soil}$
H' = *H x 41*
H = *Henry's Law Constant (chemical-specific)*
ρb = *1.5 g/cm3*

Exceptions

There are a few exceptions to the standard procedures described in this document where modifications in the exposure assumptions or toxicity value were necessary to meet a certain class of chemicals.

Metals. Many of the metals only have oral toxicity values listed in IRIS or HEAST. In order to have complete information, it was necessary to extrapolate the oral toxicity values to inhalation exposures as well. The exposure routes were also modified based on the characteristics of metals. Soil exposure included ingestion, dermal exposure, and particulate inhalation. Exposure to tap water considered only ingestion. Elemental mercury, even though it is a metal, was assumed to be a volatile for exposure to soil and water. These conditions fit typical exposure conditions for tap water. If a site has potential exposure to mists containing metals in water, then exposure via inhalation should be considered in a site-specific tap water screening value calculated for the site using the formulae contained in this document.

Gases. Some of the constituents on the table are considered to be gases or vapors at standard temperature. In consideration of their physical state, both soil and water exposure consider only inhalation since their residence time in soil would not be expected to be long for ingestion or dermal exposure.

Extrapolation. Some chemicals had only oral or inhalation toxicity values listed on the Region IX PRGs Table. In those cases, extrapolation was necessary. Literature reviews were done to verify the potential for effects in other media of exposure.

Lead. U.S. EPA has implemented use of the IEUBK Model to estimate environmental levels that will result in a target blood lead level. KYDEP performed a review of lead issues (KYDEP, 1996) and determined that the most appropriate metric for lead risk assessment was the RfD_o and RfD_i derived based on the LOAEL in laboratory rats. For further discussion of lead see the Lead Issues document (KYDEP, 1996). KYDEP also has an action level of 50 ppm in residential or unrestricted use in soil, 400 ppm in commercial or industrial soils, and a tap water action level of 0.015 mg/L that are listed on the table. The soil value of 50 mg/kg was originally developed in the UST program.

MTBE. Methyl t-Butyl Ether had an oral RfD issued by NCEA, which was withdrawn. The RfD was retained and listed as withdrawn on the table. U.S. EPA has a Drinking Water Advisory: Consumer Acceptability Advisory level in water of 20 µg/L to 40 µg/L based on odor and taste, respectively. This is below the carcinogenic and noncarcinogenic risk-based numbers.

PCBs. PCBs also received special consideration. KYDEP has used the high risk value of 2.0 $(mg/kg\text{-}day)^{-1}$ based on the observation that as a mixture of PCBs weathers, the lower chlorinated biphenyls are more likely to degrade, leaving the higher chlorinated biphenyls in a higher proportion. Since the higher chlorinated biphenyl mixture (Arochlor 1260) exhibit more toxicity, the high-risk value was used for the screening values. For noncarcinogenic effects, the table has two mixtures listed. Arochlor 1254 is applied by KYDEP for the higher chlorinated mixtures (Arochlor 1260, 1254, and 1248) and the Arochlor 1016 value is applied to mixtures that are less chlorinated (1242, 1016).

How To Use the Table

When evaluating an area using the screening values, it is useful to develop a Conceptual Site Model to verify that it fits into the assumptions that were used to derive the screening values. The first step is to identify the areas of potential contamination and analyze grab samples for a broad range of potential contaminants (typically the HSL, TAL/TCL, etc.) in several samples to refine analytical parameters. The contaminants of potential concern are then identified. The potential ecological and human health receptors should be determined and also the potential pathways of exposure.

The screening values table is organized with the toxicity values in the left-hand columns, each one followed by the source of the RfD or Slope Factor. The VOC Column identifies (with "1" being volatile) which compounds use a volatilization factor in the soil exposure. The soil dermal absorption value is shown for each compound, and the Chemical Abstract Service (CAS) registry number and contaminant name are shown. The next four columns represent the risk-based concentration associated with each of the contaminants for soil, air, and water.

The Soil Screening Levels are determined for most volatiles and the compounds listed in the Soil Screening Guidance (U.S. EPA, 1996c). The Dilution and Attenuation Factor (DAF) of 1 is applicable for a screening value where there is the potential for shallow aquifers, karst terranes (a major factor in Kentucky), and areas of significant permeability. It is possible to develop Soil Screening Values for a higher DAF if site-specific information indicates that the depth to groundwater, soil type, and geological formations support that there is significant dilution between the contaminated zone and the groundwater. 401 KAR 100:100 Section 5(5) establishes procedures to modify the SSL based on site-specific conditions.

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Appendix D

Ecological Screening Values

Available on www.kentucky.gov

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Appendix E
Radionuclide Screening Values
Available on www.kentucky.gov

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Appendix F

Checklist for Ecological Assessment/Sampling

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Checklist for Ecological Assessment/Sampling

I. SITE DESCRIPTION

1. Site Name: ____________________
Location: ____________________
____
County: ____________ City: ____________ State: ____________

2. Latitude: ____________ Longitude: ____________

3. What is the approximate area of the site? ____________________

4. Please attach to the checklist USGS topographic map(s) of the site, if available.

5. Are aerial or other site photographs available? ☐ yes ☐ no If yes, please attach any available photo(s).

6. What type of facility is located at the site?
☐ Chemical ☐ Manufacturing ☐ Mixing ☐ Waste disposal
☐ Other (specify) ____________________

7. What are the suspected contaminants of concern at the site? If known, what are the maximum concentration levels?

8. Do any potentially sensitive environmental areas exist adjacent to or in proximity to the site, e.g., Federal and State parks, National and State monuments, wetlands, lakes, streams? *Remember, flood plains and wetlands are not always obvious; do not answer "no" without confirming information.*

9. Please provide the source(s) of information used to identify these sensitive areas, and indicate their general location on the site map.

10.

The land use on the site is:	The area surrounding the site is:
	____________________ mile radius
_____% Urban	_____% Urban
_____% Rural	_____% Rural
_____% Residential	_____% Residential
_____% Industrial (☐ light ☐ heavy)	_____% Industrial (☐ light ☐ heavy)
_____% Agricultural	_____% Agricultural
(*Crops*:_______________________)	(*Crops*:_______________________)
_____% Recreational	_____% Recreational
(Describe; note if it is a park, etc.)	*(Describe; note if it is a park, etc.)*
_____________________________	_____________________________
_____________________________	_____________________________
_____% Undisturbed	_____% Undisturbed
_____% Other	_____% Other

11. If known, what is the approximate depth to the water table? _______________________________

12. Is the direction of surface runoff apparent from site observations? ☐ yes ☐ no If yes, to which of the following does the surface runoff discharge? Indicate all that apply.

☐ Surface water ☐ Groundwater ☐ Sewer ☐ Collection impoundment

13. Is there a navigable waterbody or tributary to a navigable waterbody? ☐ yes ☐ no

14. Is there a waterbody anywhere on or in the vicinity of the site?

☐ yes (approx. distance____________________) ☐ no

15. Is there evidence of flooding? ☐ yes ☐ no *Wetlands and flood plains are not always obvious; do not answer "no" without confirming information.*

16. Are any threatened and/or endangered species (plant or animal) known to inhabit the area of the site?

☐ yes ☐ no

17. Are there any wooded areas at the site? ☐ yes ☐ no.

18. What percentage or area of the site is wooded? (_____% _____ acres). Indicate the wooded area on the site map which is attached to a copy of this checklist.

19. Is shrub/scrub vegetation present at the site? ☐ yes ☐ no.

20. What percentage of the site is covered by scrub/shrub vegetation? (_____% _____ acres). Indicate the areas of shrub/scrub on the site map.

21. Are there open (bare, barren) field areas present at the site? ☐ yes ☐ no

22. What percentage of the site is open field? (_____% _____ acres). Indicate the open fields on the site map.

23. Based on observations and/or available information, are designated or known wetlands definitely present at the site? ☐ yes ☐ no

24. Please note the sources of observations and information used (e.g., USGS Topographic Maps, National Wetland Inventory, Federal or State Agency, etc.) to make this determination.

25. CONTINUE WITH ECOLOGICAL RISK ASSESSMENT. **YES_____** **NO_____**

Record weather conditions at the time this checklist was prepared:

DATE: ______________________

______________Temperature (EC/EF) ______________Normal daily high temperature

______________Wind (direction/speed) ______________Precipitation (rain, snow)

______________Cloud cover

Completed by ____ Affiliation ___________________

Additional Preparers ____

Site Manager____

Date ___

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Appendix G

Development of Generic Background Concentrations for Kentucky Soils

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Development of Generic Background Concentrations for Kentucky Soils

Background, as defined in 401 KAR 42:005 (definitions codified to support the Underground Storage Tank regulations), means the concentration of substances consistently present in the environment at, or regionally proximate to, a release but outside the influence of the release. There are two types of background:

a) Natural background is the amount of naturally occurring substances in the environment, exclusive of that from anthropogenic sources.

b) Ambient background means the concentrations of naturally-occurring inorganic substances and ubiquitous anthropogenic inorganic substances in the environment that are representative of the region surrounding the site and not attributable to activities on the property.

Since sites undergoing environmental assessment are often found in industrialized and potentially contaminated areas, the determination of site-specific background concentrations is difficult. Generic ambient background values applicable to all sites in Kentucky would be useful for comparison to site data for the purpose of identifying those constituents requiring remedial action (i.e., removal or exposure control). These generic ambient background values would provide a party or VERP applicant an alternative to attempting to identify site-specific background soils in areas that are likely contaminated.

To address this issue, the NREPC used background sample values provided by regulated facilities, as well as background sample values collected by cabinet employees. These samples were collected from areas generally considered to be outside of the influence of site activities, but were potentially impacted by regional or citywide activity. Therefore, these samples represent "ambient," as opposed to "natural," background. From 400 to over 800 samples for each constituent were used in the analysis. For each constituent, a 95% Upper Confidence Limit (UCL) of the arithmetic mean, 60th Percentile, and 95th percentile were calculated. The 95% UCL is the value that represents that the mean of the data set falls below that value with 95% confidence. The 60th and 95th percentiles indicate that 60 percent and 95 percent of the data falls below those values.

The following methodology was employed to calculate ambient background:

1. Values reported as "non-detected" were retained in the database at ½ the reporting limit (USEPA, 1998).

2. As the data sets came from areas having varied uses (e.g., industrial, commercial, residential, agricultural, woodlands, etc.), the probability that some of the samples were taken in contaminated areas is significant. Data sets were tested for outliers by the Grubb's test, and individual samples that had a calculated Z-score above 3.8 were generally removed from the background data set. The Grubb's test formula is as follows:

$$Z = \frac{\left| population\ mean - value\ of\ individual\ sample \right|}{standard\ deviation}$$

3. The descriptive statistics of mean and standard deviation were calculated by standard parametric methods assuming normality and are listed in Table G-1. Parametric methods were used to allow for comparisons between NREPC background values and other published values.

   a. Standard deviation was calculated by the "nonbiased" method employing the formula:

$$S.D. = \sqrt{\frac{\sum \left(X_i - \overline{X}\right)^2}{n-1}}$$

   b. Mean was calculated as the sum of all individual scores divided by the total number of observations.

4. The data sets were analyzed with Lillefor's test for normality. Since the data sets are not normally or log normally distributed, the parameters that are to be used in determining if site samples are consistent with background (i.e. 95% UCL of mean, 60th percentile and 95th percentile) were calculated by nonparametric methods and are listed in Table G-2.

5. The 95% upper confidence limit of the arithmetic mean for each constituent was calculated on the trimmed data set using ProUCL. ProUCL is a statistical package developed by Lockheed Martin under contract with the U.S. EPA.

6. The 60th percentile value is used as the midpoint for each constituent. It was calculated as follows:
   a. The constituent values were ranked in increasing order of magnitude.
   b. The quantity 60(n)/100 was used to identify the measurement with the resulting rank.

7. The 95th percentile value is used as the upper bound value for each constituent and was calculated as follows:
   a. The constituent values were ranked in increasing order of magnitude.
   b. The quantity 95(n)/100 was used to identify the measurement with the resulting rank.

The thallium data were characterized by a large number of non-detects (633 non-detects verses 54 detects). Due to the large number of non-detects, non-detects were <u>not</u> entered as ½ the non-detect concentration. Each non-detect sample was assumed to have a concentration equal to the recorded non-detect concentration. Considering the number of non-detects and the likelihood that the recorded values skew thallium concentrations upward, only the 95th percentile of the total data is cited in table G-2.

Comparison to Background

- The mean site concentration for inorganic constituents must be below the 95% UCL of the mean concentrations of background for inorganic constituents. At least ½ of the data points should be less than the midpoint (60th percentile), and no data point above the upper bound value (95th percentile). The site data should be segregated by surface and subsurface data. The surface and subsurface site data may be compared to the statewide numbers in Table G-2, or to site-specific background samples.

Horizontal and Vertical Extent

401 KAR 100:100 Section 5(4) states that during site characterization, a minimum of two additional sampling locations is required for each sampling point at the edge of an area of concern that exceeds the method detection limit or ambient background and shall be located at a

minimum distance of ten (10) feet from the previous sampling point that had a confirmed exceedance of method detection limits, or ambient background. The following criteria may be used to determine if the sampling point exceeds generic or site-specific ambient background.

- If the value for the individual sample is less than the 95% UCL of the arithmetic mean of background, then no additional samples are required.
- If the sampling point is greater than the 95th percentile of background, then a minimum of two additional sampling points are required.
- If the sampling point is between the 95% UCL of background and the 95th percentile of background, then the complete dataset needs to be evaluated to determine if two additional sampling locations are required. If at least half of all data points at the edge of the AOC are at or below the 95% UCL of background and the remaining data points are between the 95% UCL of background and the 95th percentile of background, then no additional samples are required. If this criteria is not met, then two additional sampling points are required.

The cabinet may require additional sample locations if the data indicate that the extent of contamination has not been determined.

Literature Cited

United States Environmental Protection Agency (USEPA), 1995. Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites. Office of Research and Development. Office of Solid Waste and Emergency Response. EPA/540/S-96/500. December, 1995.

United States Environmental Protection Agency (USEPA), 1998. Statistical Tests for Background Comparison at Hazardous Waste Sites. Supplemental Guidance to RAGS: Region 4 Bulletins – Addition #1. Interim Draft. USEPA Region 4, Waste Management Division. Atlanta, Georgia. November, 1998.

Table G-1. Summary Statistics for Ambient Inorganic Chemicals

Element	**Number of Samples**	**Range (mg/kg)**	**Mean (mg/kg)**	**Standard Deviation (mg/kg)**
Aluminum	679	1290 - 38,100	10969	5462.9
Arsenic	539	0.059 - 55.5	8.9	7
Barium	756	6.14 – 1160	111.3	92.4
Beryllium	696	0.061 - 3.57	0.8	0.5
Cadmium	701	0.004 - 9.46	0.68	1.4
Chromium	771	2.83 - 168	20.5	13.9
Cobalt	649	0.29 - 67.6	11.9	8.1
Copper	729	0.49 - 636	18.9	39.7
Iron	697	222 - 86,900	22456	13269.7
Lead	808	0.03 - 284	30	31.3
Manganese	685	8.43 - 5100	1017	854.9
Mercury	459	0.007 - 0.721	0.06	0.1
Nickel	716	0.39 - 83.7	20.9	13.1
Selenium	714	0.001 - 3.93	0.94	0.7
Silver	697	0.006 - 5.2	0.42	0.6
Thallium	633	0.13 - 28		
Vanadium	679	4.82 - 92.1	26.9	11.8
Zinc	721	6 - 470	55	46.3

Table G-2. Generic Statewide Ambient Background for Kentucky

Element	**Mean (mg/kg)**	**95% UCL of Mean (mg/kg)**	**60th Percentile (mg/kg)**	**95th Percentile (mg/kg)**
Aluminum	10969	11314	10800	21000
Arsenic	8.9	9.4	8.3	21.2
Barium	111.3	116.9	100	241
Beryllium	0.8	0.83	0.75	1.8
Cadmium	0.68	0.78	0.27	3.9
Chromium	20.5	21.3	19.3	40
Cobalt	11.9	12.4	13.1	25.1
Copper	18.9	21.3	13.8	41.7
Iron	22456	23284	22000	47600
Lead	30	33	20.9	84.6
Manganese	1017	1071	948	2620
Mercury	0.06	0.07	0.059	0.14
Nickel	20.9	21.7	20.2	46.8
Selenium	0.94	0.99	1.38	2.1
Silver	0.42	0.45	0.257	1.2
Thallium				7.95
Vanadium	26.9	27.7	27.3	48.6
Zinc	55	57	48.6	115

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Kentucky Guidance for Ambient Background Assessment

January 8, 2004

Natural Resources and
Environmental Protection Cabinet

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Introduction

This guidance document is intended to assist in comparing site data and background data for sites undergoing environmental assessment. These procedures provide a simplified statistical procedure for determining if the site data is part of the background population. It also provides generic statewide background values for inorganic chemicals that may be used in lieu of collecting site-specific background samples. The statistical procedures may be used for site-specific data or the generic statewide values in Tables 1 and 2. This guidance does not preclude other appropriate statistical comparisons from being made, but rather a simplified screening method that does not require a deep knowledge of statistics. If the site data set fails the statistical procedures in this guidance, it may be appropriate to perform a more complete statistical comparison.

Background, as defined in 401 KAR 42:005 (definitions codified to support the Underground Storage Tank regulations), means the concentration of substances consistently present in the environment at, or regionally proximate to, a release but outside the influence of the release. There are two types of background:

a) Natural background is the amount of naturally occurring substances in the environment, exclusive of that from anthropogenic sources.

b) Ambient background means the concentrations of naturally occurring inorganic substances and ubiquitous anthropogenic inorganic substances in the environment that are representative of the region surrounding the site and not attributable to an identifiable release.

Since sites undergoing environmental assessment are often found in industrialized and potentially contaminated areas, the determination of site-specific background concentrations is difficult. Generic ambient background values applicable to all sites in Kentucky would be useful for comparison to site data for the purpose of identifying those constituents requiring remedial action (i.e., removal or exposure control). These generic ambient background values would provide an alternative to attempting to identify site-specific background soils in areas that are likely contaminated.

Methodology

To provide an alternative to site-specific background sampling, the NREPC used background sample values provided by regulated facilities, as well as background sample values collected by cabinet employees. These samples were collected from areas generally considered to be outside of the influence of site activities, but were potentially impacted by regional or urban activity. Therefore, these samples represent "ambient," as opposed to "natural," background. From 400 to over 800 samples for each constituent were used in the analysis. For each constituent, a 95% Upper Confidence Limit (UCL) of the arithmetic mean, 60th percentile, and 95th percentile were calculated. The 95% UCL is the value below which the true mean of the data set falls, with 95% confidence. The 60th and 95th percentiles indicate that 60 percent and 95 percent of the data falls below those values.

The following methodology was employed to calculate ambient background:

1. Values reported as "non-detected" were retained in the database at half the reporting limit (USEPA, 1998).

2. As the data sets came from areas having varied uses (e.g., industrial, commercial, residential, agricultural, woodlands, etc.), the probability that some of the samples were taken in contaminated areas is significant. Data sets were tested for outliers by the Grubb's test, and individual samples that had a calculated Z-score above 3.8 were generally removed from the background data set. The Grubb's test formula is as follows:

$$Z = \frac{\left| population\ mean - value\ of\ \ individual\ sample \right|}{standard\ \ deviation}$$

3. The descriptive statistics of mean and standard deviation were calculated by standard parametric methods assuming normality and are listed in Table 1. Parametric methods were used to allow for comparisons between these generic ambient background values and the results of other published studies of background.

a. Standard deviation was calculated by the “nonbiased” method employing the formula:

$$S.D. = \sqrt{\frac{\sum\left(X_i - \overline{X}\right)^2}{n-1}}$$

b. Mean was calculated as the sum of all individual scores divided by the total number of observations.

4. The data sets were analyzed with Lillefor’s test for normality. Since the data sets are not normally or lognormally distributed, the parameters that are to be used in determining if site samples are consistent with background (i.e. 95% UCL of mean, 60th percentile and 95th percentile) were calculated by nonparametric methods and are listed in Table 2.

5. The 95% UCL of the arithmetic mean for each constituent was calculated on the trimmed data set using ProUCL. ProUCL is a statistical package developed by Lockheed Martin under contract with the U.S. EPA.

6. The 60th percentile value is used as the midpoint for each constituent. It was calculated as follows:
   a. The constituent values were ranked in increasing order of magnitude.
   b. The quantity 60(n)/100 was used to identify the measurement with the resulting rank.

7. The 95th percentile value is used as the upper bound value for each constituent and was calculated as follows:
   a. The constituent values were ranked in increasing order of magnitude.
   b. The quantity 95(n)/100 was used to identify the measurement with the resulting rank.

The thallium data were characterized by a large number of non-detects (633 non-detects verses 54 detects). Due to the large number of non-detects, non-detects were <u>not</u> entered as ½ the non-detect concentration. Each non-detect sample was assumed to have a concentration equal to the recorded non-detect concentration. Considering the number of non-detects and the likelihood that the recorded values skew thallium concentrations upward, only the 95th percentile of the total data is cited in Table 2.

Procedure for Comparison to Background

The site data should be segregated by surface and subsurface data. The surface and subsurface site data may be compared to the statewide numbers in Table 2, or to site-specific background samples. The following three criteria may be used to demonstrate that the site data is background:

1. The mean site concentration for inorganic constituents must be below the 95% UCL of the mean concentrations of background for inorganic constituents.
2. At least half of the data points should be less than the 60th percentile.
3. No data points should be above the upper bound value (95th percentile).

These procedures provide a tool for comparing site data with either generic statewide or site-specific background using the statistical characteristics of the two populations. Other statistical comparisons may be used, if appropriate.

Determining Site-specific Background

Site-specific ambient background levels may be determined at the site. The site-specific ambient background data set shall consist of an appropriate number of samples for the statistical method employed. The number of samples necessary to characterize site-specific background will vary based on the variability of the data. Twenty data points may be used as a minimum number of samples per horizon (surface and subsurface) as a default number, unless other statistical methods can be used to develop a different number. A site-specific determination of the number of required samples may be calculated based on the statistical characteristics of the background population.

Upgradient groundwater samples are to be obtained from the same hydrogeological unit as the groundwater contamination at the site. The background monitoring wells shall be located hydrogeologically upgradient from the release(s) of concern, unless it can be demonstrated to the cabinet that the upgradient location is undefinable or infeasible.

Background soil samples should be collected from native soil in areas of similar soil type as found at the site. Background concentrations should be determined separately for surface and subsurface areas that are consistent with the on-site investigation.

The following areas are inappropriate to sample when determining soil background unless otherwise necessary to reach a corrective action decision or identify potential sources of contamination:

1. Fill areas;
2. Areas in which management, treatment, handling, storage or disposal activities of any of the following are known or suspected to have occurred: hazardous substances or petroleum, solid or hazardous wastes, or waste waters;
3. Areas within three feet of a roadway;
4. Parking lots and areas surrounding parking lots or other paved areas;
5. Railroad tracks or railway areas or other areas affected by their runoff;
6. Areas of concentrated air pollutant depositions or areas affected by their runoff;
7. Storm drains or ditches presently or historically receiving industrial or urban runoff; or
8. Areas within three feet of any current structure, or the former location of any structure, which is likely to have been painted with lead-based paint.

Literature Cited

United States Environmental Protection Agency (USEPA), 1995. Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites. Office of Research and Development. Office of Solid Waste and Emergency Response. EPA/540/S-96/500. December, 1995.

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Chromium	771	2.83 - 168	20.5	13.9
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Iron	697	222 - 86,900	22456	13269.7
Lead	808	0.03 - 284	30	31.3
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Selenium	714	0.001 - 3.93	0.94	0.7
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Thallium	633	0.13 - 28		
Vanadium	679	4.82 - 92.1	26.9	11.8
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Table 2. Generic Statewide Ambient Background for Kentucky

Element	**Mean (mg/kg)**	**95% UCL of Mean (mg/kg)**	**60th Percentile (mg/kg)**	**95th Percentile (mg/kg)**
Aluminum	10969	11314	10800	21000
Arsenic	8.9	9.4	8.3	21.2
Barium	111.3	116.9	100	241
Beryllium	0.8	0.83	0.75	1.8
Cadmium	0.68	0.78	0.27	3.9
Chromium	20.5	21.3	19.3	40
Cobalt	11.9	12.4	13.1	25.1
Copper	18.9	21.3	13.8	41.7
Iron	22456	23284	22000	47600
Lead	30	33	20.9	84.6
Manganese	1017	1071	948	2620
Mercury	0.06	0.07	0.059	0.14
Nickel	20.9	21.7	20.2	46.8
Selenium	0.94	0.99	1.38	2.1
Silver	0.42	0.45	0.257	1.2
Thallium				7.95
Vanadium	26.9	27.7	27.3	48.6
Zinc	55	57	48.6	115

Kentucky Guidance for Groundwater Assessment Screening

January 15, 2004

Environmental and
Public Protection Cabinet

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Introduction

This document provides guidance for evaluating contaminated sites to determine whether superficial and shallow contamination in soils indicates an existing or potential groundwater contamination problem, and whether a direct assessment of groundwater conditions is necessary. This method is intended to provide the party or applicant a cost-effective approach using soils data collected as part of the site characterization for determining the need to assess groundwater quality.

Methodology

An assessment of the effect of a release of a hazardous substance or petroleum on groundwater quality may not be necessary at all sites. This process is intended for sites that lack adequate groundwater monitoring data and where the party or applicant anticipates to leave in place contaminants of concern (COCs).

This approach to evaluating impacts and potential impacts of a release on groundwater is based on the attenuation of contaminants moving through the soil profile by means of biodegradation, hydrolysis, volatilization, adsorption, and dilution. Contaminants may not attenuate similarly in all situations, and therefore conservative Dilution Attenuation Factor (DAF) values are applied. However, conditions at some sites may result in contaminant migration through the soil profile in a manner that bypasses physical, chemical, and biological processes in the soils. Caution should be applied to use of this methodology at sites where normal physical, chemical, and biological processes in the soils are bypassed, including sites underlain by soils with large, interconnected pores (macropores) that provide for the rapid transport of water and contaminants through the soil profile, sites underlain by well-developed karst terrane, sites underlain by highly fractured media, or where contamination extends to the soil-bedrock interface. These types of sites may not provide for the soil processes assumed to be in effect in this method. In addition, this process is primarily intended for COCs that are relatively insoluble and are expected, under normal conditions, to remain in the soil profile and not to migrate to groundwater. Therefore, caution should be used in applying this methodology at sites where soluble or mobile COCs such as volatile organic compounds, nitrates, or dense non-aqueous phase liquids (DNAPL) are present; the presence of such COCs in the soils may indicate that a groundwater assessment may be necessary. The cabinet reserves the authority to require a direct assessment of groundwater at sites where it deems such investigation is prudent to understanding the extent of contamination and the risks associated with the release.

To determine whether a direct assessment of groundwater conditions is necessary, analytical data from the soil profile may be evaluated by the methods outlined in this document in combination with an evaluation of other soil conditions, and the geology and hydrology of the site. These data can be used to determine whether groundwater was likely to have been impacted, and whether these soils will serve as a future source of groundwater contamination.

In order to use this method, the horizontal and vertical extent of soil contamination must be known. An adequate number of soil borings with multiple, discreet sampling intervals of sufficient length and spacing to characterize vertical distribution of contamination are also necessary.

If it can be demonstrated using one of the following options that a release has not had and will not have an adverse effect on groundwater quality, a direct assessment of groundwater impacts may not be necessary.

1. An assessment of groundwater for a release may not be necessary if the applicable Soil Screening Levels, or SSL (DAF 1), in the U.S. EPA Region 9 Preliminary Remediation Goals (October 1, 2002) are not exceeded in the bottom two (2) sampling intervals of each soil boring.

2. Rather than using the default SSLs (DAF 1), a modified SSL may be used. This modified SSL takes into account the surface area of the site, the vertical separation between the contamination in the soil profile and groundwater, and the underlying bedrock conditions. The appropriate modified SSL is equivalent to the SSL (DAF 1) referenced in the U.S. EPA Region 9 Preliminary Remediation Goals, (October 1, 2002) multiplied by the applicable value in Table 1, below. An assessment of groundwater for a release may not be necessary if the applicable modified SSLs are not exceeded in samples from the bottom two (2) sampling intervals.

Table 1.

Vertical Separation Between Contamination in the Soil Profile and the Zone of Saturation	**Surface Area of Site and other considerations**		
	< 0.5 acres	**0.5-10 acres**	**> 10 acres, or site underlain by karst or highly fractured media**
0-5 ft	1	1	1
5-10 ft	5	2.5	1
10-15 ft	10	5	1
15-20 ft	15	7.5	2.5
Greater than 20 ft	20	10	5

3. A site-specific SSL may be developed and applied based on site-specific conditions, including soil types, characteristics of COCs, total organic carbon in the soil, soil porosity, infiltration rate, and the vertical separation between the contamination in the soil profile and groundwater. If the analytical results in the bottom two (2) sampling intervals do not exceed the site-specific SSLs, a groundwater assessment may not be necessary for that site.

4. A fate and transport evaluation may be developed to demonstrate that levels of COCs in the soils will not result in groundwater contamination beyond the property boundary. If a fate and transport evaluation adequately demonstrates that levels of COCs in the soils will not result in groundwater contamination beyond the property boundary, a groundwater assessment may not be necessary. However, a direct groundwater assessment will be required to make such a determination in most situations.

5. An analysis of the results of current and historical groundwater monitoring may be used to determine whether groundwater has been adequately characterized. Such an analysis shall contain sufficient information to determine whether groundwater has been affected by any releases at the site. The report of this analysis shall include:

a. The location of monitoring wells relative to the location of the soil contamination at the site, and to groundwater flow direction at the property;

b. Monitoring well construction details, including diameter of the annulus, diameter of the well casing, the depth and length of the screened interval, construction of the sand pack, and the type and manner of sealing materials used;

c. The proximity of wells to one another and to the property boundary; and

d. The results of all groundwater analyses conducted to date on samples collected at the property, including sample dates, the parameters analyzed, and the methods of collection and analysis.

A groundwater assessment is necessary and prudent in some circumstances. Any direct evidence of groundwater contamination, including seeps, contaminated wells and springs, or other similar information is compelling evidence to conduct a thorough groundwater investigation. The cabinet may direct a person or applicant to conduct a groundwater assessment in regards to a known or suspected release, regardless of the results of the methods employed above.

References

1. U.S. EPA 1996. Soils Screening Guidance: Technical Background Document, May 1996. United States Environmental Protection Agency 9355.-17a, EPA/540/R-95/128, PB96-963502.

2. U.S. EPA 2002. Region 9 Preliminary Remediation Goals and the Region 9 PRGs Table User's Guide/Technical Background Document (October 1, 2002).

Trichloroethylene Environmental Levels of Concern

Kentucky Department for Environmental Protection
Division of Environmental Services
Risk Assessment Branch
Jeri W. Higginbotham, Ph.D.

April 21, 2004

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Kentucky Risk Based Screening Values for Trichloroethylene

Based on a Slope Factor of 3.22E-01 per mg/kg-d

Ambient Air – 0.013 ug/m^3

Tap Water – 0.046 ug/l

Residential Soil – 0.031 mg/kg

Industrial Soil – 0.077 mg/kg

Rural Residential Soil – 0.027 mg/kg

Recreational Soil – 0.5 mg/kg

Farmer Exposure Soil – 0.089 mg/kg

Outdoor Worker Soil – 0.1 mg/kg

Short-Term Outdoor Worker Soil – 2.5 mg/kg

Ambient Air (Child age 1 to 18) – 0.00084 ug/m^3

Tap Water (Child age 1 to 18) – 0.0018 ug/l

Trichloroethylene (TCE) is a colorless liquid with a somewhat sweet odor (ATSDR 1997a) similar to that of chloroform (Plunkett 1987). Synonyms are 1,1,2-trichloroethylene, trichloroethene, acetylene trichloride, and ethylene trichloride (Proctor, Hughes, and Fischman 1989). Registered trade names include Algylen, Blacosolv, Dow-Tri, Perma-A-Chlor, Trilene, and Vestrol (ATSDR 1997a). It has been produced commercially since the 1920's (IARC 1997) and is commonly used as a cleaning and degreasing agent in the manufacture of furniture and fixtures, fabricated metal products, electric and electronic equipment, transport equipment, and, to a lesser extent, textiles, paper, and glass (HSDB 2004). It is an ingredient in adhesives, paint removers, typewriter correction fluids, and spot removers (ATSDR 2003). Between the 1930's and 1950's, it was used in the dry cleaning industry (IARC 1997). In 1977, the United States Food and Drug Administration (FDA) banned the use of TCE as a grain fumigant, disinfectant, anesthetic, and as an extraction solvent to extract caffeine from coffee, oleoresins from spices, and oil from palm, coconut, and soybean seed (ATSDR 1997a).

Due to its long history of use, TCE is a widespread environmental contaminant. Between 1988 and 2001, total on-site and off-site releases of TCE in the United States decreased from 57,445,582 pounds to 8,484,115 pounds (Table 1). In every year, at least 97% was in the form of air emissions (TRI 2003) but there were also releases to land, surface water discharge, and underground injection. It has been found at 861 Superfund National Priorities List (NPL) sites (ATSDR 1997a). And not surprisingly, by leaching through soil, the rate of which is dependent on organic matter and soil moisture content, it has contaminated underground water sources (ATSDR 1997a).

Table 1. Releases of trichloroethylene by year from 1988 to 2001 in the United States. All values are reported in pounds. Data from TRI, 2003.

total air emissions	surface water discharge	under-ground injection	releases to land	total on-site releases	total off-site releases	total on- and off-site releases	year	air/total
8,249,587	406	98,220	12,609	8,360,822	123,296	8,484,118	2001	0.972356
9,759,536	593	47,877	9,713	9,817,719	159,396	9,977,115	2000	0.978192
10,605,822	1,034	0	148,867	10,755,723	168,374	10,924,097	1999	0.970865
13,265,539	882	593	800	13,267,814	126,053	13,393,867	1998	0.990419
18,224,059	568	986	3,975	18,229,588	182,423	18,412,011	1997	0.989792
21,886,451	541	1,291	9,740	21,898,023	89,527	21,987,550	1996	0.995402
26,282,939	1,477	550	3,577	26,288,543	74,145	26,362,688	1995	0.996975
30,948,761	1,671	288	4,070	30,954,790	96,312	31,051,102	1994	0.996704
31,007,030	5,220	460	8,212	31,020,922	233,561	31,254,483	1993	0.992083
30,838,983	8,606	466	20,726	30,868,781	248,714	31,117,495	1992	0.99105
36,356,277	12,784	800	62,991	36,432,852	115,973	36,548,825	1991	0.994732
40,028,932	14,285	805	12,554	40,056,576	753,864	40,810,440	1990	0.98085
49,798,528	15,849	390	8,686	49,823,453	1,250,933	51,074,386	1989	0.97502
55,943,736	13,801	390	21,186	55,979,113	1,466,469	57,445,582	1988	0.973856

TCE is degraded most rapidly in the air and least rapidly in groundwater. Degradation products depend on the medium and have adverse health effects of their own. In air, TCE persists for 11 to 14 days before decomposing to hydrochloric acid, dichloroacetyl chloride, phosgene, and carbon monoxide (Cal/EPA 1999). It rapidly evaporates from surface water but may persist in groundwater and soil for prolonged periods (ATSDR 2003). There is some evidence for microbiological degradation to cis and trans 1,2-dichloroethylene in soil and groundwater. In one study, a half-life of 1.0 to 1.5 years in groundwater was calculated (Cal/EPA 1999). Other studies have calculated half-lives in groundwater of 10.7 months and 4.5 years (Howard 1991). Rate of degradation depends on the presence of organisms capable of degrading the chemical, the availability of other metabolic requirements, and the amount of chemical present. In the absence of appropriate microflora or appropriate microfloral habitat, TCE may persist for centuries as a dense nonaqueous phase liquid (DNAPL) in subsurface pools and lenses. With a solubility of 1.1 grams per liter (Verschueren 1983), DNAPL TCE slowly dissolves into groundwater over prolonged periods, creating contaminant plumes (Newell and Ross 1992).

In mammals, the liver is the primary site of TCE metabolism with trichloroacetic acid (TCA) being the major end product. Other metabolic products are trichloroethanol, trichloroethanol-glucuronide, dichloroacetic acid, and dichlorovinyl cysteine. In addition to the liver, TCE metabolism occurs in the lungs and kidneys (EPA 2001). Blood and urine tests can detect TCE and many of its metabolic products for up to a week after exposure (ATSDR 2003).

Exposure to TCE has been linked to adverse health effects including liver and neurological dysfunction (ATSDR 1997a) and, accordingly, occupational and drinking water standards have been set. Based on adverse central nervous system effects, the Occupational Safety and Health Administration has established a time-weighted average permissible exposure limit (TWA PEL) of 50 ppm and a short term exposure limit (STEL) of 200 ppm (NIOSH 2001). The maximum contaminant level (MCL) for trichloroethylene in drinking water is 0.005 mg/L and the maximum contaminant level goal (MCLG) is zero. The basis for the MCL and MCLG was its potential to cause liver damage and certain cancers from a lifetime exposure above 0.005 mg/L (EPA 2002a).

However, carcinogenicity data for TCE was withdrawn from the United States Environmental Protection Agency (EPA) Integrated Risk Information System in 1989. The most recent EPA document concerning TCE is a preliminary draft entitled, "Trichloroethylene Health Risk Assessment: Synthesis and Characterization," from the National Center for Environmental Assessment (EPA 2001). It draws on 16 state-of-the-science papers published as a supplemental issue of Environmental Health Perspectives (volume 108, supplement 2, May 2000) as well as many other papers and was reviewed by a panel of the EPA Science Advisory Board's Environmental Health Committee (EPA 2002b).

In this draft, EPA concludes that TCE is "highly likely to produce cancer in humans" and can be classified as a "probable human carcinogen" (group B1). The International Agency for Research on Cancer (IARC), also, classifies TCE as "probably carcinogenic to humans" (Group 2A). Their evaluation was based on limited evidence in humans and sufficient evidence in experimental animals for the carcinogenicity of trichloroethylene (IARC 1997).

Many epidemiological studies are reported for the effects of TCE, but their quality and informational content vary considerably. One of the less informative studies concerned a cohort of workers at one manufacturing plant in Roscoe, Illinois (Shindell et al. 1985). As compared to the entire U.S. population, fewer individuals than expected died, and this was true for every cause of death (cardiovascular, respiratory cancer, nonrespiratory cancer, stroke, trauma, and other). Statistically significant deficits were in overall mortality, nonrespiratory cancer, and trauma. That there were deficits for every cause of death suggests that other parameters besides TCE exposure were varying between the cohort and the comparison group (healthy worker effect). The authors end by postulating the presence of "some other factor contributing to the favorable experience." Furthermore, cancers were only categorized as respiratory or nonrespiratory and exposure data were not provided. This study is simply not informative and provides no evidence for TCE health effects of any kind. Wartenberg (2000) placed it in his Tier II group of cohort studies, Tier I being composed of the most informative studies. The Science Advisory Board review panel endorsed

Wartenberg's classification system and went on to recommend that EPA weight the Tier I studies more strongly than other studies (EPA 2002b).

Of the four epidemiological studies discussed by EPA (2001), three were Tier I cohort studies and one was community based (Wartenberg 2000). A New Jersey study tracked individuals in a 75-town area affected by drinking water contamination (Cohn et al. 1994). Occupational exposure of Finnish workers to three halogenated hydrocarbons, tetrachloroethylene (PCE), 1,1,1-trichloroethane, and TCE was reported by Anttila et al. (1995). Blair et al. (1998) followed a cohort of workers who were employed at Hill Air Force Base for at least one year and who were exposed by vapour inhalation. A fourth and final study reported on the incidence of kidney cancer in German cardboard workers (EPA 2001).

In the New Jersey study, female residents had statistically significant excesses of leukemia and non-Hodgkin lymphoma where relative risks (RR), 95% confidence intervals (CI), and the number of cases (N) were RR=1.43, 95% CI=1.07-1.90, N=56 and RR=1.36, 95% CI-1.08-1.70, N=87 respectively (Cohn et al. 1994). Epidemiological studies often report data as relative risk where the probability of disease in the study group is divided by the probability of disease in the control group. A RR value above 1.0 indicates an excess of disease in the study group while a RR value below 1.0 indicates a deficit of disease in the study group. If the confidence interval does not contain 1.0, then the relative risk is statistically significant at the stated level of confidence which is usually 95%.

Based on this study, a unit risk estimate and slope factor for non-Hodgkin lymphoma was calculated by EPA (2001) using the following rationale. A relative risk factor of 1.36 is interpreted as a 36% increased risk of getting this disease. (EPA actually rounded up the relative risk to 1.40.) By multiplying the background risk of getting non-Hodgkin lymphoma by 0.36 and dividing by the average concentration of TCE in those homes where the concentration exceeded the MCL of 5 ppb a unit risk estimate was calculated. The background risk was given as 6E-04 (prevalence of the disease in the United States), and the average concentration was 23.4 ug/L. The unit risk is 9.2E-06 per ug/L. The resulting slope factor based on a 70 kg adult drinking 2 L/d is 3.22E-01 per mg/kg-d average lifetime exposure to TCE for non-Hodgkin lymphoma. (EPA, using 1.4 as the relative risk and rounding up, listed 4.00E-01 per mg/kg-d in Table 4-9.) Dividing this slope factor into 10^{-6} yields a risk-specific dose of 3.1E-06 mg/kg-d. For a 70 kg individual, the maximum daily dose is 2.2E-04 mg/d (0.22 ppb) which is well below the routine detection limit of 1.0E-03 mg/l (1.0 ppb) in water (King County 2002).

One weakness of this study was that it was impossible to control for other impurities in the water, some of which might contribute to the risk of developing these two cancers. Though TCE was present in the greatest concentration, PCE was also a common contaminant. Both are thought to exert carcinogenic effects through common metabolites. To that end, it is estimated that only from 1-3% of the absorbed PCE is metabolized (ATSDR 1997b), whereas from 40-75% of the absorbed TCE is metabolized (ATSDR 1997a). Furthermore, very little research has been done to confirm or refute the hypothesis that combinations of compounds act in an additive or greater-than-additive (synergistic) manner. Certain combinations might act in a less-than-additive (antagonistic) manner. And there is one report indicating that PCE inhibits the metabolism of TCE in humans (ATSDR 2002). As for other contaminants, no association was detected between leukemia or non-Hodgkin lymphoma incidence and trihalomethanes, benzene, 1,1,1-trichloroethane, carbon tetrachloride, and trans-1,2-dichloroethylene. The apparent risk seems largely attributable to TCE.

A strength of the study was the socio-economic similarity of the municipalities compared. And, as with any epidemiological study, uncertainties in extrapolating from animal to human effects and from high to low doses are avoided (EPA 2001).

In the Finnish study, the following statistically significant standardized incidence ratios (SIRs) and 95% CI were reported for the entire cohort of 3974 workers: 2.35 for cervical cancer (95% CI-1.08-4.46), 2.13 for non-Hodgkin's lymphoma (95% CI-1.06-3.8), and 1.63 for lymphohematopoietic cancers (95% CI-1.06-2.41). Standardized incidence ratios are the ratio of observed cancer incidence in the cohort to the expected cancer incidence based on the population of Finland adjusted for age and sex. The cohort was subdivided according to exposure and duration of exposure. One subgroup was monitored for urinary TCA, a major metabolite of TCE, and had been followed for at least 19 years since the first measurement. This subgroup had statistically significant SIRs of 1.57 for all cancers (95% CI-1.2-2.02), 2.98 for stomach cancer (95% CI-1.2-6.13), 6.07 for liver cancer (95% CI-1.25-17.7), 3.57 for prostate cancer (95% CI-1.54-7.02), and 2.98 for lymphohematopoietic cancers (95% CI-1.2-6.14). Among a subgroup who were monitored for blood PCE levels, no statistically significant SIRs were reported. By the author's calculations though, exposure was greatest for TCE accounting for 80% of the person-years at risk (Anttila et al. 1995).

Using urinary TCA to quantify exposure, slope factors were calculated for liver cancer (7.0E-02), kidney cancer (2.0E+00), and non-Hodgkin lymphoma (7.0E+00) (EPA 2001). However, only liver cancer was statistically significantly elevated among those workers with known exposure to trichloroethylene. Of the 11 cases of non-Hodgkin lymphoma, 3 were attributed to exposure to PCE resulting in a statistically non-significant excess in those exposed to TCE (SIR=1.81, 95% CI-0.78-3.56). In addition to the small number of cancer cases, exposure duration was uncertain (Anttila et al. 1995). Even though the comparison group was generated from the Finnish population, Anttila (1995) argues that, "It is not probable that chemicals other than solvents, or life-style patterns (such as alcohol consumption, smoking, sexual habits) explain the excesses in the present cohort, because excesses of the same primary sites were not seen in a parallel, in many respects comparable, cohort of workers monitored for lead exposure."

In the Hill Air Force Base study, statistically non-significant excesses of non-Hodgkin lymphoma (RR=2.0, 95% CI=0.9-4.6), multiple myeloma (RR=1.3, 95% CI=0.5-3.4), breast cancer (RR=1.8, 95% CI=0.9-3.3), kidney cancer (RR=1.6, 95% CI=0.5-5.1), and cancer of the liver (RR=1.7, 95% CI=0.2-16.2) and biliary passages (RR=1.3, 95% CI=0.5-3.4) were reported. It is, perhaps, timely to note here that a trend may be biologically significant but not statistically significant. Strengths of this study include it's size (n=14,457), the extended follow up that enables inclusion of effects with long latent periods, and the use of an internal control group to "minimise the potential for selection and socioeconomic problems associated with the use of the general population for comparison." Limitations of the study include the fact that other solvents were used on base, though TCE was the main solvent used historically, and exposure estimates were qualitative rather than quantitative (Blair et al. 1998). Without quantitative exposure estimates, risk estimates cannot be derived.

The fourth study discussed by EPA (2001) tracked German cardboard workers exposed to TCE. This study noted an increased incidence of kidney cancer but may have been initiated after the observation of a cluster (IARC 1997). Problems associated with this study include a lack of exposure data, the use of other solvents in addition to TCE, an unadjusted incidence (EPA 2001), and differing diagnostic methodology between the cohort and comparison group (EPA 2002b).

More recently, Raaschou-Nielsen et al. (2003) reported on a Danish cohort of 40,049 blue-collar workers in 347 Danish companies with documented TCE use. The SIR for all cancers was 1.08 (95% CI-1.04-1.12). Other statistically significant SIRs were:

- 1.8 for esophageal adenocarcinoma (95% CI-1.15-2.73) among men,
- 2.8 for primary liver cancer (95% CI-1.13-5.80) among women,
- 2.8 for gallbladder and biliary passage cancer (95% CI-1.28-5.34) among women,
- 1.4 for lung cancer (95% CI-1.28-1.51) among men and
- 1.9 (95% CI-1.48-2.35) among women,
- 1.9 for cervical cancer (95% CI-1.42-2.37),
- 1.2 for non-Hodgkin's lymphoma (95% CI-1.0-1.5) among the entire cohort, and
- 1.8 for esophageal adenocarcinoma (95% CI-1.2-2.7) among the entire cohort.

A non-significant SIR of 1.7 was noted for leukemia (95% CI-0.89-2.86) in women. An obvious strength of this study is its large cohort size. Unfortunately, it suffers from a poorly chosen control group, the Danish population. The authors admit that their experimental and control groups probably differed in the proportion of individuals in each socio-economic group. Cigarette smoking is known to be higher in the least educated groups in Denmark and may be a confounding factor in this study weakening the association between TCE and lung cancer. The authors note that social class is probably a confounding factor for cervical cancer as well. And because exposure was not quantified, risk estimates cannot be calculated.

Raaschou-Nielsen et al. (2003) as well as the three studies used by EPA (2001) report increased incidence of lymphohematopoietic cancers (non-Hodgkin's lymphoma, multiple myeloma, and leukemia). Three studies noted excesses of liver cancer. Leukemia and myeloma originate in the bone marrow while lymphoma originates in lymphatic tissues. These cancers are considered to be related because they involve the uncontrolled growth of cells with similar functions and origins. The diseases are not thought to be heritable, although a few cases of familial lymphoma have been reported, but rather to result from acquired injury to the cell, which becomes abnormal (malignant) and multiplies continuously (Bock 2004). Lymphohematopoietic cancers are basically environmentally caused diseases. Known environmental risk factors for liver cancer include aflatoxin, anabolic steroids, arsenic, cirrhosis, hepatitis, thorium dioxide, tobacco use, and vinyl chloride (ACS 2003).

Furthermore, three of these cancers have increased in incidence over the last 30 years as reported by the Surveillance, Epidemiology, and End Results (SEER) database. The incidence of non-Hodgkin's lymphoma across all races in the US increased from 11.1 per 100,000 in 1975 to 19.9 per 100,000 in 1994 with a subsequent decline to 19.0 per 100,000 in 2000. Incidence of myeloma followed a similar pattern increasing from 4.65 per 100,000 in 1973 to 6.0 per 100,000 in 1997 with a subsequent decline to 5.47 per 100,000 in 2000. Leukemia incidence actually declined from12.5 per 100,000 in 1973 to 11.9 per 100,000 in 2000, but not by much (SEER 2003). Liver cancer has increased from 2.7 per 100,000 in

1973 to 5.3 per 100,000 in 2000 (SEER 2003). All of the above-mentioned rates are age adjusted with all age groups, 0 to 85+, used.

Genetic toxicity studies using cultured cells from exposed and unexposed individuals lend support to the epidemiological connection between TCE and lymphohematopoietic cancers in humans. As reviewed by the California Environmental Protection Agency (Cal/EPA), in some, but not all, studies using peripheral lymphocyte cultures, genetic effects were noted. These included hyperdiploidy, hypodiploidy, sister chromatid exchanges, and chromosome structural anomalies including breaks, deletions, gaps, inversions, and translocations (Cal/EPA1999).

The epidemiological evidence is, also, supported by studies in rats and mice. Cal/EPA noted, "The principal findings are: 1) liver carcinomas in male mice by inhalation and in both sexes by gavage administration; 2) lung carcinomas in female mice by inhalation; and 3) kidney tubular carcinoma in male rats by inhalation and gavage dosing." In one study, an increased incidence of malignant lymphoma was observed in TCE-exposed female Han:NMR1 mice and, in another, TCE was associated with the development of testicular interstitial cell tumors in Marshall rats (Cal/EPA 1999).

Cal/EPA (1999) used data from two liver tumor studies in mice to generate slope factors. Using total amount of TCE metabolized by the liver, the lower 95% confidence limit on the dose associated with a 10% tumor incidence (LED_{10}) was calculated (EPA 1996). The following four slope factors were calculated as $0.1/LED_{10}$:

- 2.1E-02 in females by gavage,
- 7.7E-02 in males by gavage,
- 4.7E-03 in females by inhalation, and

- 3.4E-03 in males by inhalation.

The geometric mean of these slope factors is 1.3E-02 per mg/kg-d which is what Cal/EPA used to calculate their public health goal for the concentration of TCE in drinking water. The author admits ignorance as to how an average value can be protective of sensitive populations. On the other hand, their public health goal of 0.8 ppb is below the routine detection limit of 1.0 ppb. Moreover, this is the slope factor which was endorsed by EPA Region 4 last year (email from Ted Simon 2003).

Risk estimates associated with the rat and mice studies were reported by EPA (2001) as well. The slope factor and risk-specific dose for kidney cancer in rats was 3.0E-04 and 3.3E-03 respectively. Slope factors and risk-specific doses for liver cancer in mice using internal TCA as the dose metric ranged from 3.0E-02 to 2.0E-01 per mg/kg-d and from 0.5E-05 to 3.1E-05 mg/kg-d respectively.

Considering both the epidemiological studies and the rat and mice studies, slope factors range from 7.0 to 3.0E-04 per mg/kg-day which is a 23,000 fold difference. EPA proposed ignoring the lowest and highest estimates. The remaining slope factors range from 4.0E-01 (3.22E-01 as calculated here) to 2.0E-02 per mg/kg-d which is a 20 fold difference. This is slightly higher than EPA's previous slope factor of 1.1E-02 and Cal/EPA's, 1.3E-02.

EPA (2001), following National Research Council recommendations, did not consolidate these slope factors into a single estimate. They advise selecting an appropriate slope factor from the range. For example, "Risk assessments involving the presence of risk factors such as diabetes or alcohol consumption, or high background exposure to TCE or its metabolites, would more appropriately choose a higher slope factor." An estimated 6.3% of the population in this country have diabetes (NIDDK 2003) and in Kentucky, 6.8% have been diagnosed with it (CDC 2003). Given that diabetes is so prevalent, the higher slope factor should be chosen all the time.

Historically, EPA (1989) has been protective of sensitive populations and, in calculating reference doses, has recommended an uncertainty factor of 10 to account “for variation in the general population….intended to protect sensitive subpopulations.” Moreover, the Science Advisory Board review panel (EPA 2002b) expressed concern “for diseased individuals (diabetes, hepatitis, HIV positive, etc.), who may be especially susceptible to TCE exposure.” We are only just beginning to understand the range of human metabolic variation, the frequency of metabolic variants within the population, and what amount and kind of variation would cause susceptibility to the effects of chronic exposure to TCE (see Lipscomb et al. 2003 for an example). Until we know the frequency of metabolic variants susceptible to low level exposure to TCE we must assume that the frequency is greater than 1.0E-06.

The Science Advisory Board review panel (EPA 2002b) recognized the importance of epidemiological studies, stating that they “merit special attention because they may be potentially important in terms of population-attributable risk.” Furthermore, the panel recommended that where such studies are the basis of risk estimates, they should be the ones, “among the studies that are well designed, that would generate the most health-protective number.”

EPA Region 9 (2002) lists 4.00E-01 per mg/kg-d as both the oral and inhalation slope factor for TCE citing NCEA as the source. In an effort to find the origin of that slope factor, I contacted EPA Environmental Health Scientist, Dr. Weihsueh Chiu, who thought it came from the 2001 draft assessment (EPA 2001 and email from Weihsueh Chiu 2004). EPA

(2001) provides two slope factors using data from Cohn et al. (1994), 4.00E-01 per mg/kg-d in Table 4-9 and 3.5E-01 per mg/kg-d in Section 4.5.1.3. A slope factor of 4.00E-01 per mg/kg-d is not associated with any other study in EPA (2001). Using the original paper (Cohn et al. 1994), it is calculated as 3.22E-01 per mg/kg-d here.

The choice of a higher slope factor (3.22E-01 per mg/kg-d) seems easily justified. It is being used in EPA Region 9 and EPA Region 10 (2004) who uses Region 9's values. The higher risk estimates are protective of sensitive populations. This specific risk estimate is based on an epidemiological study. The epidemiological studies are supported by evidence from rat, mice, and cell culture studies.

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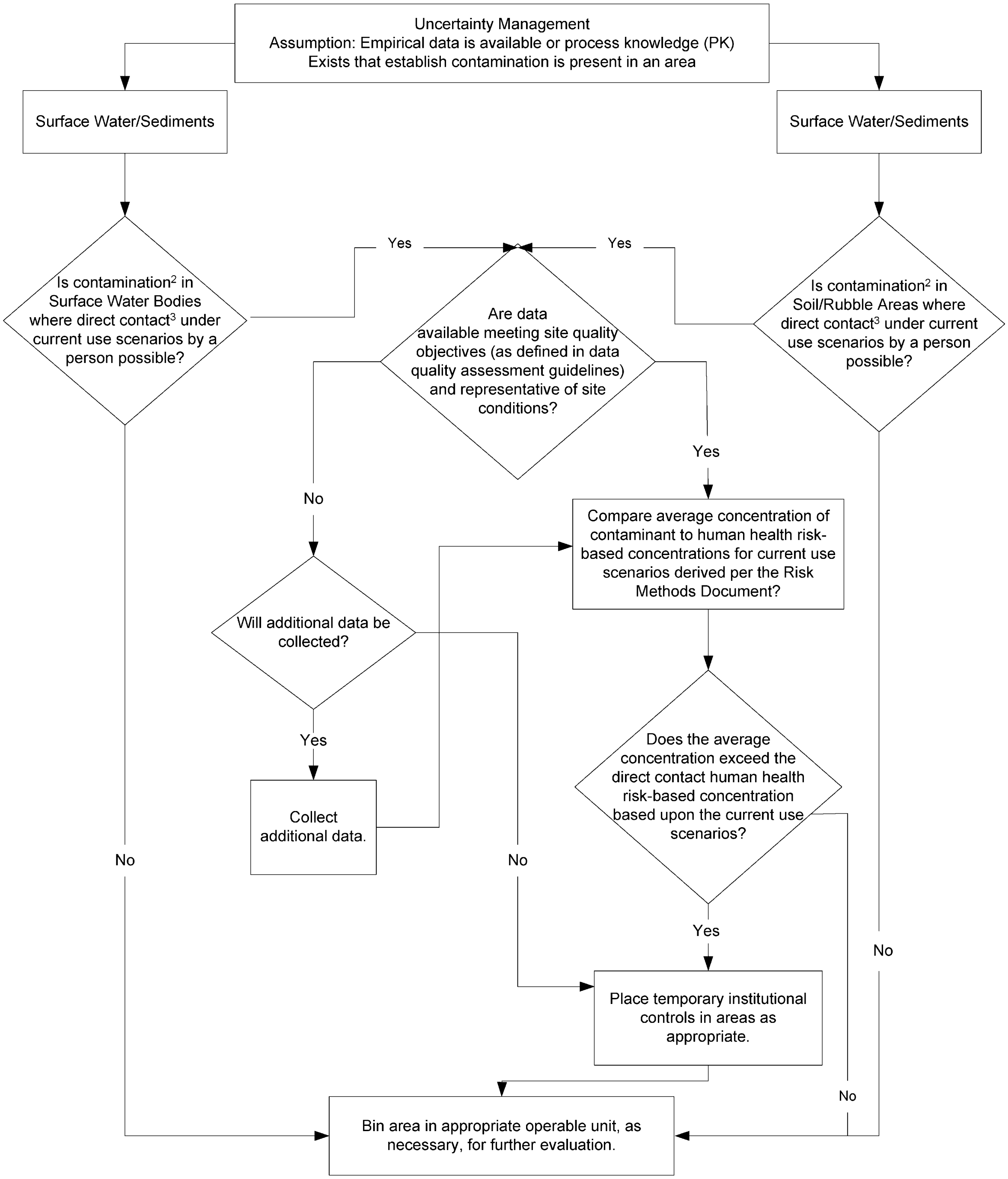
E.4. FLOWCHART FOR UNCERTAINTY MANAGEMENT FOR UNKNOWN AREAS OF CONTAMINATION

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.

Uncertainty Management Flowchart



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[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.

Further Explanation of Flowchart Steps

Uncertainty Management Assumption: Empirical data is available or process knowledge (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 licenses 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 nonworker exposures associated with DOE-owned property described above. Sufficient data or credible process knowledge must exist for this process to be activated.
Is contamination 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 hunt.
Area 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 area 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 (calculated from existing data using protocols defined in the Risk Methods Document and other guidance documents) from existing data will be compared to the human health risk-based concentrations. Risk-based concentrations 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 KDEP will determine the appropriate operable unit under which the area may be placed for future evaluation in accordance with the Federal Facility Agreement. 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 (issued May 2006). 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.

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.

  $$K = k\frac{g}{\nu} \tag{1}$$

  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

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

  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.

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

- **Organic Carbon Content:** Site-specific data were available for the organic carbon content of the RGA, and these data were assumed applicable to the RGA at each source area and along the contaminant flow paths. A set of 38 results was available. The minimum, maximum, and most likely values selected were 3.0E-03, 2.53E-01, and 3.5E-02%, respectively. The coefficient of variation was estimated as 1.05%, and the skewness was estimated as 4.0. Given the coefficient of variation and skewness, a log-normal distribution was assumed. The organic carbon content was assumed not correlated to any other parameter. Summary statistics for the values output by Crystal Ball® and used in runs for AT123D modeling are provided in Table F.2.9. A histogram of the output values for organic carbon content is in Fig. F.2.23.

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

6. CORRELATION MATRIX

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

The correlation values are presented in Table F.2.3.

7. SENSITIVITY ANALYSIS

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

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

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

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

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

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

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

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SAIC (Science Applications International Corporation) 2002. Final White Paper on *Sensitivity Analysis on Distribution Coefficient (K_d) Values for TCE and Tc-99 with the Regional Flow and Transport Model at the Paducah Gaseous Diffusion Plant*, submitted to BJC on June 2002.

UT (University of Tennessee) 2002. Spatial Analysis and Decision Assistance (SADA), Version 2.3, User Guide, January. Accessible at http://www.tiem.utk.edu/~sada/.

Yeh, G. T. 1981. *AT123D: Analytical Transient One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System*, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN, Publication No. 1439.

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

DOE 1999. *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky*, DOE/OR/07-1777/V4&D2, June.
DOE 2000. *Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant Paducah, Kentucky*, DOE/OR/07-1857&D1, July.

Table F.2.2. 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

DOE 1999. *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky,* DOE/OR/07-1777/V4&D2, June.
EPA 1994. Risk Reduction Engineering Laboratory (RREL) Treatability Database, ver. 5.0, Office of Research and Development, Cincinnati, OH.
EPA 1996. *Soil Screening Guidance: Technical Background Document*, Office of Solid Waste and Emergency Response, Washington, DC.

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

Input Parameter	Statistics	Unit	SWMU 1	C-720 Building	Remark
Vertical Hydraulic Conductivity[a]	Minimum	cm/sec	1.00E-08	1.00E-08	DOE 1997a, DOE 1997b
	Likeliest	cm/sec	1.64E-05	1.64E-05	DOE 1997a, DOE 1997b
	Maximum	cm/sec	2.00E-04	2.00E-04	[b]DOE 1997a, DOE 1997b
	Standard Deviation	cm/sec	5.52E-05	5.52E-05	DOE 1997a, DOE 1997b
	Count	#	13	13	DOE 1997a, DOE 1997b
	Coefficient of Variation	%	336.49	336.49	DOE 1997a, DOE 1997b
	Skew	-	3.60	3.60	DOE 1997a, DOE 1997b
	Maximum	cm/sec	3.20E-05	3.20E-05	[c,d]Recharge-specific (to RGA) calibration
	Distribution	-	Triangular	Triangular	See Section 4.0, Intrinsic Permeability
	Correlation Pair	-	None	None	None
	Correlation Coefficient	-	NA	NA	NA
Organic Carbon Content	Minimum	%	2.48E-02	2.48E-02	Site-specific (to PGDP) field data
	Likeliest	%	8.01E-02	8.01E-02	Site-specific (to PGDP) field data
	Maximum	%	4.55E-01	4.55E-01	Site-specific (to PGDP) field data
	Standard Deviation	%	5.27E-02	5.27E-02	Site-specific (to PGDP) field data
	Count	#	138	138	Site-specific (to PGDP) field data
	Coefficient of Variation	%	65.82	65.82	Site-specific (to PGDP) field data
	Skew	-	4.30	4.30	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	None	None	See Section 4.0, Organic Carbon Content
	Correlation Coefficient	-	NA	NA	NA
Soil Concentration - Layer 1	Minimum	mg/kg	0.00E+00	0.00E+00	Site-specific (to PGDP) field data
	Likeliest	mg/kg	2.14E+00	1.56E+00	Site-specific (to PGDP) field data
	Maximum	mg/kg	8.70E+01	1.70E+01	Site-specific (to PGDP) field data
	Standard Deviation	mg/kg	1.12E+01	5.12E+00	Site-specific (to PGDP) field data
	Count	#	135	11	Site-specific (to PGDP) field data
	Coefficient of Variation	%	522.90	328.48	Site-specific (to PGDP) field data
	Skew	-	6.42	3.32	Site-specific (to PGDP) field data
	Distribution	-	Log normal	Log normal	Site-specific (to PGDP) field data
	Correlation Pair	-	see Layer 2	see Layer 2	Site-specific (to TCE) SADA analysis
	Correlation Coefficient	-	see Layer 2	see Layer 2	Site-specific (to TCE) SADA analysis

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

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

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

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

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

[a] Field observation was available for vertical hydraulic conductivity. Therefore, intrinsic permeability was estimated from vertical hydraulic conductivity.

[b] The maximum from DOE 1997a and DOE 1997b was judged to be high and was re-estimated through calibration.

[c] The maximum was estimated through calibration to a recharge of 22 cm/yr (DOE 2000).

[d] The value selected for probabilistic method.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, *Environmental Degradation Rates*, Lewis Publishers, Inc. Chelsea, MI, 1991.

LMES (Lockheed Martin Energy Systems) 1997. *Evaluation of Natural Attenuation Processes for Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/EM-113.

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

DOE, 1997b. *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Grouping 22 at the PGDP Paducah, Kentucky,* DOE/OR/07-1549&D1, February.

DOE 2000. *Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant Paducah, Kentucky,* DOE/OR/07-1857&D1, July.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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)

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

BJC 2006.

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

DOE 1997a. *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Grouping 22 at the PGDP Paducah, Kentucky*, DOE/OR/07-1549&D1, February.

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

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

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

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

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

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

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

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

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

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

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

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

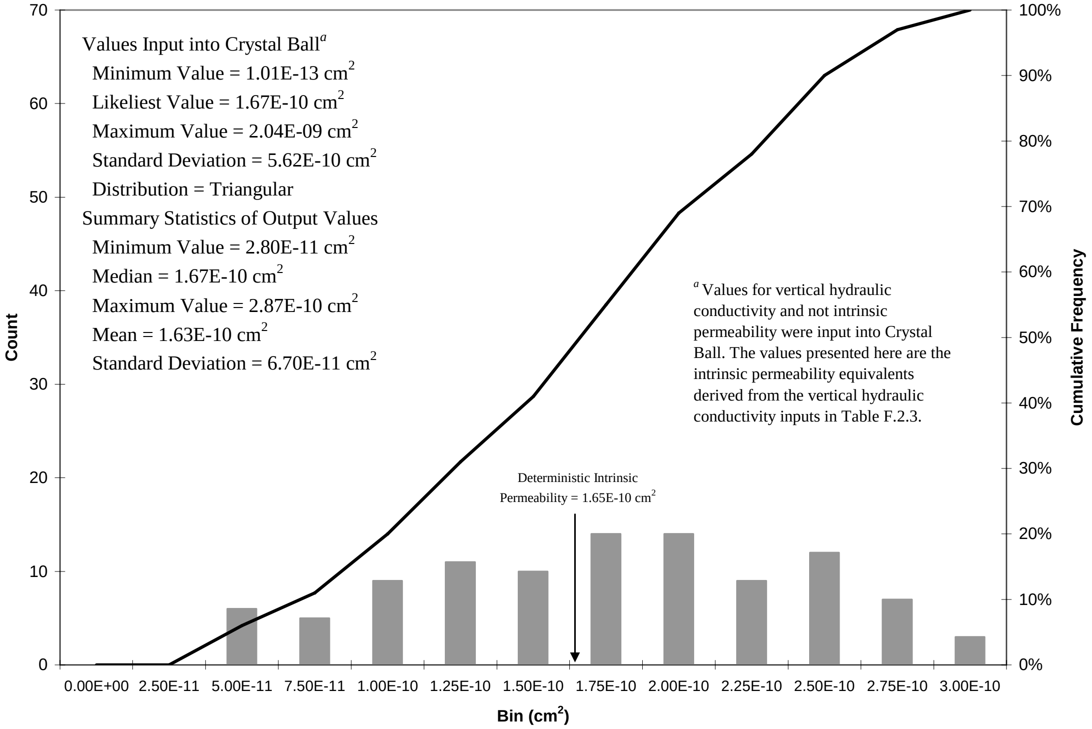
Table F.2.9. Statistics of variable inputs used in Monte Carlo runs for AT123D modeling (see Table F.50) (continued)

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

[a] Effective porosity was estimated from porosity (see text).
[b] Degradation rate was estimated from degradation half-life in units of hours using the formula: rate = [(ln 2)/degradation half-life].
[c] This parameter was only used for secondary source term modeling.

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

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



Values Input into Crystal Ball[a]
Minimum Value = 1.01E-13 cm^2
Likeliest Value = 1.67E-10 cm^2
Maximum Value = 2.04E-09 cm^2
Standard Deviation = 5.62E-10 cm^2
Distribution = Triangular
Summary Statistics of Output Values
Minimum Value = 2.80E-11 cm^2
Median = 1.67E-10 cm^2
Maximum Value = 2.87E-10 cm^2
Mean = 1.63E-10 cm^2
Standard Deviation = 6.70E-11 cm^2

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

Deterministic Intrinsic Permeability = 1.65E-10 cm^2

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

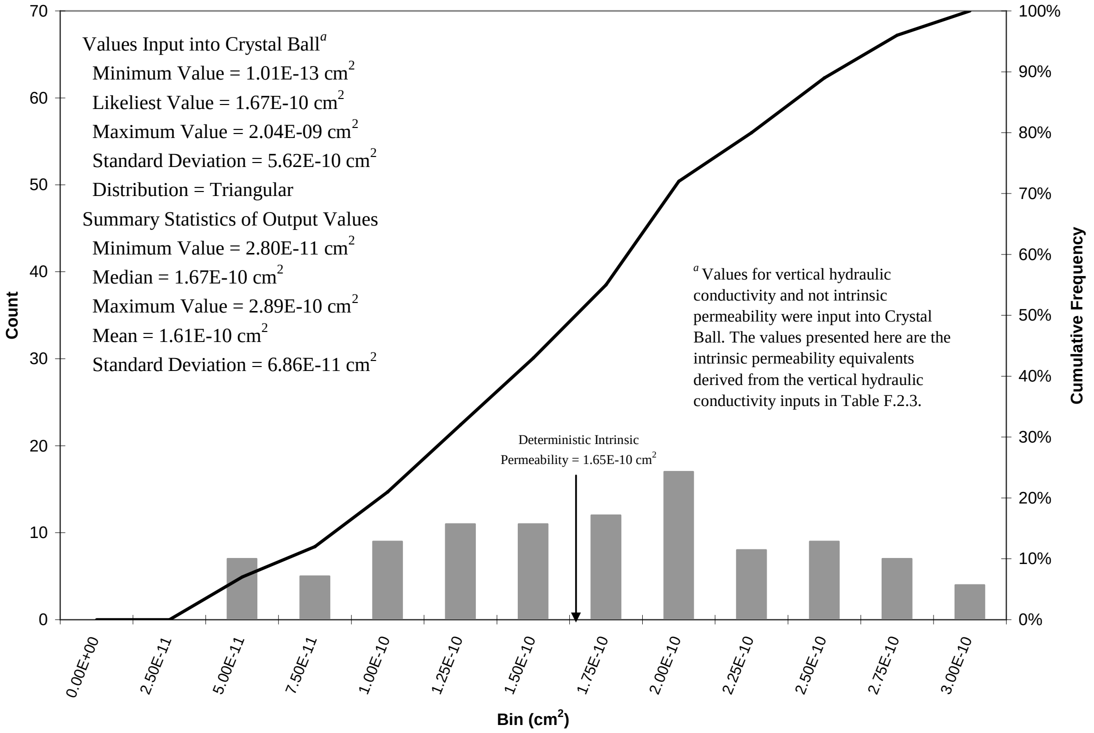


Fig. F.2.2. Histogram of Intrinsic Permeability SESOIL inputs for the C-720 Area.

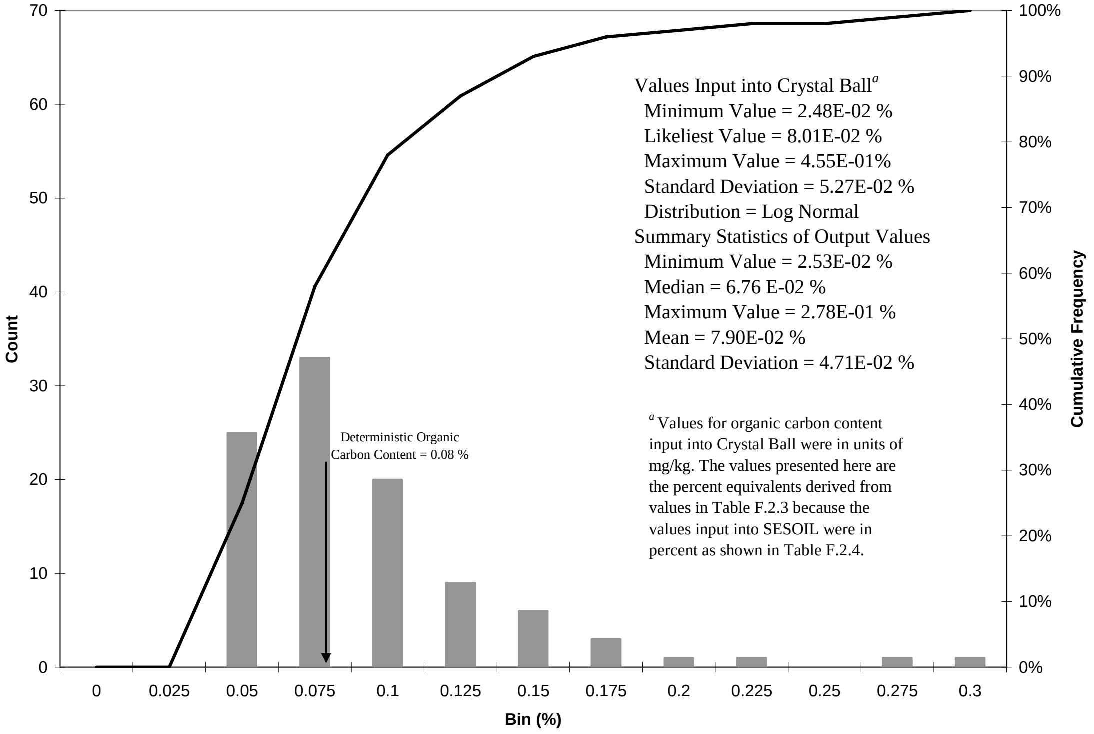
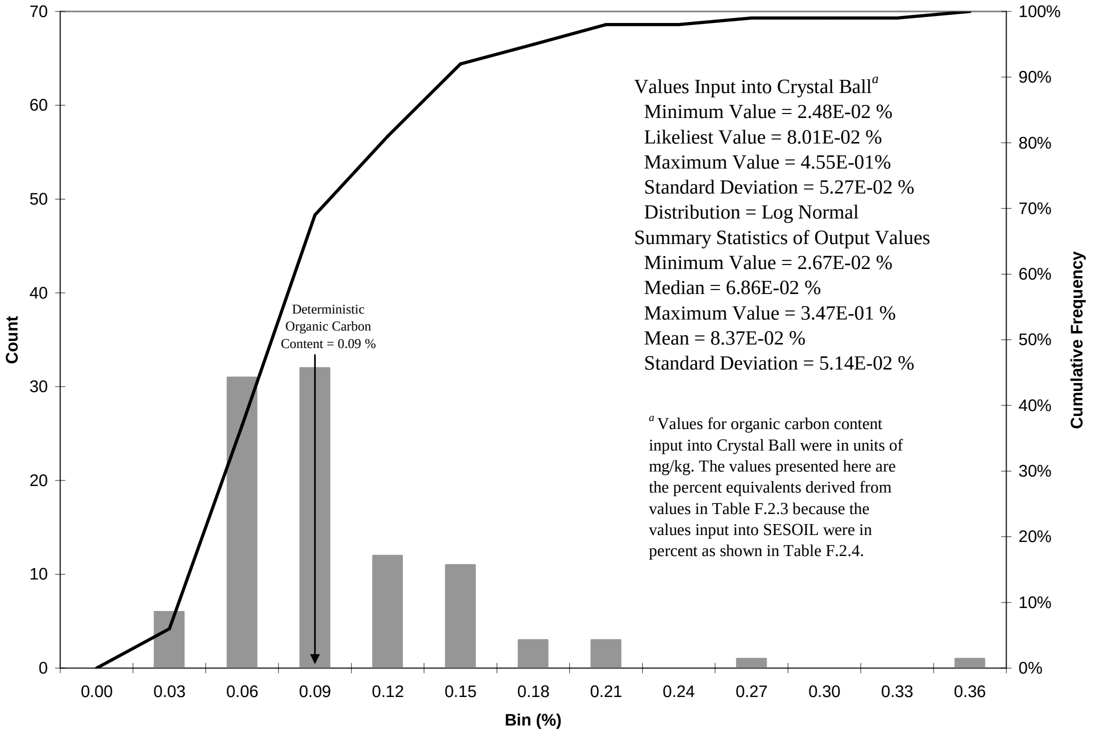


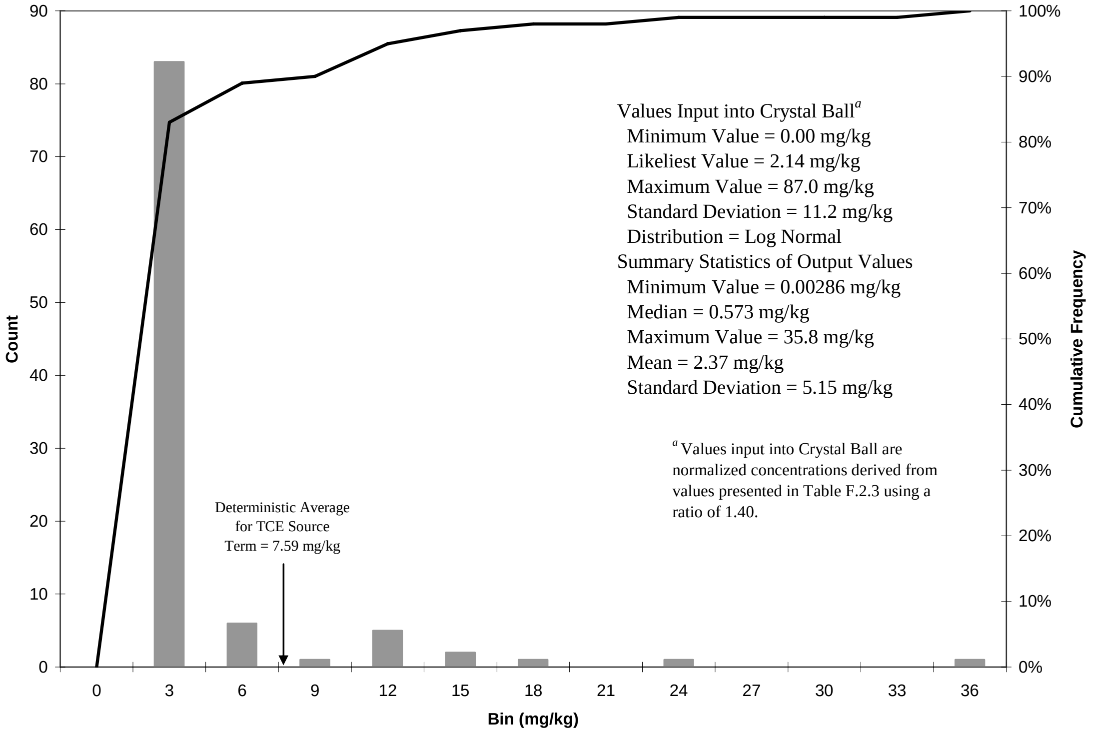
Fig. F.2.3. Histogram of Organic Carbon Content SESOIL inputs for SWMU 1.



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

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

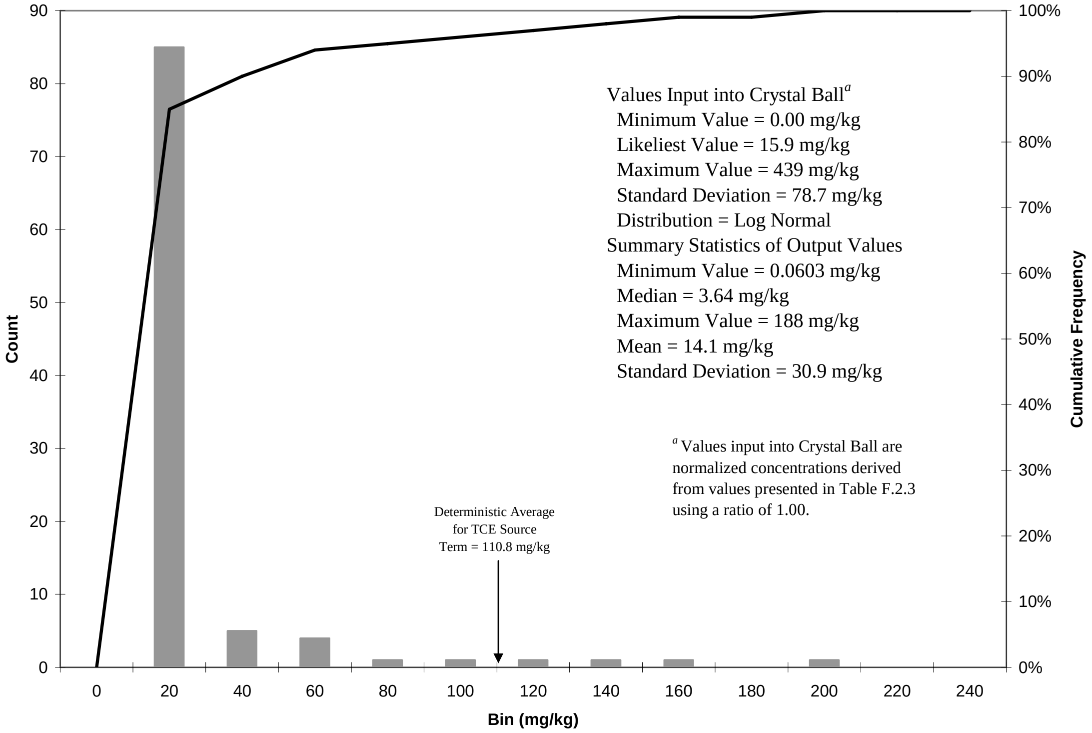
Fig. F.2.4. Histogram of Organic Carbon Content SESOIL inputs for the C-720 Area.



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

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

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



Values Input into Crystal Ball[a]

Minimum Value = 0.00 mg/kg
Likeliest Value = 15.9 mg/kg
Maximum Value = 439 mg/kg
Standard Deviation = 78.7 mg/kg
Distribution = Log Normal

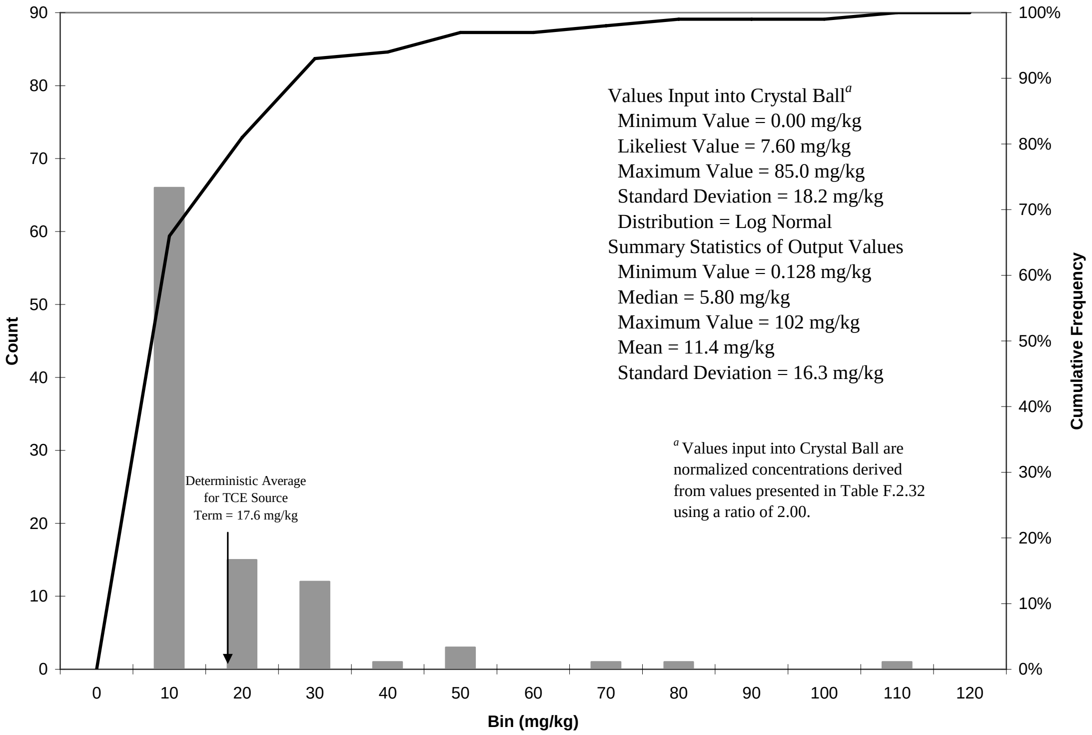
Summary Statistics of Output Values

Minimum Value = 0.0603 mg/kg
Median = 3.64 mg/kg
Maximum Value = 188 mg/kg
Mean = 14.1 mg/kg
Standard Deviation = 30.9 mg/kg

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

Deterministic Average for TCE Source Term = 110.8 mg/kg

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

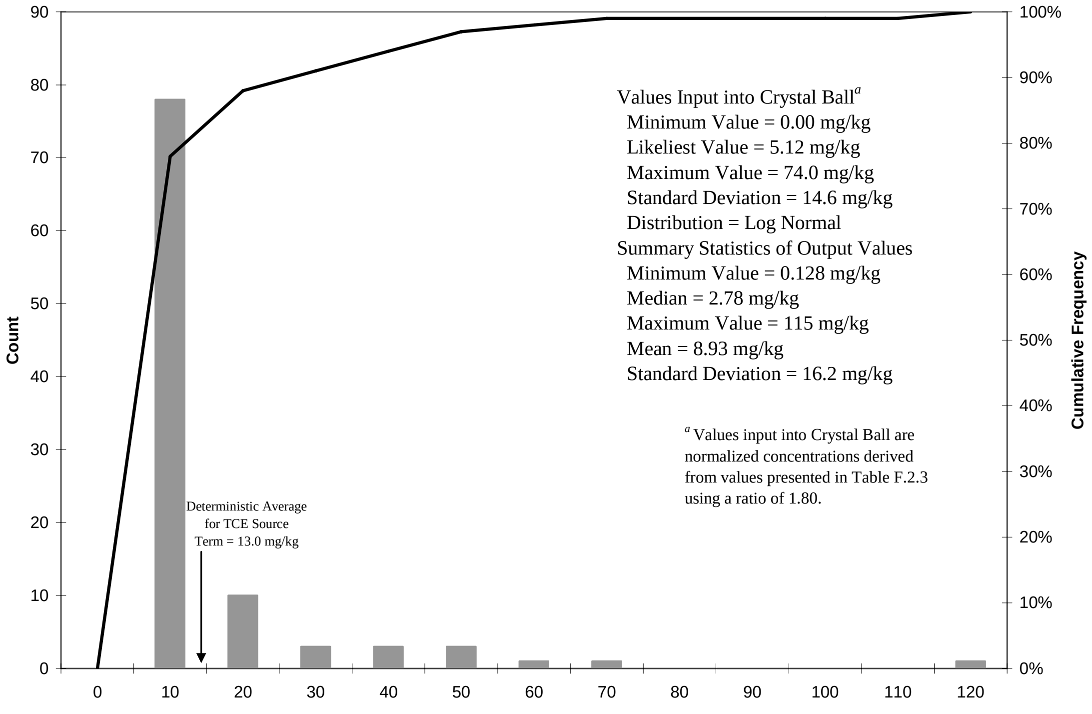


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 7.60 mg/kg
Maximum Value = 85.0 mg/kg
Standard Deviation = 18.2 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.128 mg/kg
Median = 5.80 mg/kg
Maximum Value = 102 mg/kg
Mean = 11.4 mg/kg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

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

Deterministic Average for TCE Source Term = 17.6 mg/kg

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

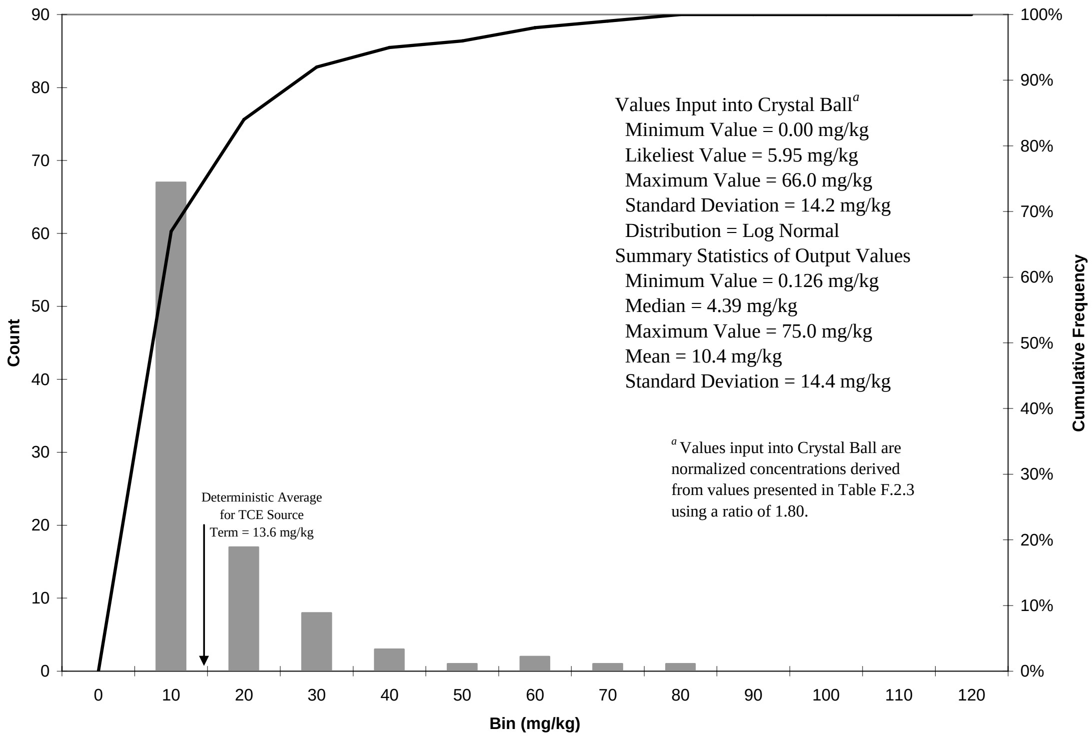


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 5.12 mg/kg
Maximum Value = 74.0 mg/kg
Standard Deviation = 14.6 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.128 mg/kg
Median = 2.78 mg/kg
Maximum Value = 115 mg/kg
Mean = 8.93 mg/kg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

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

Deterministic Average for TCE Source Term = 13.0 mg/kg

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

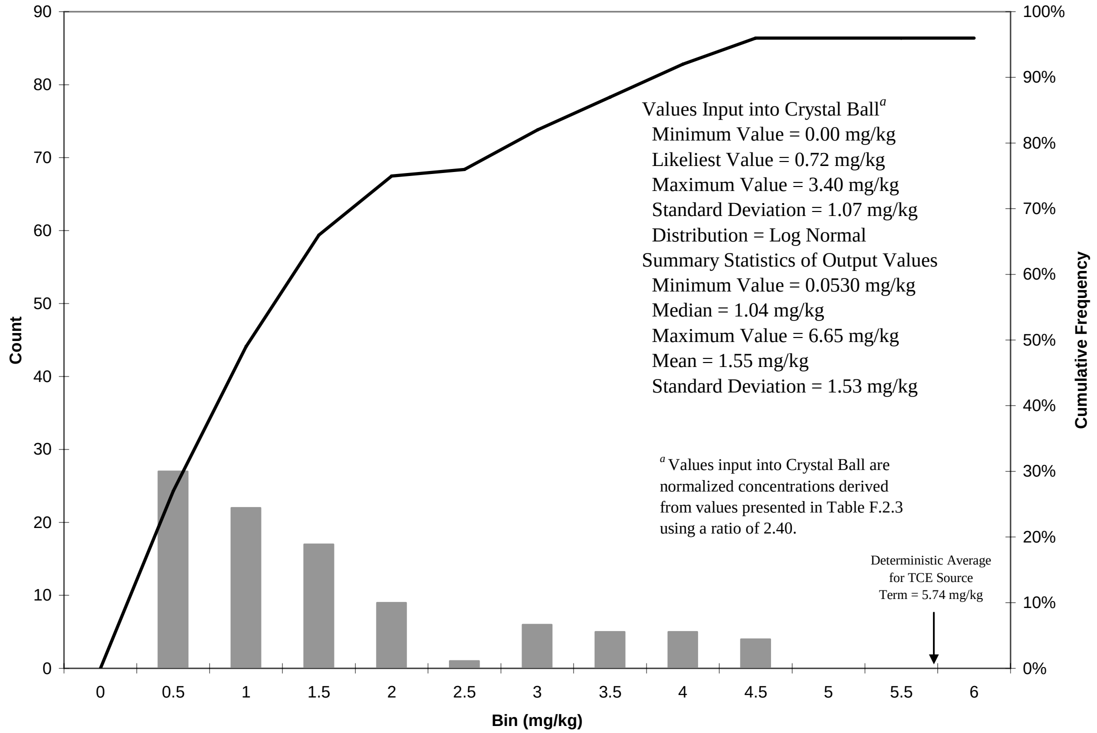


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 5.95 mg/kg
Maximum Value = 66.0 mg/kg
Standard Deviation = 14.2 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.126 mg/kg
Median = 4.39 mg/kg
Maximum Value = 75.0 mg/kg
Mean = 10.4 mg/kg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

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

Deterministic Average for TCE Source Term = 13.6 mg/kg

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

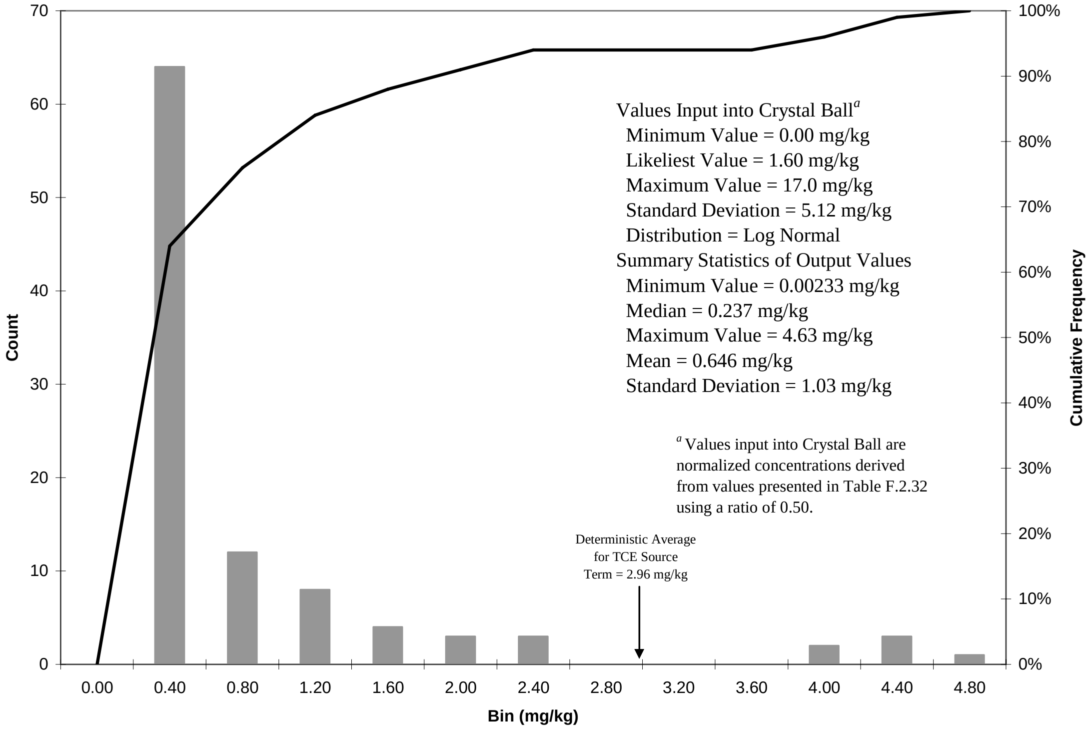


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 0.72 mg/kg
Maximum Value = 3.40 mg/kg
Standard Deviation = 1.07 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.0530 mg/kg
Median = 1.04 mg/kg
Maximum Value = 6.65 mg/kg
Mean = 1.55 mg/kg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

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

Deterministic Average for TCE Source Term = 5.74 mg/kg

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

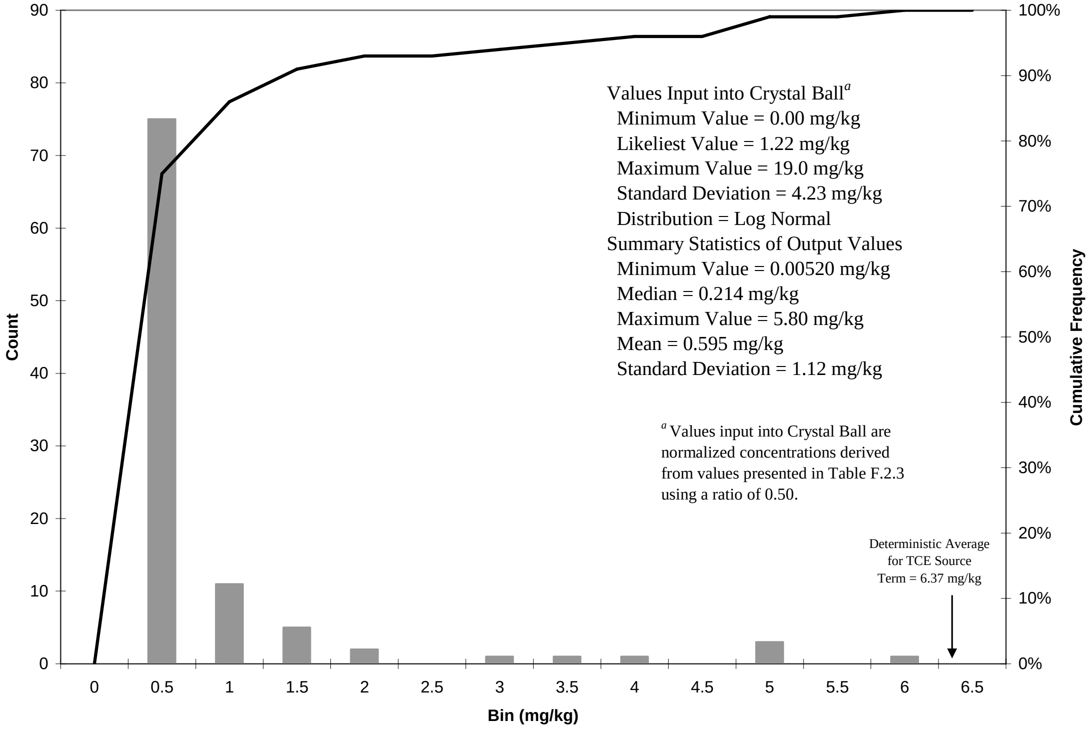


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 1.60 mg/kg
Maximum Value = 17.0 mg/kg
Standard Deviation = 5.12 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.00233 mg/kg
Median = 0.237 mg/kg
Maximum Value = 4.63 mg/kg
Mean = 0.646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

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

Deterministic Average for TCE Source Term = 2.96 mg/kg

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

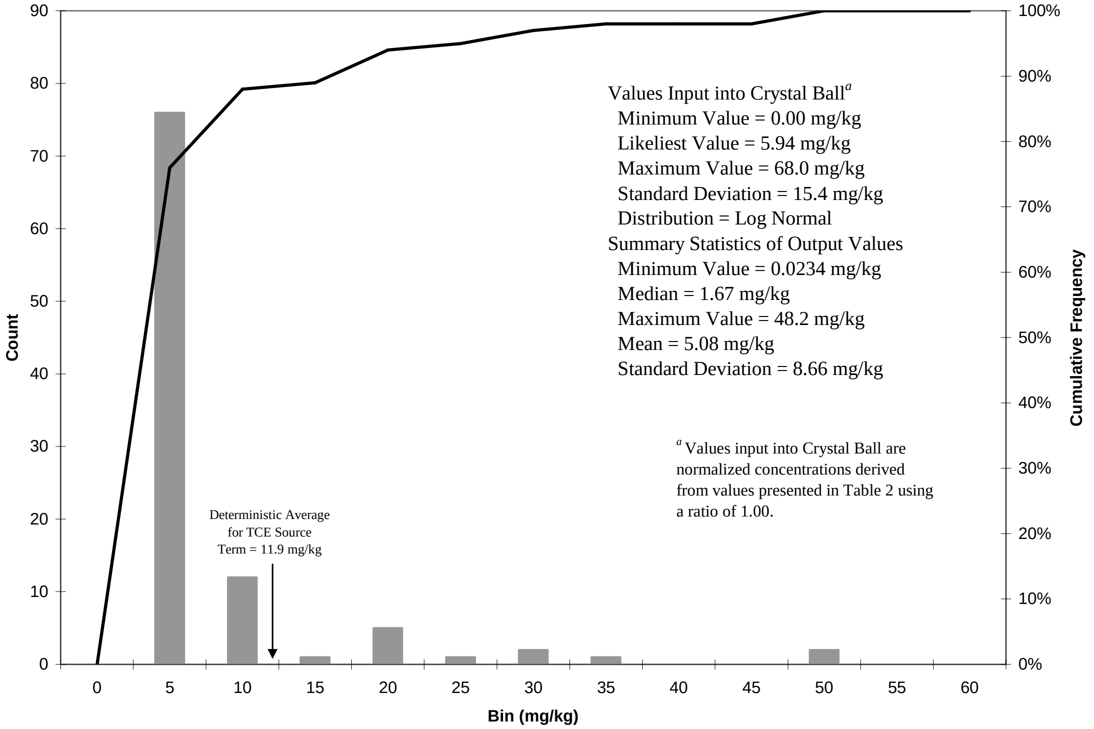


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 1.22 mg/kg
Maximum Value = 19.0 mg/kg
Standard Deviation = 4.23 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.00520 mg/kg
Median = 0.214 mg/kg
Maximum Value = 5.80 mg/kg
Mean = 0.595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

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

Deterministic Average for TCE Source Term = 6.37 mg/kg

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

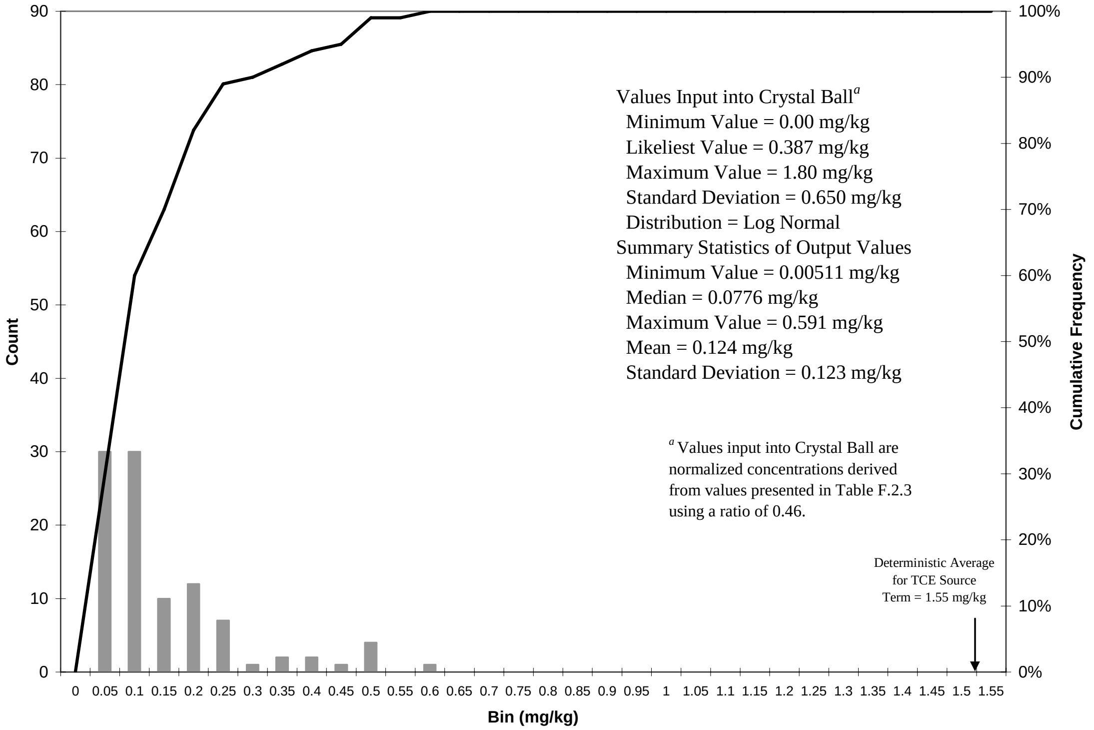


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 5.94 mg/kg
Maximum Value = 68.0 mg/kg
Standard Deviation = 15.4 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.0234 mg/kg
Median = 1.67 mg/kg
Maximum Value = 48.2 mg/kg
Mean = 5.08 mg/kg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

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

Deterministic Average for TCE Source Term = 11.9 mg/kg

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

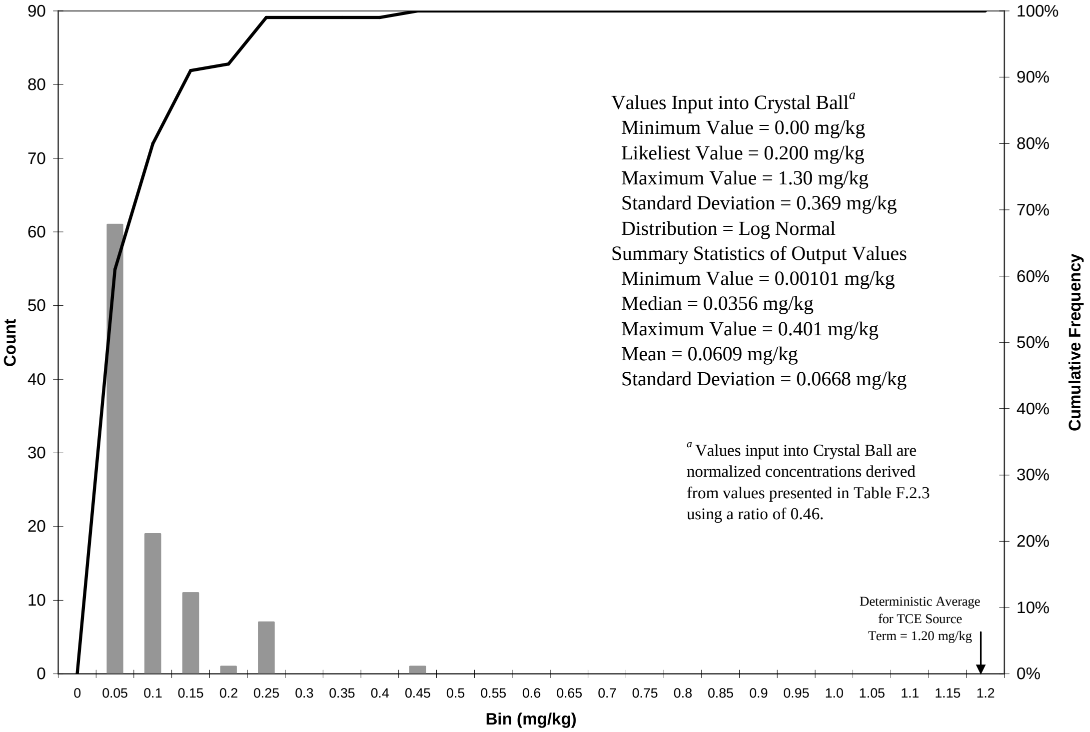


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 0.387 mg/kg
Maximum Value = 1.80 mg/kg
Standard Deviation = 0.650 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.00511 mg/kg
Median = 0.0776 mg/kg
Maximum Value = 0.591 mg/kg
Mean = 0.124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

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

Deterministic Average for TCE Source Term = 1.55 mg/kg

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

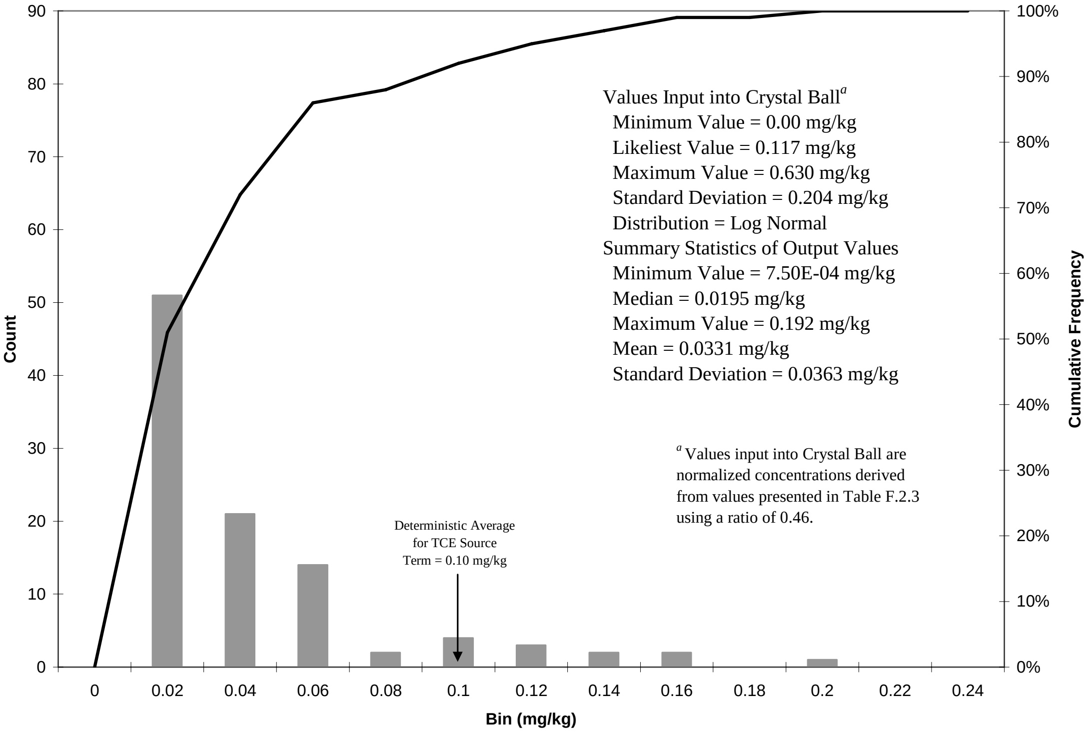


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 0.200 mg/kg
Maximum Value = 1.30 mg/kg
Standard Deviation = 0.369 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 0.00101 mg/kg
Median = 0.0356 mg/kg
Maximum Value = 0.401 mg/kg
Mean = 0.0609 mg/kg
Standard Deviation = 0.0668 mg/kg

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

Deterministic Average for TCE Source Term = 1.20 mg/kg

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

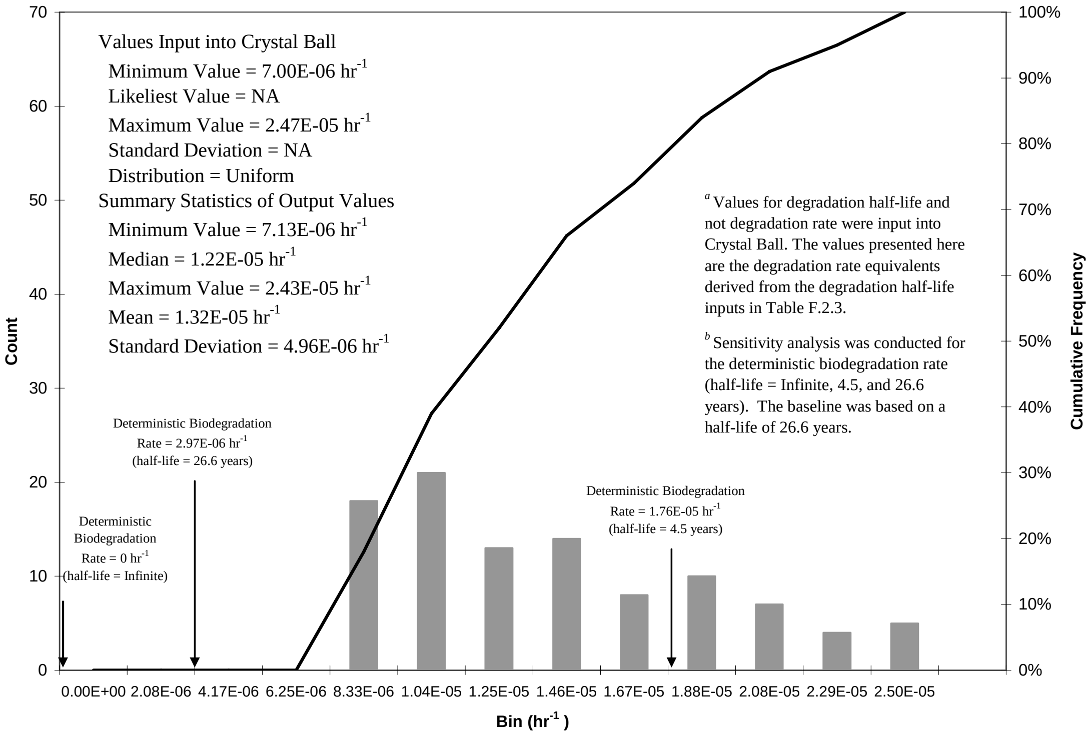


Values Input into Crystal Ball[a]
Minimum Value = 0.00 mg/kg
Likeliest Value = 0.117 mg/kg
Maximum Value = 0.630 mg/kg
Standard Deviation = 0.204 mg/kg
Distribution = Log Normal
Summary Statistics of Output Values
Minimum Value = 7.50E-04 mg/kg
Median = 0.0195 mg/kg
Maximum Value = 0.192 mg/kg
Mean = 0.0331 mg/kg
Standard Deviation = 0.0363 mg/kg

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

Deterministic Average for TCE Source Term = 0.10 mg/kg

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



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

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

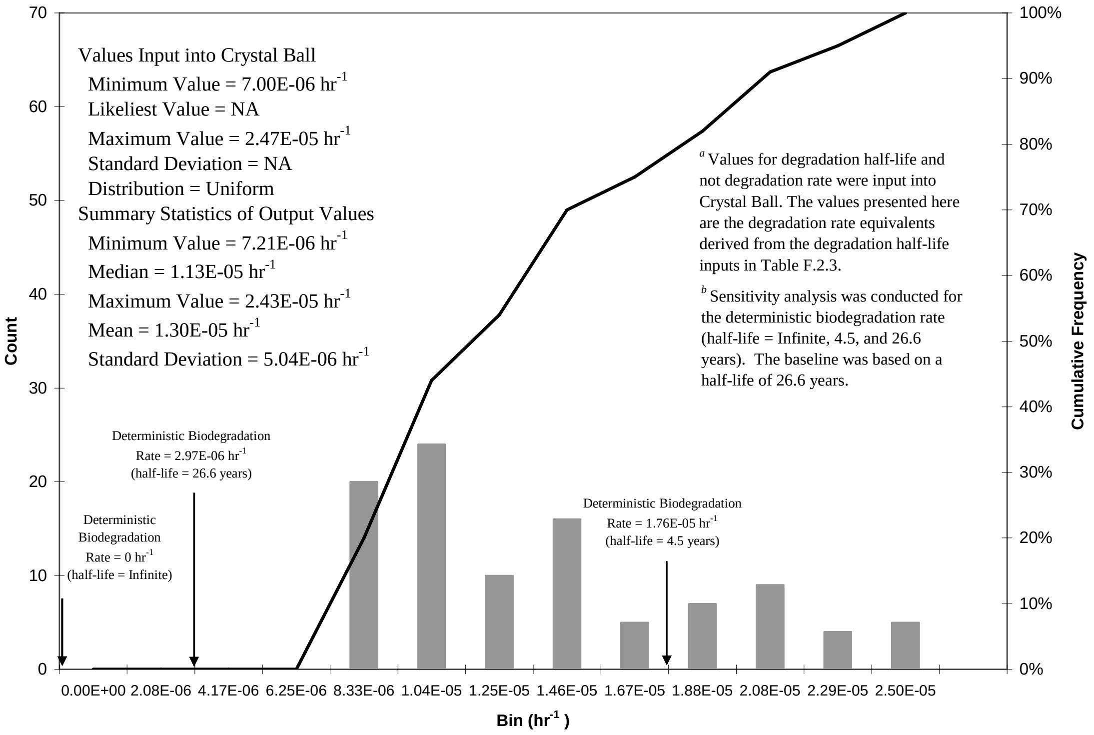
Deterministic Biodegradation
Rate = 2.97E-06 hr^{-1}
(half-life = 26.6 years)

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

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

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

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

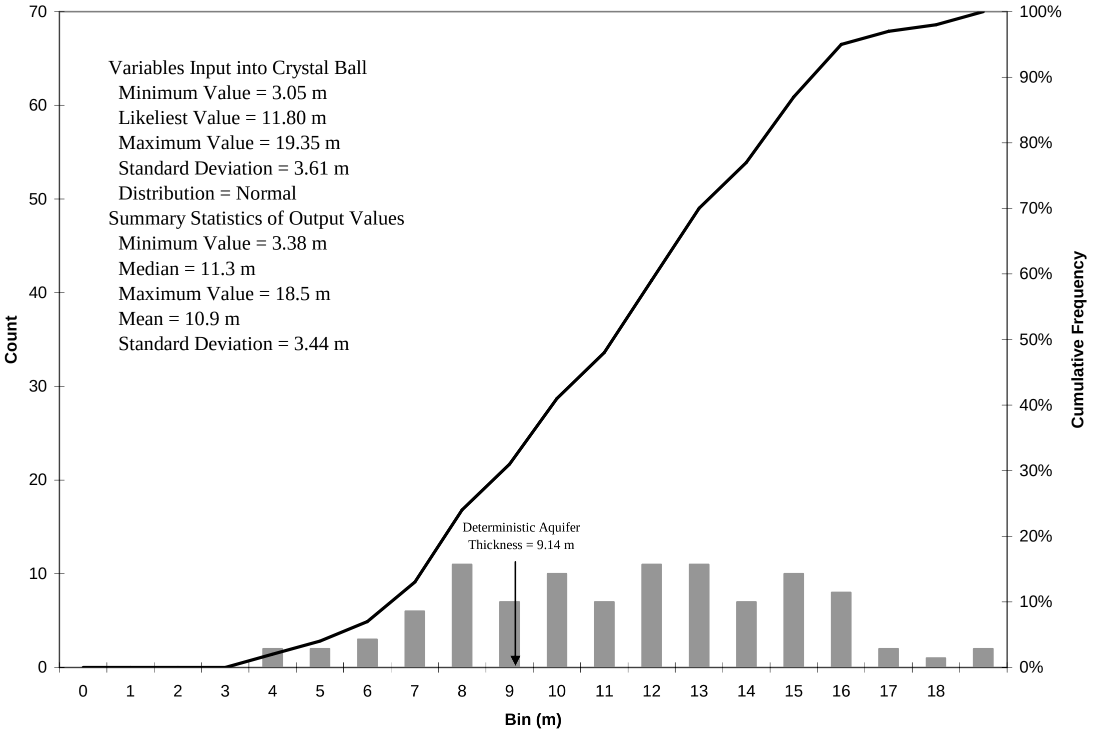


Values Input into Crystal Ball
Minimum Value = 7.00E-06 hr^{-1}
Likeliest Value = NA
Maximum Value = 2.47E-05 hr^{-1}
Standard Deviation = NA
Distribution = Uniform
Summary Statistics of Output Values
Minimum Value = 7.21E-06 hr^{-1}
Median = 1.13E-05 hr^{-1}
Maximum Value = 2.43E-05 hr^{-1}
Mean = 1.30E-05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

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

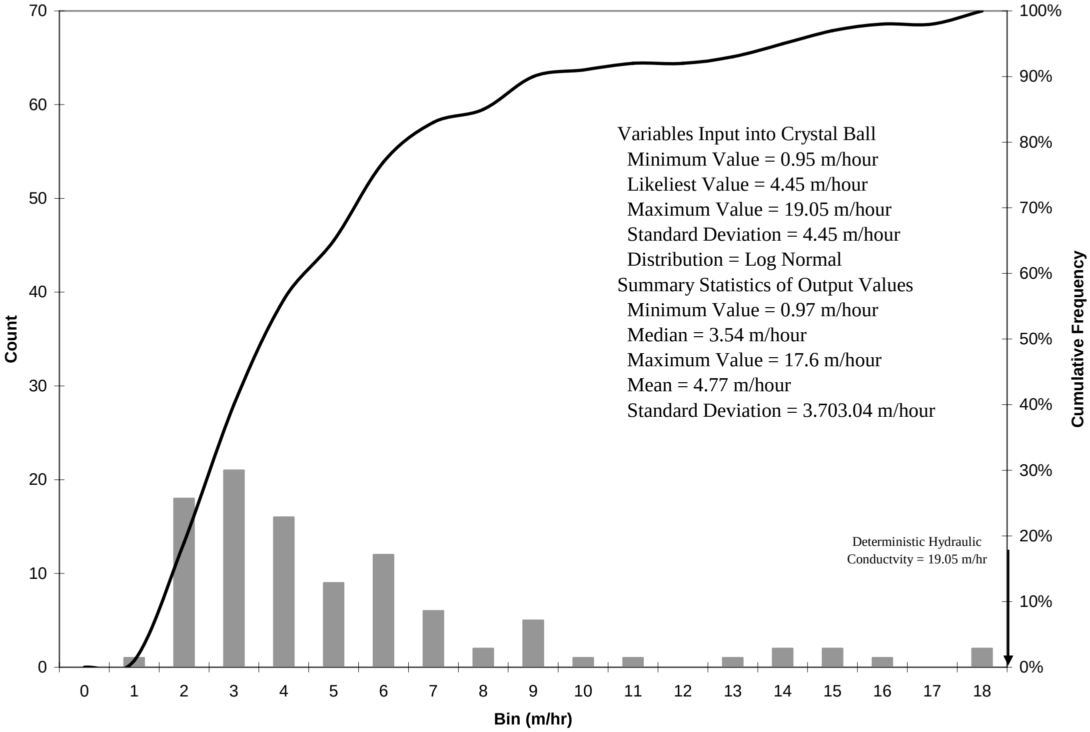
[b] Sensitivity analysis was conducted for the deterministic biodegradation rate (half-life = Infinite, 4.5, and 26.6 years). The baseline was based on a half-life of 26.6 years.

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



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

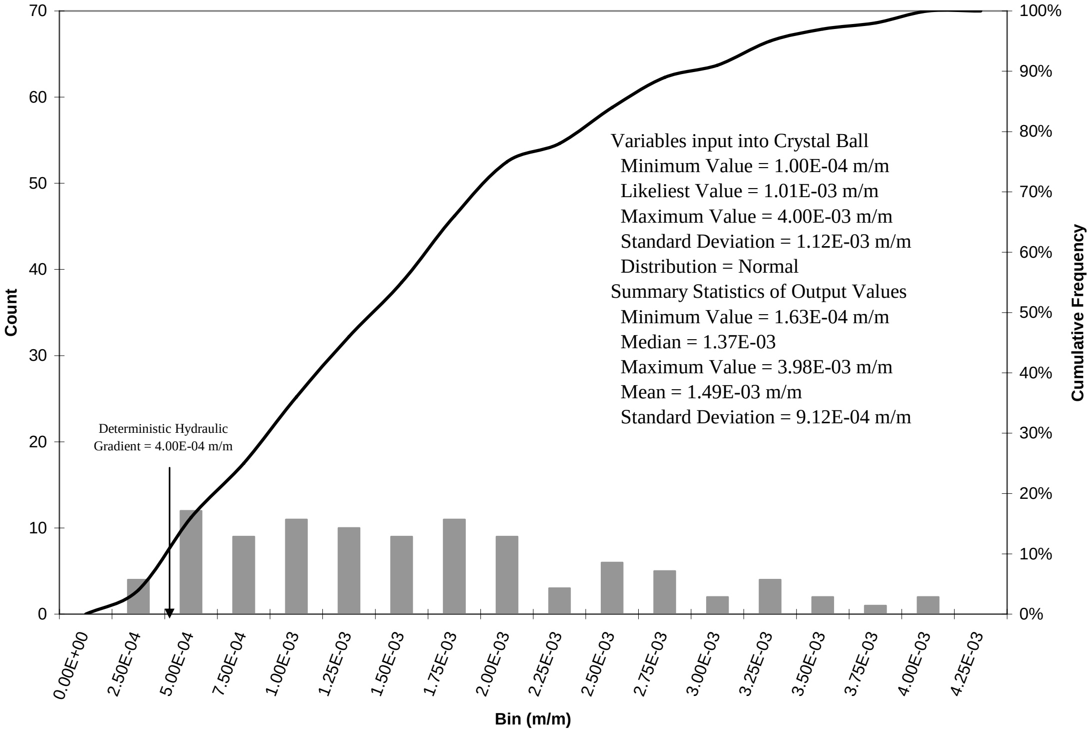
Fig. F.2.19. Histogram of Aquifer Thickness AT123D inputs for SWMU 1 and the C-720 Area.



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

Deterministic Hydraulic
Conductvity = 19.05 m/hr

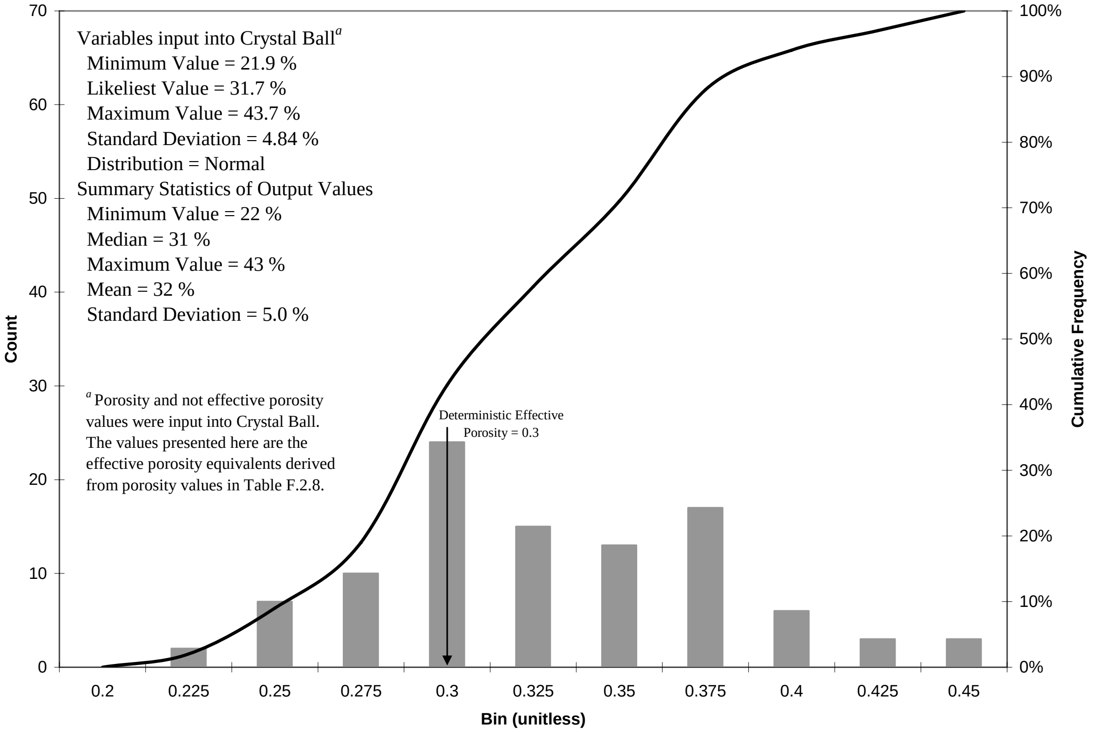
Fig. F.2.20. Histogram of Hydraulic Conductivity AT123D inputs for SWMU 1 and the C-720 Area.



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

Deterministic Hydraulic
Gradient = 4.00E-04 m/m

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

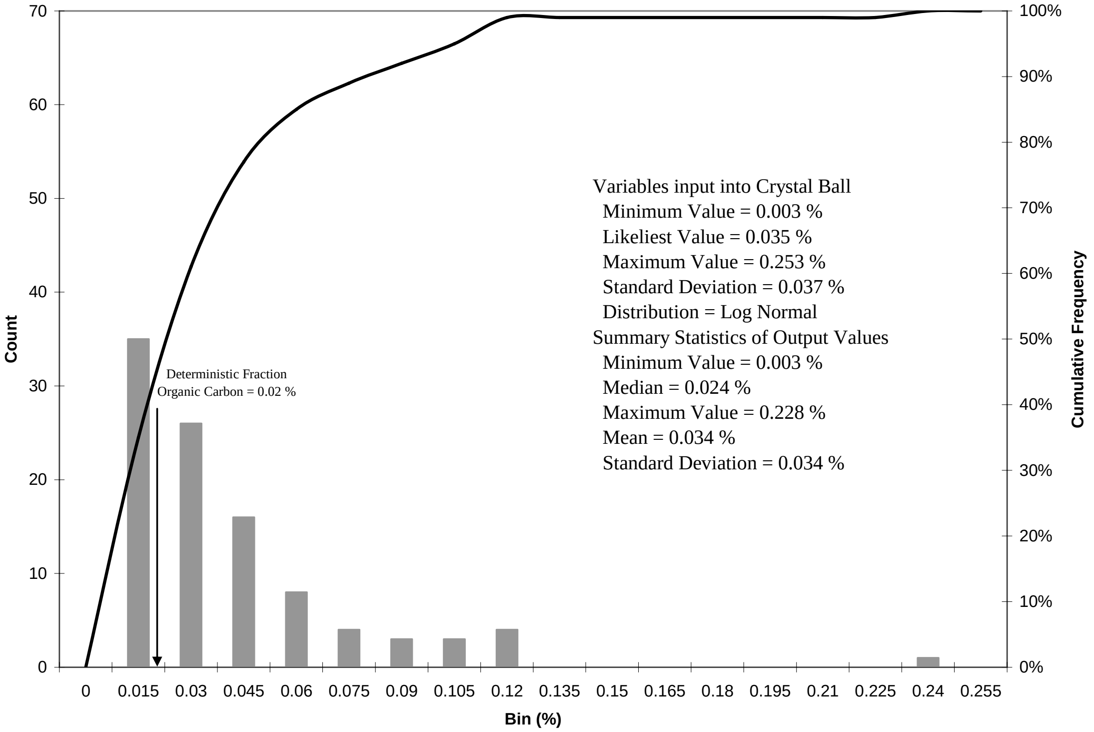


Variables input into Crystal Ball[a]
Minimum Value = 21.9 %
Likeliest Value = 31.7 %
Maximum Value = 43.7 %
Standard Deviation = 4.84 %
Distribution = Normal

Summary Statistics of Output Values
Minimum Value = 22 %
Median = 31 %
Maximum Value = 43 %
Mean = 32 %
Standard Deviation = 5.0 %

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

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



Variables input into Crystal Ball
Minimum Value = 0.003 %
Likeliest Value = 0.035 %
Maximum Value = 0.253 %
Standard Deviation = 0.037 %
Distribution = Log Normal

Summary Statistics of Output Values
Minimum Value = 0.003 %
Median = 0.024 %
Maximum Value = 0.228 %
Mean = 0.034 %
Standard Deviation = 0.034 %

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

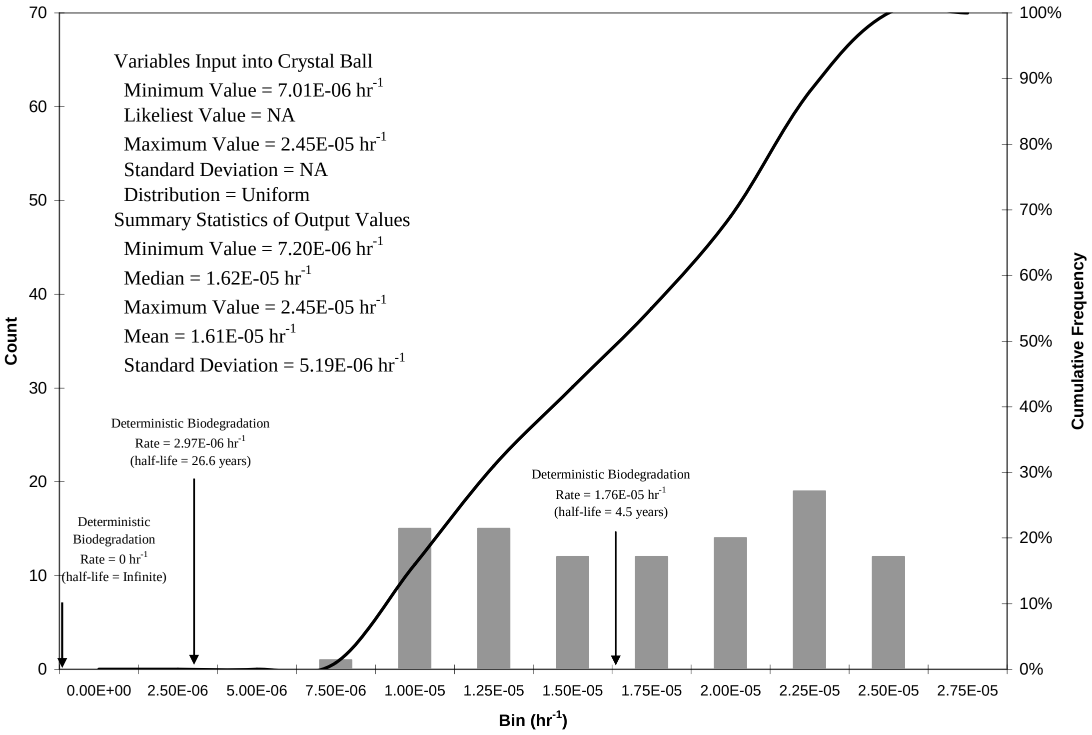


Fig. F.2.24. Histogram of Degradation Rate inputs for SWMU 1, and the C-720 Area.

E.6. MEETING MINUTES FROM PADUCAH RISK ASSESSMENT WORKING GROUP

This chapter presents meeting minutes from the Paducah Risk Assessment Working Group, beginning in June 2012. Future revisions of this document will present meeting minutes held to date.

Risk Assessment Working Group
Quarterly Meeting Minutes—June 13, 2012—Revised August 2012

1. **No Action Level (NAL)/Action Level (AL) tables:**
   a. **Discuss use of PORTS calculator for Paducah instead of NAL/AL tables in the Risk Methods Document (RMD) or use of EPA's Regional Screening Levels (RSLs).**

   After discussion, it was agreed to revise NALs and ALs and post them by September 30, 2012, and to include an "as of" date. These values will use updated toxicity values.
   Targets for hazard: NAL is 0.1; AL is 3.
   Targets for ELCR: AL is 10E-4; NAL is 10E-6 with statement regarding cumulative risk.
   Issues arising during NAL calculations will be brought up and addressed by email.
   NOTE: These revised NALs/ALs will NOT affect current projects (specifically the Soils OU RI, with a few noted exceptions to be written up in the risk assessment sections of the Soils OU RI Report).
   An e-mail was sent July 24, 2012, proposing use of RAIS for calculating NALs using site-specific exposure parameters to the extent possible. RAIS is consistent with RSL values.
   No responses to the e-mail were received.

   In a comment to the minutes, KY expressed a reluctance to use the PORTS calculator in determining NALs for Paducah.

   For dose, ranges are 1 mrem/yr, 4 mrem/yr (for water only), 15 mrem/yr, and 25 mrem/yr. 100 mrem/yr will be added to relate to the DOE order and KY public dose limits. It should be noted that 1 mrem/yr and 15 mrem/yr are not DOE or KY standards, and none of these radiation dose rates are EPA's standards, including the 15 mrem/yr.

   b. **Revise lead action levels**

   Currently, 400 mg/kg is listed as the action level for the resident. The industrial worker action level also is listed as 400 mg/kg—this number will be changed to 800 mg/kg. A reference will be provided prior to change. The MCL is 15 ug/L, this will remain unchanged in the RMD.

   c. **Tox factors and dermal; but also MCLs for Rad, SSLs**

   An "as of" date will be used and sent by email for review and concurrence. The RSL table will be used for toxicity values and original references (although the original references may be revisited if it proves problematic). The actual hierarchy of the source of the toxicity values will remain as in the current RMD (consistent with EPA guidance.) This hierarchy is on page 3-33 of the 2011 RMD.

   Use GI ABS value for calculating dermal absorption from oral values.
   Add section to RMD/Risk Assessments that recognizes the uncertainty of using RAGS Part E for metals and volatiles for dermal. This text will be sent for review by the RAWG prior to the next meeting and approval of the revised NALs/ALs

   RESRAD to be used to determine risk or dose-based values and SSLs based on dosimetry—presenting the results based on the current dosimetry, and also consistent with the factors designated in the standards.

For example, the current EPA MCLs for Tc-99, etc. will continue to be recognized even though we agree that the dosimetry is outdated (i.e., 1959 vs current dosimetry calculations). (That is, we will present both the 900 pCi/L and the 4 mrem/yr-based value.)

d. **SSLs for noncancer are usually based on an HI of 1, not 0.1 for the groundwater pathway.**
The SSL table in the RMD (Table A.7a) will now only include those from EPA-based values (remove values calculated for NALs). The first preference for calculation will be the MCL value, if an MCL is not available, the risk-based value will be used, as shown in the EPA RSL table (note: values in the RSL table are for a DAF of 1). RMD will include values for DAFs of 1, 20, and 58.

2. **Setting cleanup goals for the various soil horizons**

Background: the FS for BGOU SWMUs, IW RGO based on 0-1 ft bgs; OW RGO (for subsurface) based on 1-16 ft bgs.

For BGOU SWMUs IW cleanup set at 10^{-5} and OW set at 10^{-4} (for subsurface) (though KY may not agree with this value).

Cleanup scenarios need to be explained over all horizons, not just the surface layer.

The key is that the scenarios need to be explained. Additional information will be provided in the BGOU FS.

3. **Risk result presentation**

Discussion of possible formats that may help the agency review. It was decided that the presentation was okay, as is.

4. **Gamma walkovers**

A discussion was held as to the process that should be used on how to incorporate/consider gamma walkover survey results in the assessment. It was decided that gamma walkover survey results can be used in determining boundaries for determining exposure point concentrations (EPCs), but not in calculating EPCs.

Further, discussion was held regarding how we handle gamma walkover survey results that cast doubt on analytical values and what upfront QC can be done. Results of gamma walkover surveys should be included in the data representativeness evaluation prior to calculating risk. A specific evaluation for inconsistencies between gamma survey results and analytical results will be added to the uncertainty section (list of uncertainties) in RMD.

Nature and extent determinations need to be connected to the risk evaluation. "Is data sufficient to determine what you have…"

A sample text write-up will be sent to the group for comment.

5. **Principal Threat Waste Determination: Establish Additional Criteria**

a. **The RMD needs further direction with respect to PTW on the outcome for currently required calculations resulting in an ELCR, HI, or dose greater than the benchmarks.**
Additional comments regarding Meeting Notes with respect to PTW were made and will be addressed with the revised PTW text box for the RMD.

b. **Current dose benchmark of 25 mrem/yr is not the same scale of magnitude above the acceptable level, as is the ELCR benchmark. Propose setting the benchmark for PTW. Radiation dosimetry should be based on ICRP 60 and ICRP 72. All dosimetry should be consistent with DOE Order 458.1. DCFs should be the consistent with 458.1.**

   See #1 for additional dose benchmarks added.
   A revised textbox (from RMD) will be circulated to the Risk Assessment Working Group (RAWG) for review and concurrence in July, prior to presenting to managers. The entire textbox may be dropped instead of revising.

6. **Background Values**
   Currently used values may need to be revisited to develop recommendation on future activities.
   All background values, but especially groundwater are listed as provisional. Many background values are set at detection limits values. There are no plans for changes here. Background values should be finalized and will be placed on the next quarter's agenda.

   Background values over all media are considered to be a range. The basic background screen is against Paducah-specific values; for COPC identification Paducah-specific values are used.

Additional criteria for comparison, such as the KY state background values (listed in Appendix E of the RMD) and fallout values, can be used to refine COC selection. These chemicals do remain as COPCs. As discussed, caution should be used when comparing sample results at PGDP with nationwide fallout averages that are an order of magnitude in range. It may not be very defensible to make that comparison (especially concerning results that indicate a very heterogeneous distribution of the contaminant) and there are likely better ways of evaluating the importance of elevated (but still low) activity concentrations of radionuclides attributable to fallout.

7. **Lessons Learned from Recent Projects**
   a. **Begin development of lessons learned for the Modeling Matrix from the recent CERCLA Cell and SW Plume modeling efforts.**
   b. **Begin development of lessons learned for Remedial Goal (RG) calculations from the internal ditches and SW Plume projects.**
   No specific issues were discussed.

8. **PAHs: Establish Direction for Handling PAH Contamination in Establishing Remedial Goals (RGs).**
   Background: for the SWOU Onsite RA, PAHs were not used in cleanup determination based on their sporadic nature.
   It was proposed to include criteria in the next RMD revision to exclude PAH contamination from RG calculations, though KY has commented on meeting notes that they are not in favor of this. This text, if adopted, could be included in the SMP regarding ubiquitous PAH contamination in the CSOU.
   One KAR states that PAHs near roadways are not subject to cleanup (find citation)
   Draft text for presentation to risk managers will be sent for review/concurrence to RAWG.

9. **Recreational User Equations**
   The proposed new equation is below on the following page. A replacement page will be sent for the RMD.

10. **Dermal Risk for Metals**

See Minutes Item #1.

RMD Appendix D footnotes will be revised to "Chemical-specific absorption factors available are listed in Table B.5 [38]."

Table B.5 of the RMD will be updated from the RSL table; KY ABS values will remain in the table in order to compare as an uncertainty. It was noted that the uncertainty discussion needs to be as transparent as possible.

11. **Revisit SSLs**
    See Minutes Item #1d.

12. **Difference(in calculations for exposure to Rads) between what is currently used in the (1) PORTS Risk Calculator and is used by the (2) Oak Ridge Risk Analysis Information System (RAIS); *lambda and t* are used.**
    Example equations from RAIS documentation are shown on pages 5 and 6.

    PORTS and RAIS equations correct for decay and time of release. Equations in the RMD are simpler. Paducah radionuclides of interest (specifically uranium and technetium) do not decay very fast; therefore, while the preliminary remediation goal (PRG) would be lower than if the decay rate were used, the simpler equation will be used for Paducah. If the PORTS calculator is used for Paducah in the future, their equation will need to be changed.

    NOTE: These equations were not changed for the NALs to be reviewed for the September 2012 meeting. RAIS equations were used as is with no changes, unless otherwise noted.

    This calculation needs further discussion with respect to decay correction.

13. **Example RGO Discussion (provided through Soils OU team)**
    The example text will be discussed/commented upon by e-mail. Additional information (like from Appendix D) needs to be sent.

Table D.15. Reasonable Maximum Exposure Assumptions and Human Intake Factors for Incidental Ingestion of Sediment by a Recreational User[a]

Equations:

$$\textbf{Chemical Intake}\,[\textbf{mg/(kg} \times \textbf{day]} = \frac{C_{sed} \times CF \times EF \times ED \times IR \times FI}{BW \times AT}$$

$$\textbf{Radionuclide Intake}\,(\textbf{pCi}) = A_{sed} \times CF_{rad} \times EF \times ED \times IR \times FI$$

Parameter	Units	Value used	References[b]
Concentration in sediment = $\mathbf{C_{sed}}$	mg/kg	Chemical-specific	-----
Conversion factor = **CF**	kg/mg	10^{-6}	-----
Activity in soil = $\mathbf{A_{sed}}$	pCi/g	Chemical-specific	-----
Conversion factor = $\mathbf{CF_{rad}}$	g/mg	10^{-3}	-----
Exposure frequency = **EF**	day/yr	104 (adult) 140 (child and teen)	[14]
Exposure duration = **ED**	year	12 (adult) 12 (teen) 6 (child)	[14]
Ingestion rate = **IR**	mg/day	100 (adult) 100 (teen) 200 (child)	[14]
Fraction ingested = **FI**	unitless	1	[14]
Body weight = **BW**	kg	70 (adult) 43 (teen) 15 (child)	[14]
Averaging time = **AT**	yr × day/yr	70 × 365 (carcinogen) ED × 365 (noncarcinogen)	[14]

[a] Equation after [1].

[b] References follow Table D.50.

Residential Soil from RAIS

The residential soil land use equations, presented here, contain the following exposure routes:

incidental ingestion of soil,

$$PRG_{res\text{-}soil\text{-}rad\text{-}ing}(pCi/g)=\frac{TR\times t_{res}\times\lambda}{\left(1-e^{-\lambda t_{res}}\right)\times SF_{s}\left(\frac{risk}{pCi}\right)\times IFS_{adj}\left(\frac{120\ mg}{day}\right)\times EF_{r}\left(\frac{350\ days}{year}\right)\times ED_{r}(30\ years)\times\left(\frac{g}{1000\ mg}\right)}$$

where

$$IFS_{adj}\left(\frac{120\ mg}{day}\right)=\frac{\left(IRS_{c}\left(\frac{200\ mg}{day}\right)\times ED_{c}(6\ years)+IRS_{a}\left(\frac{100\ mg}{day}\right)\times ED_{r}-ED_{c}(24\ years)\right)}{ED_{r}(30\ years)}$$

inhalation of particulates emitted from soil,

$$PRG_{res\text{-}soil\text{-}rad\text{-}inh}(pCi/g)=\frac{TR\times t_{res}\times\lambda}{\left(1-e^{-\lambda t_{res}}\right)\times SF_{i}\left(\frac{risk}{pCi}\right)\times IFA_{adj}\left(\frac{18\ m^3}{day}\right)\times EF_{r}\left(\frac{350\ days}{year}\right)\times ED_{r}(30\ years)\times\frac{1}{PEF\left(\frac{m^3}{kg}\right)}\times\left[ET_{ro}\left(\frac{0.073\ hour}{hour}\right)+\left(ET_{ri}\left(\frac{0.683\ hour}{hour}\right)\times DF_{i}(0.4)\right)\right]\times\left(\frac{1000\ g}{kg}\right)}$$

where

$$IFA_{adj}\left(\frac{18\ m^3}{day}\right)=\frac{IRA_{c}\left(\frac{10\ m^3}{day}\right)\times ED_{c}(6\ years)+IRA_{a}\left(\frac{20\ m^3}{day}\right)\times ED_{r}-ED_{c}(24\ years)}{ED_{r}(30\ years)}$$

external exposure to ionizing radiation and

$$PRG_{res\text{-}soil\text{-}rad\text{-}ext}(pCi/g)=\frac{TR\times t_{res}\times\lambda}{\left(1-e^{-\lambda t_{res}}\right)\times SF_{x}\left(\frac{risk/year}{pCi/g}\right)\times ACF(0.9)\times\left[ET_{ro}+\left(ET_{ri}\times GSF(0.4)\right)\right]\times EF_{r}\left(\frac{350\ days}{year}\right)\times\left(\frac{1\ year}{365\ days}\right)\times ED_{r}(30\ years)}$$

Total.

$$PRG_{res\text{-}soil\text{-}rad\text{-}tot}(pCi/g)=\frac{1}{\frac{1}{PRG_{res\text{-}soil\text{-}rad\text{-}ing}}+\frac{1}{PRG_{res\text{-}soil\text{-}rad\text{-}inh}}+\frac{1}{PRG_{res\text{-}soil\text{-}rad\text{-}ext}}}$$

RADIONUCLIDE SOIL SCREENING LEVELS FOR RESIDENTS from PORTS calculator

Soil Ingestion

$$SL_{r-ing}\left(\frac{pCi}{g}\right)=\frac{TR\times t_r\times\lambda}{(1-e^{-\lambda t_r})\times SF_s\times IFS_{r-adj}\times EF_r\times ED_r\times\frac{g}{1000mg}}$$

$$IFS_{r-adj}\left(\frac{mg}{day}\right)=\frac{ED_{r-c}\times IRS_{r-c}+ED_{r-a}\times IRS_{r-a}}{ED_{r-a}}$$

Inhalation

$$SL_{r-inh}\left(\frac{pCi}{g}\right)=\frac{TR\times t_r\times\lambda}{(1-e^{-\lambda tr})\times SF_i\times IFA_{r-adj}\times EF_r\times ED_r\times\frac{1}{PEF}\times\frac{1000g}{kg}\times ET_r\times\frac{1day}{24hours}}$$

$$IFA_{r-adj}\left(\frac{m^3}{day}\right)=\frac{ED_{r-c}\times IRA_{r-c}+ED_{r-a}\times IRA_{r-a}}{ED_{r-a}}$$

External

$$SL_{r-ext}\left(\frac{pCi}{g}\right)=\frac{TR\times t_r\times\lambda}{(1-e^{-\lambda tr})\times SF_{ext-sv_i}\times ACF\times EF_r\times\frac{1year}{365days}\times ED_r\times[ET_{r-o}+(ET_{r-i}\times GSF_i)]}$$

Risk Assessment Working Group
Proposed Agenda—September 2012

1. **Additional changes to June 2012 Meeting Minutes.**
   Changes made and finalized.
2. **Discuss FY 13 RAWG Work Plan and Quarterly Meeting Schedule.**
   December 5, 2012—8:30-11:00 central (9:30-12:00 eastern)
   March 6, 2013—8:30-11:00 central (9:30-12:00 eastern)
   June 5, 2013—8:30-11:00 central (9:30-12:00 eastern)
   September 11, 2013—8:30-11:00 central (9:30-12:00 eastern)
   RMD is site-specific guidance for risk assessment. LATA to provide page changes for review/approval. (Include in plan for proceeding – see Item 7)
3. **Revisions to the Risk Methods Document text:**

   a. Suggest deletion of the following text from page 3-21:"The total dioxin concentration will be compared to the EPA residential cleanup level of 1 ppb toxicity equivalents (TEQs) for residential and 5 to 20 ppb TEQs for industrial scenarios (EPA 1998c), in addition to comparison to the PRGs in Appendix A."
   These levels are no longer recommended.
   EPA recommends the use of the RSL values. These are screening levels, not necessarily cleanup levels.

   b. Remove Cobalt-60 from PGDP COPC List.
   No indication Co-60 is site contaminant. Still including Co-60 in risk assessments? Would still be included in dataset, but dropped from COPC list because the Co-60 results would not be representative. This explanation would need to be included in the risk assessment write-up. IF cobalt-60 shows up in new sample data, values would be included in risk assessment [Follow up: how is gross gamma screen performed? How do we ensure we don't miss other rads (e.g., Sr-90)? Double-check with Sample Management to ensure Co-60 is in gamma library for labs—this would need to remain in the lab SOW].
   -Won't be in PRG tables.
   -Won't be in Site QAPP (footnote that Co-60 remain in lab's gamma library).

4. **Discussion to incorporate RAGS Part F.**
   RAGS Part F is the inhalation unit risk guidance.
   RMD text would be updated to refer to RAGS Part F.
   The equations in Appendix D would be updated, with reference to RAGS Part F.
   Changes to other tables?

5. **Discussion regarding PAHs text. See attached file.**
   Coal-fire facility at PGDP is likely a source for PAHs that need to be remediated.
   Comments on PAH paper expected by Wednesday, October 31. Look at doing a sitewide PAH study (using data already available, noting data within 2(?) ft of roadway and outside influence of coal plant). The purpose is to understand the concentration distribution at the site.
   Risk from PAHs could also be addressed as an uncertainty.

Follow-up: map of existing PAH samples (separated surface and subsurface), is it possible to use these samples for a sitewide study?

6. **Discussion regarding revised PTW language. Revised text box language for the Risk Methods Document is not available at this time. Discussion will be in general.**
RMD will reference EPA guidance (1991, fact sheets) and text box will be removed. "High risks lead to early actions." Principal threats discussed in RMD (esp. ROD section) will refer to EPA guidance. Also should be discussed in FS section. Figure 1.1 will reference guidance (1991).

7. **Discussion regarding revised NALs/ALs and Table B.5.**
Jerri's e-mail (text is below)– Corrections will be sent.

In addition to our previous discussions via e-mail, here are some errors/clarifications that need to be discussed tomorrow.

Chromium (total)	KY ABS	5E-02	Change to 2.5E-02 (CrVI) or 1.3E-02 (CrIII)
Manganese (diet)	KY ABS	4E-02	Change to 5E-02 (default); current value is GI ABS non-dietary exposure
Vanadium	KY ABS	2.6E-02	Change to 5E-02 (default)
1,1-Dichloroethylene	VF Res	1.02E+03	Change to 1.2E+03
1,1-Dichloroethylene	VF Ind	6.84E+02	Change to 1.2E+03
Naphthalene	KY ABS	2.5E-02	Change to 1.3E-1 (EPA ABS)

Acenaphthylene	What is surrogate source of ABS and Permeability Constant?
Phenanthrene	What is surrogate source of ABS and Permeability Constant?
PCB (high risk)	What is surrogate source of Permeability Constant?
PCB (low risk)	What is surrogate source of Permeability Constant?
PCB (lowest risk)	What is surrogate source of Permeability Constant?

Add columns for reference to ABS and permeability constant.
Ensure parameters input into RAIS calculator are transparent.
Use RSL/RAIS calculator, working through issues.
Each media to be sent separately with documentation of any issues and parameters input so that values can be reproduced.

Recommendation for any tables to be removed from RMD Appendices—(Table B.4?) TableB.5 would likely stay for documentation purposes.

First week of October: plan for proceeding, including review cycle (30 day review—keeping holidays in mind).

Risk Assessment Working Group
Agenda—December 5, 2012
and Draft Meeting Minutes

Present:

Jerri Martin	**Tim Fredrick**	**Rich Bonczek**
Nathan Garner	**Turpin Ballard**	**Bobette Nourse**
Gaye Brewer	**Jon Richards**	**John Volpe**
Todd Mullins		**Joe Towarnicky**
		LeAnne Garner

1. **Review of the September 2012 Meeting Minutes.**
Meeting minutes are acceptable, but need to add PAH discussion to this agenda.

2. **Discussion of Revisions sent to date.**

a. Soil/Sediment NALs and associated write-ups
Action level for HI = 3. Range of values for HI, based on RGO tables were 0.1, 1, and 3.
*A footnote explaining why the action level for HI is 3 needs to be added (Might refer to Figure 1.1).
Also add to introduction notes in Appendix A.
RAIS screens were helpful.
*Check with RAIS why the adherence factor and surface area are not input parameters available for adjustment in the calculator for the industrial worker scenario.

b. Groundwater NALs and associated write-ups
Action level for HI = 3. Range of values for HI, based on RGO tables were 0.1, 1, and 3. A footnote explaining why the action level for HI is 3 needs to be added (Might refer to Figure 1.1).

c. Gamma Screens (removing Co-60 as a Paducah COPC and discussion of Pb-210)

Current recommendation, after comments received: "Currently, contracted laboratories only report what is requested in the laboratory SOW, which typically is the PGDP COPC list.
For future SOWs that are applicable (i.e., have gamma analyses), it will be requested that if cobalt-60 appears in the gamma screen above the MDA, it will be noted.
This also will be documented in the appropriate QAPP.
For the USEC lab, the presence of cobalt-60 will appear as a laboratory comment. For offsite labs, the presence of cobalt-60 will be reported in their case narratives; this information will then be manually input into the database systems (most likely in lab comments).
While lead-210 is another radionuclide that has been detected in some samples onsite (notably SWMU 222), it is not expected to be a sitewide contaminant. Lead-210 may be requested as a special analysis on specific projects. On these projects, the MDC should be set at 1 pCi/g or less for lead-210 (46 KeV peak) using a thin window HPGe detector. Additionally, the counting uncertainty should be less than 50% for lead-210."

Additional information regarding lead-210 is included in Attachment 1.

***What is the risk for MDC of lead-210 with no special detector?**

Residential default at 10^{-6} is 0.7 pCi/g. Industrial worker at 10^{-6} is 4 pCi/g.
***Check to see if labs would need to recalibrate equipment to see lead-210.**

d. Revisions to Risk Methods Document
- Main text
    1. Discussion regarding RGO text in Section 4.1. Excerpts from guidance documents are included for reference on Pages 6 and 7.
       Text will be added to Section 4.1.4 Include information here regarding RGO and PRG revision guidance. Some discussion was in the 2001 RMD, but this was deleted during revision because the language was not accurate.
       Any revision of PRGs needs to be clear as to the reason for revision. Revising PRGs after the FS is final is not likely. The general expectation is that cleanup goals in the ROD would be the revised PRGs in the FS.
       Jerri will send state guidance if there is any.
       *Revised text will be sent out to RAWG.
    2. KY Risk Assessment Branch Comments (see Pages 8-10).
       Include in Section 3.3.4.3. "(2a) General discussion of options to determine the ten or more samples." Write-up on how to handle soils data. Include example determination of EPC from grid values (from Soils OU). Revised text to be sent as scheduled. Adding this discussion for EPC calculations for soils is consistent with the groundwater EPC discussion found later in Section 3.3.4.3.
       Include rationale for choosing KDEP-specific values for dermal absorption as a footnote or text box to Section 3.3.5.2.
       Add 8b and 11b equations for inhalation pathways, since they are different using RAGS Part F guidance. Send revisions to RAWG as scheduled.

- Appendix A
    1. Revised Table A.14 was sent for review.
       See comments from Jon Richards from CERCLA Cell. EPA prefers Table A.14 list 900 pCi/L as the MCL for Tc-99 and footnote the uncertainty. Other comments (especially for uranium isotopes) can be e-mailed.
- Appendix B
    1. KY Risk Assessment Branch Comments (see Pages 8-10).
       Need to correct non-cancer AT (days x years), as appropriate. This is a table (presentation) error and not a AL/NAL calculation error.
       Jerri has sent a list of surrogate chemicals as follows.

Acenaphthylene → Acenaphthene

Benzo(g,h,i)perylene → Pyrene or Fluoranthene

Phenanthrene → Acenaphthene or Fluoranthene

Send revision to Appendix B as scheduled.

2.
- Appendix D
  Highlight in introduction to Appendix D that the parameters shown in equations may not be the same as those used in PRG calculations and why. Revisions to be sent to RAWG as scheduled.

Also see Items 3 and 7.

Follow-up on radionuclides calculations from June meeting minutes.

Discussion regarding the addition of decay correction (i.e., lambda and t) to the equations in the Paducah Risk Methods Document.

The following is taken from the June meeting minutes:
"Difference (in calculations for exposure to Rads) between what is currently used in the (1) PORTS Risk Calculator and is used by the (2) Oak Ridge Risk Analysis Information System (RAIS); *lambda and t* are used.
Example equations from RAIS documentation are shown on Pages 11 and 12.
PORTS and RAIS equations correct for decay and time of release. Equations in the RMD are simpler. Paducah radionuclides of interest (specifically uranium and technetium) do not decay very fast; therefore, while the preliminary remediation goal (PRG) would be lower than if the decay rate were used, the simpler equation will be used for Paducah. If the PORTS calculator is used for Paducah in the future, their equation will need to be changed.
NOTE: These equations were not changed for the NALs to be reviewed for the September 2012 meeting. RAIS equations were used as is with no changes, unless otherwise noted.
This calculation needs further discussion with respect to decay correction."

Revision to Appendix D should include lambda and t. Note that PRG calculations include use of lambda and t. Revised Appendix D to be sent to RAWG as scheduled.

3. **Provisional Groundwater Background**

Values have been used as a screening tool even though they are still provisional. Should these be called final?
Many values in Table A.13 are not truly background, they are detection limits. If analyzed today, these may be lower. This is not a problem for most metals [note Arsenic background value is listed as 0.005 mg/L (a detection limit), but the MCL for Arsenic is 0.01 mg/L]. For chromium, results may need additional evaluation.
*Calculation for background value for Nickel needs to be checked.
*In Table A.13, highlight the background values based on detection limits that are greater than the MCL or, if no MCL, the residential GW NAL.
*Since the background values were originally included in Groundwater OU FS and they were never approved, leave values as "provisional."

4. **An issue to consider is how to screen XRF and isotope-specific rad detector results against background. The background we have are really not appropriate to use with results from these field techniques.**

Difference in fixed-base and field-base results should be noted in RMD as an uncertainty—XRF results are likely higher than fixed-base results. If it is agreed that the XRF data is of sufficient quality to determine risk, the uncertainty should not drive decision.
Add this as a bullet to Section 3.3.1. Also add to page 3-16 (discussion of XRF).

5. **For SSLs derived from RESRAD, consider verification that the DCFs and dose calculation are consistent with requirements in DOE Order 458.1. Thus must make sure ICRP 60 and ICRP 72 were used.**

SSL are derived using a spreadsheet from RESRAD inputs. Need to make sure the dose-based PRGs are correct. Tables in Appendix A will be evaluated with an update and/or revised tables to the RAWG as scheduled. See #7, below.

6. **Review exposure times for residents; currently we are using 24 hours/day.**

Table D.8 in the Risk Methods Document lists the equation and reasonable maximum exposure assumptions for external exposure to ionizing radiation from soil.
The exposure frequency (EF) is 350/365 day/day.
The gamma exposure time (ET) factor is 24/24 hr/hr.

A question was raised during review of the proposed Paducah Soil/Sediment No Action Levels as to why outdoor and indoor exposure times encoded by RAIS (0.073 hr/hr and 0.683 hr/hr, respectively) for the rad PRGs did not equal 1 hr/hr. The exposure time for the resident outside (ETro) and exposure time for the resident inside (ETri) assumed by RAIS allows for time spent away from home. The default scenario for the resident is 18 hr/day, 350 days/yr.

Should the Paducah default scenario remain as it is or should the equation and exposure assumptions be revised to account for indoor and outdoor time (i.e., gamma shielding applied for indoor time and not for outdoor time) and should the time be 18 hr/day instead of 24?

Exposure time in this instance only applies to external gamma exposure. These exposure times should be changed to be consistent, so that the default scenario is 18 hr/day, 350 days/yr. Changes will be reflected in Appendix D and Table B.4. Additionally, revisions to dose PRGs/SSLs will be necessary (see #6 above).

7. **Reporting soil sample results on a dry weight basis.**

LATA has noted that the industry accepted practice is for laboratories to report soil samples on a dry weight corrected basis. Because of the increase in soil projects going to the field, we believed that this was a good time to discuss a change with the USEC Analytical Lab.
The topic was discussed at length with the USEC lab recently and also input was enlisted from DOECAP auditors who were on sight at the time. As a result of those conversations, we believe we have a pathforward on this process; LATA has asked them to analyze one aliquot for moisture and enter that result in LIMS. Then, as other analyses are completed (metals, volatiles, etc) are completed, the LIMS system will perform a dry weight correction utilizing the one moisture result that was entered in the system. This way, all analyses for the sample are adjusted utilizing the same correction factor. Therefore, the resulting values reported by the lab will be based on a dry weight basis.

These changes may take a little while, so they may not be able to make the corrections within LIMS to start the process immediately, but we directed them to conduct (and report) moisture analysis on our next upcoming project (SWMU 4). This data can be presented on either an “as received” basis or dry weight corrected basis.

The key for this will be how to use historical data.

*Uncertainties will need to be captured in project-specific documents. Also include in RMD as a potential uncertainty in Section 3.3.7.1 and also Step 2 on page 3-16. Revision to be sent as scheduled.
*Send update to RAWG with method the lab is using to determine moisture.
Drying samples is part of CLP

As an update, the method shown below was sent to the group on 12/17/2012, as the method the USEC lab will be using to determine moisture:

ASTM D2974-07a, Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils

EPA supplied the following information:
Usually, each method would include the % moisture, but if the sample is reasonably homogenous, then one analysis applied to all aliquots should work. In the methods, VOAs do not require drying as it is a closed-system and the vial is loaded directly to the machine with any interaction being performed via the septum seal. Drying would create loss of contaminants. For extractables (SemiVOA, Pest, PCB, etc), the sample does have any standing water decanted off and then is mixed with sodium sulfate or Hydromatrix, so it doesn't go into the extraction all soupy exactly. For Metals, there isn't really a discussion or rationale and usually we don't even decant, though that optionally be done. There are definitely arguments out there that we should be doing better homogenization and particle size partitioning for Metals and drying would be a part of that. (Hg might not be amenable to drying without contaminant loss.) Overall, I think it comes down to trying to bring the sample into the process as close to its natural state in the environment as possible. A high moisture sample is often problematic, though, and we do ask the field to try to minimize the moisture content to the extent possible when collecting. Some references are SW-846 3500 (generic extraction methodology) at http://www.epa.gov/epawaste/hazard/testmethods/sw846/online/index.htm. In the CLP SOWs, most relevant discussion is in Exhibit D, Section 10 of each method where the sample prep is discussed. See SOM01.2 and ISM01.3 at www.epa.gov/superfund/program/clp.

8. Add PAH discussion to agenda.

The intent of the PAH paper was to send a recommendation to the FFA managers for how we propose to handle PAHs in risk assessments and why. A map of existing PAH samples is due to the RAWG January 4. Comments from EPA on paper may be available mid January.

Next meeting: March 6. Between now and then individual meetings may need to take place in order to facilitate revisions to RMD.

***Schedule for Revisions will be sent following this meeting.**

Revisions to Risk Methods Document

Excerpts from Guidance Documents Regarding RGO Text

In RAGS Volume 1 Part B it is stated:

From Section 2.3 Future Land Use

"When waste will be managed onsite, land-use assumptions and risk-based PRG development become more complicated because the assumptions for the site itself may be different from the land use in the surrounding area. For example, if waste is managed onsite in a residential area, the risk-based PRGs for the ground water beneath the site (or at the edge of the waste management unit) may be based on residential exposures, but the risk-based PRGs for the site soils may be based on an industrial land use with some management or institutional controls."

From Section 2.8 Modification of Preliminary Remediation Goals

"Upon completion of the baseline risk assessment (or as soon as data are available), it is important to review the future land use, exposure assumptions, and the media and chemicals of potential concern originally identified at scoping, and determine whether PRGs need to be modified. Modification may involve adding or subtracting chemicals of concern, media, and pathways or revising individual chemical-specific goals."

RAGS Volume 1 Part B also includes the following in a text box:

NCP PREAMBLE: EXPOSURE, TECHNICAL, AND UNCERTAINTY FACTORS (55 Federal Register 8717, March 8, 1990)

"Preliminary remediation goals ... may be revised ... based on the consideration of appropriate factors including, but not limited to: exposure factors, uncertainty factors, and technical factors. Included under exposure factors are: cumulative effect of multiple contaminants, the potential for human exposure from other pathways at the site, population sensitivities, potential impacts on environmental receptors, and crossmedia impacts of alternatives. Factors related to uncertainty may include: the reliability of alternatives, the weight of scientific evidence concerning exposures and individual and cumulative health effects, and the reliability of exposure data. Technical factors may include: detection/quantification limits for contaminants, technical limitations to remediation, the ability to monitor and control movement of contaminants, and background levels of contaminants. The final selection of the appropriate risk level is made when the remedy is selected based on the balancing of criteria .... "

Revisions to Risk Methods Document
Excerpts from Guidance Documents Regarding RGO Text
Continued

Finally, OSWER DIRECTIVE 9355.0-30 "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" states:

In USE OF BASELINE RISK ASSESSMENT TO MODIFY PRELIMINARY REMEDIATION GOALS

"Remediation goals developed under CERCLA section 121 are generally medium-specific chemical concentrations that will pose no unacceptable threat to human health and the environment. Preliminary remediation goals are developed early in the RI/FS process based on ARARs and other readily available information, such as concentrations associated with 10(-6) cancer risk or a hazard quotient equal to one for noncarcinogens calculated from EPA toxicity information. These preliminary goals may be modified based on results of the baseline risk assessment, which clarifies exposure pathways and may identify situations where cumulative risk of multiple contaminants or multiple exposure pathways at the site indicate the need for more or less stringent cleanup levels than those initially developed as preliminary remediation goals. In addition to being modified based on the baseline risk assessment, preliminary remediation goals and the corresponding cleanup levels may also be modified based on the given waste management strategy selected at the time of remedy selection that is based on the balancing of the nine criteria used for remedy selection (55 Fed. Reg. at 8717 and 8718)."

Comments to Risk Methods Document

Received from KY Risk Assessment Branch

Main Text

3.3.4.3 Quantification of Exposure

- Discussion of how the grid values will be determined should be included, similar to the following:

  Grid values were determined following guidance in the work plan. Basically, the maximum detected result from within the grid applies to the grid. If not detected, the minimum detection limit applies to the grid.

  If a grid had no result (detect or non-detect) for the COPC, an average of the results for the grids with results was used.

NO RESULT	RESULT = 9	NO RESULT	RESULT = 2
RESULT = 7	NO RESULT	RESULT = 3	NO RESULT
RESULT = 3	NO RESULT	RESULT = 5	RESULT = 5

  For grids with "NO RESULT," the average of the grids with results was used.
  (9+2+7+3+3+5+5)/7= 4.857143

  The UCL95 would be calculated from the following:

4.857143	9	4.857143	2
7	4.857143	3	4.857143
3	4.857143	5	5

3.3.5.2 Sources of toxicity information

- Discussion of the "KDEP-specific values for dermal absorption" should be included, such as the following:

In RAGS E 2004, Exhibit 4-1, the following GI absorption efficiencies are listed that are below the 5% dermal absorption KDEP has recommended as a default value for inorganics. For these constituents, the dermal absorption value should be modified from 5% to mimic the GI absorption efficiencies, as follows:

Beryllium	0.007 = 0.7%
Chromium III	0.013 = 1.3%
Chromium VI	0.025 = 2.5%
Manganese	0.04 = 4%
Nickel	0.04 = 4%
Silver	0.04 = 4%
Vanadium	0.026 = 2.6%

This is in addition to the chemical-specific dermal absorption fractions listed in Exhibit 3-4, including:

Arsenic	0.03 = 3%
Cadmium	0.001=0.1%

Equation 8, Page 64

- The RfD_i is not interchangeable with the RfC.
  RfD_i (mg/kg-day) = RfC (mg/m^3) x 20 m^3/day ÷ 70 kg

Equation 11, page 64

- The SF_i is not interchangeable with the inhalation unit risk (IUR)
  SF_i (kg-day/mg) = IUR (m^3/μg) x (20 m^3/day)$^{-1}$ x 70 kg x 10^3 μg/mg

Appendix B

Table B.4 Exposure Parameters Used in Calculation of Human Health PRGs

- General Parameters – Averaging time – noncancer (AT-N)

  It appears that instead of multiplying the number of years times the number of days in the year, the number of years is multiplied by 70 instead of 365…this must be corrected.

- Inhalation RGA Groundwater (Table D.2, D.27)

  It appears that instead of multiplying the number of years times the number of days in the year times the number of hours in the day, the number of years times the number of hours in the day is multiplied by 70 instead of 365…this must be corrected.

Table B.5 Toxicity Values and Information Used in PRG Derivation

- Acenaphthylene → use acenaphthene toxicity values (e.g., oral reference dose, absorbed dose)

- Acrylonitrile → absorbed dose slope factor (5.4E-01) should be added to the table

- Carbazole → absorbed dose slope factor (2.0E-02) should be added to the table

- U-235+D → the external exposure slope factor listed is for U-235, not U-235+D; the SFe Reference lists FGR12*, but there is no explanation of the "*"

Notes on Table B.5

- Note 15 should include information (or location of such) given above in the comment for the main text Section 3.3.5.2 (copied below)

  In RAGS E 2004, Exhibit 4-1, the following GI absorption efficiencies are listed that are below the 5% dermal absorption KDEP has recommended as a default value for inorganics. For these constituents, the dermal absorption value should be modified from 5% to mimic the GI absorption efficiencies, as follows:

Beryllium	0.007 = 0.7%
Chromium III	0.013 = 1.3%
Chromium VI	0.025 = 2.5%
Manganese	0.04 = 4%
Nickel	0.04 = 4%
Silver	0.04 = 4%
Vanadium	0.026 = 2.6%

  This is in addition to the chemical-specific dermal absorption fractions listed in Exhibit 3-4, including:

Arsenic	0.03 = 3%
Cadmium	0.001=0.1%

Radionuclides Calculations

Residential Soil from RAIS

The residential soil land use equations, presented here, contain the following exposure routes:

incidental ingestion of soil,

$$\mathrm{PRG}_{\text{res-sol-rad-ing}}(\mathrm{pCi/g})=\frac{\mathrm{TR}\times t_{\mathrm{res}}\times\lambda}{\left(1-e^{-\lambda t_{\mathrm{res}}}\right)\times \mathrm{SF}_{s}\left(\frac{\text{risk}}{\mathrm{pCi}}\right)\times \mathrm{IFS}_{\mathrm{adj}}\left(\frac{120\ \mathrm{mg}}{\mathrm{day}}\right)\times \mathrm{EF}_{r}\left(\frac{350\ \mathrm{days}}{\mathrm{year}}\right)\times \mathrm{ED}_{r}\,(30\ \mathrm{years})\times\left(\frac{\mathrm{g}}{1000\ \mathrm{mg}}\right)}$$

where

$$\mathrm{IFS}_{\mathrm{adj}}\left(\frac{120\ \mathrm{mg}}{\mathrm{day}}\right)=\frac{\left(\mathrm{IRS}_{c}\left(\frac{200\ \mathrm{mg}}{\mathrm{day}}\right)\times \mathrm{ED}_{c}(6\ \mathrm{years})+\mathrm{IRS}_{a}\left(\frac{100\ \mathrm{mg}}{\mathrm{day}}\right)\times \mathrm{ED}_{r}-\mathrm{ED}_{c}\,(24\ \mathrm{years})\right)}{\mathrm{ED}_{r}\,(30\ \mathrm{years})}$$

inhalation of particulates emitted from soil,

$$\mathrm{PRG}_{\text{res-sol-rad-inh}}(\mathrm{pCi/g})=\frac{\mathrm{TR}\times t_{\mathrm{res}}\times\lambda}{\left(1-e^{-\lambda t_{\mathrm{res}}}\right)\times \mathrm{SF}_{i}\left(\frac{\text{risk}}{\mathrm{pCi}}\right)\times \mathrm{IFA}_{\mathrm{adj}}\left(\frac{18\ \mathrm{m}^{3}}{\mathrm{day}}\right)\times \mathrm{EF}_{r}\left(\frac{350\ \mathrm{days}}{\mathrm{year}}\right)\times \mathrm{ED}_{r}\,(30\ \mathrm{years})\times\frac{1}{\mathrm{PEF}\left(\frac{\mathrm{m}^{3}}{\mathrm{kg}}\right)}\times \left[\mathrm{ET}_{ro}\left(\frac{0.073\ \mathrm{hour}}{\mathrm{hour}}\right)+\left(\mathrm{ET}_{ri}\left(\frac{0.683\ \mathrm{hour}}{\mathrm{hour}}\right)\times \mathrm{DF}_{i}\,(0.4)\right)\right]\times\left(\frac{1000\ \mathrm{g}}{\mathrm{kg}}\right)}$$

where

$$\mathrm{IFA}_{\mathrm{adj}}\left(\frac{18\ \mathrm{m}^{3}}{\mathrm{day}}\right)=\frac{\mathrm{IRA}_{c}\left(\frac{10\ \mathrm{m}^{3}}{\mathrm{day}}\right)\times \mathrm{ED}_{c}(6\ \mathrm{years})+\mathrm{IRA}_{a}\left(\frac{20\ \mathrm{m}^{3}}{\mathrm{day}}\right)\times \mathrm{ED}_{r}-\mathrm{ED}_{c}\,(24\ \mathrm{years})}{\mathrm{ED}_{r}\,(30\ \mathrm{years})}$$

external exposure to ionizing radiation and

$$\mathrm{PRG}_{\text{res-sol-rad-ext}}(\mathrm{pCi/g})=\frac{\mathrm{TR}\times t_{\mathrm{res}}\times\lambda}{\left(1-e^{-\lambda t_{\mathrm{res}}}\right)\times \mathrm{SF}_{x}\left(\frac{\text{risk/year}}{\mathrm{pCi/g}}\right)\times \mathrm{ACF}\,(0.9)\times\left[\mathrm{ET}_{ro}+\left(\mathrm{ET}_{ri}\times \mathrm{GSF}\,(0.4)\right)\right]\times \mathrm{EF}_{r}\left(\frac{350\ \mathrm{days}}{\mathrm{year}}\right)\times\left(\frac{1\ \mathrm{year}}{365\ \mathrm{days}}\right)\times \mathrm{ED}_{r}\,(30\ \mathrm{years})}$$

Total.

$$\mathrm{PRG}_{\text{res-sol-rad-tot}}\,(\mathrm{pCi/g})=\frac{1}{\frac{1}{\mathrm{PRG}_{\text{res-sol-rad-ing}}}+\frac{1}{\mathrm{PRG}_{\text{res-sol-rad-inh}}}+\frac{1}{\mathrm{PRG}_{\text{res-sol-rad-ext}}}}$$

Radionuclides Calculations
Continued

RADIONUCLIDE SOIL SCREENING LEVELS FOR RESIDENTS from PORTS calculator

Soil Ingestion

$$SL_{r-ing}\left(\frac{pCi}{g}\right)=\frac{TR\times t_r\times\lambda}{(1-e^{-\lambda t_r})\times SF_s\times IFS_{r-adj}\times EF_r\times ED_r\times\frac{g}{1000mg}}$$

$$IFS_{r-adj}\left(\frac{mg}{day}\right)=\frac{ED_{r-c}\times IRS_{r-c}+ED_{r-a}\times IRS_{r-a}}{ED_{r-a}}$$

Inhalation

$$SL_{r-inh}\left(\frac{pCi}{g}\right)=\frac{TR\times t_r\times\lambda}{(1-e^{-\lambda tr})\times SF_i\times IFA_{r-adj}\times EF_r\times ED_r\times\frac{1}{PEF}\times\frac{1000g}{kg}\times ET_r\times\frac{1day}{24hours}}$$

$$IFA_{r-adj}\left(\frac{m^3}{day}\right)=\frac{ED_{r-c}\times IRA_{r-c}+ED_{r-a}\times IRA_{r-a}}{ED_{r-a}}$$

External

$$SL_{r-ext}\left(\frac{pCi}{g}\right)=\frac{TR\times t_r\times\lambda}{(1-e^{-\lambda tr})\times SF_{ext-sv_i}\times ACF\times EF_r\times\frac{1year}{365days}\times ED_r\times[ET_{r-o}+(ET_{r-i}\times GSF_i)]}$$

ATTACHMENT 1
LEAD-210 at PGDP
Sent by e-mail 11/14/2012

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 1). 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).

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. Since 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.

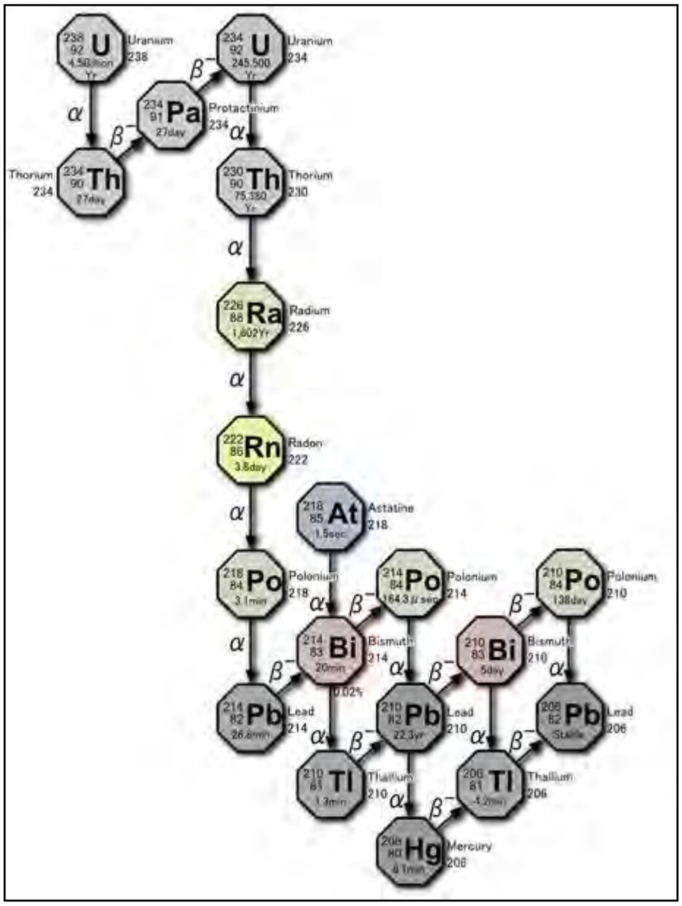


Figure 1. Lead-210 Decay Chain

Available PGDP lead-210 data was plotted to estimate an approximate background value. This map is shown in Figure 2. Since the majority of the available data is historical, data quality is not certain. However, is appears that the higher lead-210 activities within the PGDP boundaries are at background values.

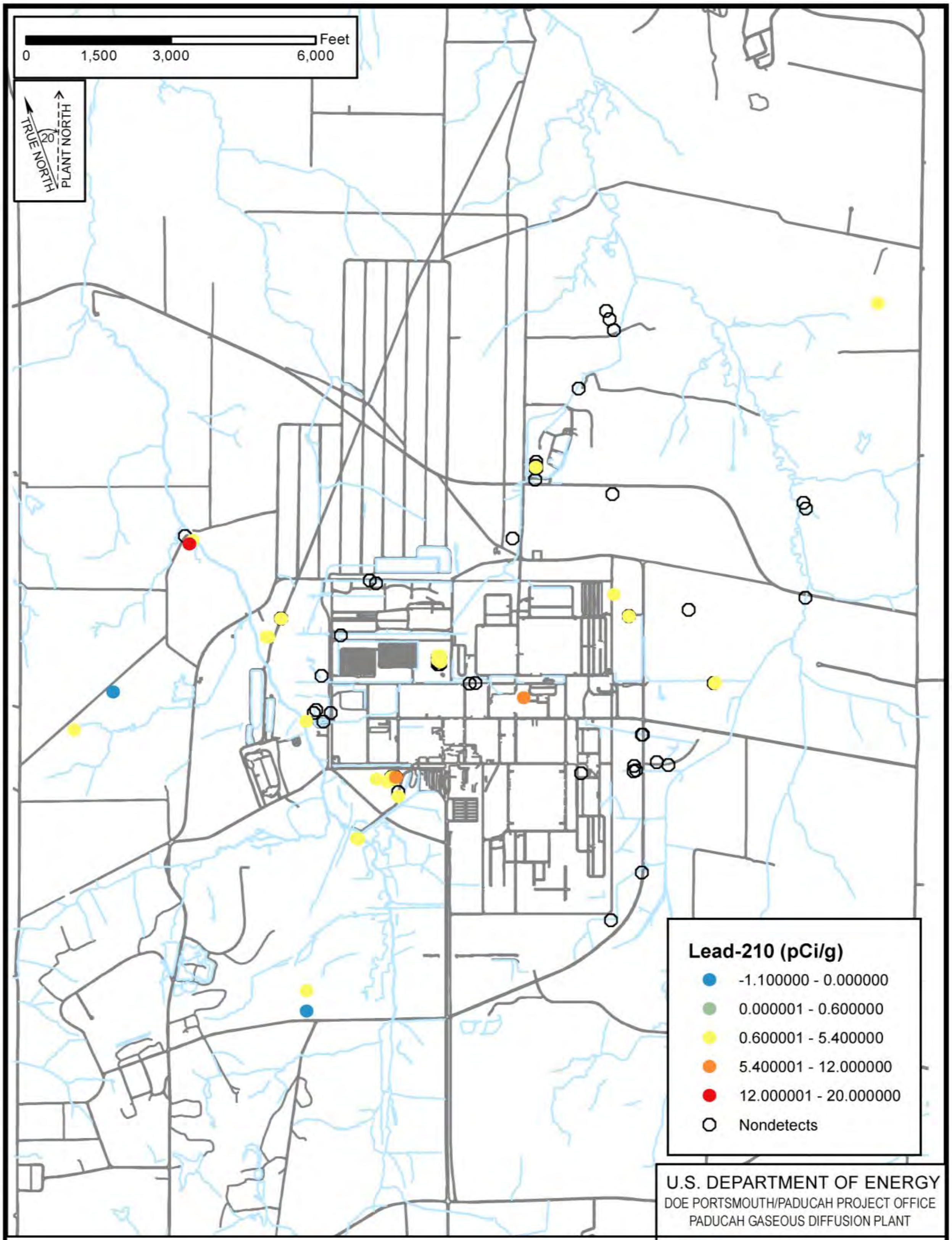


Figure 2. Lead-210 Soil/Sediment Samples

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 Pb-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 are typically present with radium-226.

After processing, radionuclides with half-lives 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 1. 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 2. Recent Soils OU soils data passed both checks.

Table 1. 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 1. 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 1. 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 1. 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.

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 MDA.

Table 2. 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 2. 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 2. 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

Paducah Risk Assessment Working Group
February 6, 2013
Minutes for Risk Methods Document Revisions

Present:

Jerri Martin	**Tim Frederick**	**Rich Bonczek**
Gaye Brewer		**Bobette Nourse**
Todd Mullins		**LeAnne Garner**
Stephanie Brock		**John Volpe**
Nathan Garner		
Mike Guffey		

1. **PAH Recommendation paper.** The paper received comments from EPA and the state. A revised paper should be sent (included in schedule at the end of these meeting notes). Once agreement is reached among the group, the paper will be presented to the FFA managers. If agreed to by the FFA managers, the paper can be appended to Risk Methods Document, Appendix E, upon decision of the RAWG.

2. **Ensure text that follows** is consistent with the rest of the document and with what we intend: **"**The dermal absorption of 5% for inorganic chemicals (or revised dermal absorption to reflect intestinal absorption) may be replaced with a lower value from EPA dermal guidance. These revised calculations may be considered in the development of revised PRGs and remediation levels to be used in the preparation of remedy selection documents. These types of decisions would be a product of the consensus of the FFA parties arrived at during project discussions at the appropriate stage in document development.**"**

3. **Whether to include the statement currently in the main text—"**Any radionuclide for which no analytical results exceed its MARLAP MDC also will be deleted from the dataset.**"**

   Text has been revised and footnoted as follows (red indicates added text):

   Any radionuclide for which no analytical results exceed its MARLAP MDC also will be deleted from the project dataset, provided the MDC is an acceptable level for the project.[6]

   [6] These types of decisions (acceptable MDCs) would be a product of the consensus of the FFA parties arrived at during project discussions at the appropriate stage in document development.

4. **Whether to add a note to the main text regarding negative values for radionuclide results.** Include footnote to text regarding radionuclides on page 3-18, if text can be agreed to. DOE/LATA Kentucky will e-mail to group for comments, but the starting point will adopt text from Soils OU RI, which is as follows: "Negative results may be reported due to a statistical determination of the counts seen by a detector, minus a background count."

   Text for comments is as follows: "Negative results may be reported due to a statistical determination of the counts seen by a detector, minus a background count seen by the same detector."

5. **NOTE with respect to correcting incidental ingestion of sediment by a recreational user:** the recreational user and the resident should not be considered additive because the ingestion rates are independent.

6. **Appendix D with respect to updating equations to be consistent with RAGs Part F:** Ensure units cancel correctly in inhalation equations (e.g., D.17). Averaging Time units have been revised for inhalation equations from "hours × yr × day/yr" to "hours/day × yr × day/yr." No changes to values. This also will affect Table B.5. Current Table B.5 lists units for Averaging Time as "hours × days" (which is "hours × yr × day/yr" with the yr canceled out). This will be revised to "hours," where both yr and days cancel out.

7. **Lead-210:** Need cost estimate for analyzing lead-210 at whatever level is possible (i.e., 10^{-5}) and at 10^{-6} levels. "Other COPCs should be identified during project scoping" added to Table 2.1. Look further into potential Lead-210 sources at PGDP and define use of the term "AL" in the response. Additionally, see markup below (red indicates added text, strikethrough font indicates text to be removed):

> However,
>
> ~~(1) There is no known PGDP source for lead-210 at Paducah; and~~
>
> ~~(2)~~ In regard to GDP process, 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 the GDP processes at PGDP contribute to presence of lead-210 as a potential contaminant/risk at PGDP.

NOTE: Additional comments resulted from this item indicating the Lead-210 paper is not complete.

8. **Updates to RAIS that affect NALs and ALs in Appendix A.** Updates of these screening values will be locked in with annual update cycle. The 2012 updates were made in October. Subsequent updates will reflect the November updates (consistent with RSL revisions). Risk assessors must ensure toxicity values used in risk assessments are up-to-date.

Remaining Schedule:

DATE	RESPONSIBLE	DESCRIPTION
February 6, 2013	meeting	Interim meeting re: Final Page Changes for main text, Appendix B and Appendix D
February 18, 2013	DOE/LATA Kentucky	Revised PAH paper.
February 20, 2013	DOE/LATA Kentucky	Appendix A remaining tables.
February 26, 2013	DOE/LATA Kentucky	Revised Nickel Groundwater Background values.
March 6, 2013	meeting	8:30-11:00 central (9:30-12:00 eastern) Update on lead-210 information
March 8, 2013	RAWG	Final comments due to DOE/LATA Kentucky for all draft page changes to RMD

DATE	RESPONSIBLE	DESCRIPTION
April 8, 2013	DOE/LATA	Final Revised Risk Methods Document - D2/R2/V1 sent to RAWG for final review
April 22, 2013	RAWG	RAWG approval of D2/R2/V1 document
April 29, 2013	DOE/LATA	Initiate DOE review of D2/R2/V1 document
May 13, 2013	DOE/LATA	DOE comments due
May 20, 2013	DOE/LATA	Transmit D2/R2/V1 document changes due to DOE comments to RAWG
June 5, 2013	meeting	8:30-11:00 central (9:30-12:00 eastern) RAWG to discuss and approve revisions to D2/R2/V1 document due to DOE comments
June 17, 2013	DOE/LATA Kentucky	Final D2/R2/V1 document to DOE for concurrence
June 30, 2013	DOE/LATA Kentucky	Transmit D2/R2/V1 document to FFA Managers (EPA/KY) for approval
September 11, 2013	meeting	8:30-11:00 central (9:30-12:00 eastern) Consider face-to-face meeting (probably in Kentucky)

Paducah Risk Assessment Working Group
March 6, 2013
Minutes for Quarterly Meeting

Present:

Jerri Martin	**Tim Frederick**	**Rich Bonczek**
Gaye Brewer	**Jon Richards**	**Bobette Nourse**
Nathan Garner		**Joe Towarnicky**
Todd Mullins		**LeAnne Garner**

1. **Additional changes to December 2012 Meeting Minutes or February 2013 Meeting Minutes.**
   a. Comments received from Stephanie Brock and Nathan Garner for February meeting minutes, incorporated. SEE NOTE.
   -Struck through text in Lead-210 paper "~~(1) There is no known PGDP source for lead-210 at Paducah; and~~"
   -Need to add additional information regarding recreational user and residential user not being additive. This information will be included in the revised RMD, if not already in there. The recreational user is assumed to be a local resident.
   b. Considered final. SEE NOTE.

   NOTE: The comment to strike through the text "There is no know PGDP source for lead-210 at Paducah" resulted in additional comments from others. The February 2013 Meeting Minutes have been changed to reflect additional comments resulted and that the Lead-210 paper is not complete.

2. **Updates to Appendix A.**
   Sent by e-mail to RAWG for review on 2/22. All draft comments due March 8, 2013.

3. **Discussion regarding PAHs text. Revised file sent February 18.**
   a. Comments received from Todd Mullins incorporated. Use of "coal" removed.

   "Due to the nature of polycyclic aromatic hydrocarbons (PAHs), as described in the *Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs)*,1 the presence of PAHs in Paducah Gaseous Diffusion Plant (PGDP) in some soils and sediments (e.g., along roads, including roadside ditches and around buildings) is not 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 ~~coal,~~ oil, gas, wood, garbage, or other organic substances or deposition due to the use of rubber, asphalt, ~~coal,~~ crude oil, coal tar, creosote, and roofing tar."

   b. Comments received from Tim Frederick: revise text to "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."
   Tim will look for a reference. If none is found, personal communication with RPM may be used.

c. Need to look for additional reference to "The most common source of PAHs in the environment currently is deposition of automobile exhaust.2" Change "The most" to "A".
d. Also note Tim's editorial comments.

Once Tim's comments addressed, send for final approval.

4. Update on Lead-210 paper.
-Need cost estimate for analyzing lead-210: working.
-Look further into potential Lead-210 sources at PGDP: working. "There is no known PGDP source for lead-210 at Paducah" was removed from paper. Still need list of potential sources (e.g., equipment from other sites). Need anecdotal references. SEE NOTE to Item 1.
-Define use of the term "AL": Analytical Laboratory

5. Remaining schedule for Risk Methods Document Revision:

March 8, 2013	RAWG	Final comments due to DOE/LATA for all draft page changes to RMD
April 8, 2013	DOE/LATA	Final Revised Risk Methods Document—D2/R2/V1 sent to RAWG for final review
April 22, 2013	RAWG	RAWG approval of D2/R2/V1 document
April 29, 2013	DOE/LATA	Initiate DOE review of D2/R2/V1 document
May 13, 2013	DOE/LATA	DOE comments due
May 20, 2013	DOE/LATA	Transmit D2/R2/V1 document changes due to DOE comments to RAWG

Need to let Jana White know that updates are coming so that she can let FFA Managers know.

6. Discussion regarding including RAWG Meeting Minutes in Appendix E
Draft consolidation of final meeting minutes to be sent for comment and additional discussion of whether they will all be incorporated. Most recent minutes (i.e, 2012 and 2013) will be included.

7. Discussion of Ni background for groundwater
Change was made in Appendix A to correct value. Old calculations are not able to be revised.
The revised background value will be footnoted in the Risk Methods Document with the text, "Nickel background value varies from previous Risk Methods Documents due to an error in calculation."
Add groundwater background to future agendas. Need to look at differences in analytical methods. There may be data currently in the database that already have lower detection level. Bobette Nourse will provide update at next meeting.

8. Next Meeting: June 5, 2013. 9:30-12:00 EST. Following that, the next meeting is September 11, 2013.

From: Garner, Leanne K (YLN)
Sent: Friday, August 02, 2013 2:48 PM
To: Rich Bonczek; 'Bobette Nourse'; John Volpe; 'Brewer, Gaye (EEC)'; 'Higginbotham, Jeri (EEC)'; 'Martin, Jerri (EEC)'; Todd Mullins; Stephanie Brock; 'Garner, Nathan (CHS-PH)'; Guffey, Mike (EEC) (Mike.Guffey@ky.gov); Towarnicky Joseph; Redfield, Myrna E (MXN); 'Frederick.Tim@epamail.epa.gov'; 'Richards.Jon@epamail.epa.gov'; White, Jana L (FMT); 'Tufts, Jennifer (Tufts.Jennifer@epa.gov)'
Subject: Paducah Risk Assessment Working Group Meeting Minutes - Comments on Risk Methods Document
Attachments: Proposed Text Revisions (outdoor worker-gardener).docx

Paducah Risk Assessment Working Group
July 31, 2013
Minutes for Risk Methods Document Comment Meeting

Present:

Jerri Martin	**Tim Frederick**	**Rich Bonczek**
Gaye Brewer	**Jon Richards**	**Bobette Nourse**
Nathan Garner		**John Volpe**
Mike Guffey		**Joe Towarnicky**
		LeAnne Garner

1. **Outdoor Worker/Gardener**

Comments on attached material are requested. If no changes to current materials (attached), then materials can be put into final Risk Methods Document (RMD) update. If not, plan to include in next year's update
The following additional summary information is to be included in Appendix A.

- Outside industrialized area—surface only and surface/subsurface soils, default exposure parameters (or as agreed to by project) (e.g., wildlife management area worker or farmer).
- Inside industrialized area—surface only soils, default exposure parameters (or as agreed to by project) (e.g., unprotected worker).
- Inside industrialized area—surface/subsurface soils, default exposure parameters with the exception of shorter exposure duration/exposure frequency consistent with civil engineering estimates, as agreed to by project (e.g., excavation worker).

Kentucky expressed some concern about the excavation worker/outdoor worker/gardener issue in regard to possibly being overly definitive. Additional comments on the issue might be forthcoming.

2. **FY 2013 RMD Approval**

No issues have been identified to date.
Approval with comments is acceptable (comments can include the understanding that the revised text regarding outdoor worker/gardener sent by e-mail will be added to the next revision).
Reminder will be sent in 2 weeks!

3. **Upcoming Schedule**

- To align the RMD with the Environmental Monitoring Plan and Programmatic QAPP schedules, need approval of the FY 13 RMD update by the FFA Managers by the end of August 2013.
- For next year, quarterly meetings will be planned; do not expect significant text changes to Human Health RMD, like this year. Hope to have FFA Managers' approval of RMD by July 2014.

Footnote on page 3-27:

[7] ~~Although a~~A single set of exposure equations and parameters are ~~used~~provided for the outdoor worker/gardener scenario~~, the gardener scenario~~ in Appendix D. The exposure parameters provided in Appendix D should ~~only be considered~~ be used without changes when assessing risk from exposure to ~~be a reasonable scenario for areas~~surface soils in locations outside the ~~limited~~industrialized area at the Paducah site. ~~Additionally~~When assessing risk from exposure to both surface and subsurface soil in locations outside the industrialized areas, however, all exposure parameters~~ for ~~, except exposure duration (ED) and exposure frequency (EF), should be used without changes to assess an outdoor worker. ED and EF for exposure by the outdoor worker/gardener ~~scenario, except exposure duration (ED), can~~to surface and subsurface soil in locations outside the industrialized area should be ~~used for~~established considering guidance in the Exposure Factors Handbook (EPA 1997b), or similar sources, and be documented. Similarly, when assessing risk from exposure to either surface soil or subsurface soil or both in locations inside the industrialized area, all exposure parameters, except ED and EF, should be used without changes to assess both an outdoor worker and a construction/excavation worker. ~~When used~~As above, ED and EF for exposure by the outdoor worker or a construction/excavation worker ~~scenario,~~to surface soil or subsurface soil or both in locations inside the ~~ED~~industrialized area should be ~~reduced to 1 and 5 years (based on~~established considering guidance ~~from~~in the Exposure Factors Handbook~~).~~ (EPA 1997b), or similar sources, and be documented.

Text on page B-3:

B.1.2.1 Receptors

Table B.1 provides a matrix~~ of~~ showing the medium-receptor combinations for which PRGs were derived. As shown there, over all media, the receptors for which no action and action direct contact risk-based PRGs were derived are the industrial worker, the resident, the recreational user, and the outdoor worker/gardener. ~~The outdoor worker/gardener scenario replaces the "excavation worker" in the 2001 version of this document. The outdoor worker/gardener uses the same exposure parameters as the former excavation worker; the receptor name was changed to better reflect that the exposure parameters are designed to assess a long-term plant worker conducting outdoor maintenance activities. The 25-year exposure duration for the outdoor worker/gardener can be modified to a value between one and five years to generate site-specific values for exposures during excavation. ~~These receptors were chosen because they represent the most likely current and future receptors for most areas and units at the Paducah Gaseous Diffusion Plant (PGDP). Also, it is believed that the PRGs derived for these receptors yield a range of values that is most useful for determining the clean~~-~~up priority for the various areas and units at PGDP. (Note that outdoor worker/gardener PRGs can be used for a construction/excavation worker; however, because the duration and frequency of exposure for a construction/excavation worker would be markedly less than that for an outdoor worker/gardener, a better approach would be to derive scenario-specific PRGs for the construction/excavation worker based on site-specific conditions, as appropriate. See discussion in Section 3.3.4.3.)

Footnote to Table B.1. on page B-4:

3. Determining which soil and sediment screening value is appropriate is a location-specific decision. For all ~~areas~~locations inside the industrialized area~~s~~ at PGDP where surface soil contamination is of concern, use of the industrial worker values is appropriate. For ~~areas~~locations inside the industrialized area~~s~~ at PGDP where contact with surface soil and subsurface soil is of concern (~~i.e~~e.g., soil from the surface down to 16 ft bgs), use of the outdoor worker/gardener values is appropriate~~. Site-specific values should be developed~~ for ~~sites at which~~ a construction/excavation worker. ~~is expected (see~~(A better approach, however, would be to derive scenario-specific PRGs for the construction/excavation worker based on site-specific conditions, as appropriate. See discussion in Section ~~1.2.1.).~~ 3.3.4.3.) For ~~areas,~~locations outside the industrialized area~~, use of~~ where surface soil contamination is of concern, screening using the recreator and/or resident values is appropriate. As with the surface water values, the child resident values are the most "conservative~~."~~ (in terms of protecting human health)." Generally, the recreator values are more appropriate for areas along ditches and creeks (i.e., for bank soils), and the resident values are more appropriate for grassy fields. ~~Also, note that the recreator and resident values are actually only applicable to surface soil.~~Finally, the outdoor worker/gardener values also can be considered for contact with soil in locations outside the industrialized area if this scenario is appropriate for the locations considered. (If screening considers both surface and subsurface soil in locations outside the industrialized area, however, development of scenario-specific PRGs for the outdoor worker based on site-specific conditions is a better approach. See discussion in Section 3.3.4.3.)

Risk Assessment Working Group
Meeting Minutes—September 2013

Present:
Jerri Martin
Mike Guffey
Nathan Garner
Tim Frederick
Jon Richards
Rich Bonczek
Bobette Nourse
LeAnne Garner

1. Call for Issues from RAWG Members

No additional issues.

2. Discussion of FY 2014 Schedule

Revisions made as follows:

Quarterly Meeting (September)	9/18/2013
Submit Work Plan (this schedule)	9/25/2013
Approve Work Plan (this schedule)	10/23/2013
Submit Appendix A (PRGs) to RAWG for Review	11/13/2013
Submit Suggested Deletions/Changes from Appendix E	12/4/2013
Comments Due for Appendix A	12/4/2013
Quarterly Meeting (December)	12/11/2013
Submit Revised Appendix B, D, and Main Text to RAWG for Review	12/11/2013
Submit Revised Appendix E	1/15/2013
RAWG Approve Appendix A	2/12/2014
Comments Due for Appendix B, D, and Main Text	2/12/2014
Comments Due for Appendix E	2/26/2014
Quarterly Meeting (March)	3/5/2014
RAWG Approve Appendix E Deletions/Changes	3/5/2014
RAWG Approve Appendix B, D, and Main Text	4/9/2014
Submit Entire Revised RMD to RAWG for Review	4/16/2014
Quarterly Meeting (June)	6/4/2014
Comments Due for Entire Revised RMD	5/16/2014
Submit RMD to FFA Managers (DOE/LX/07-0107&D2/R3/V1)	6/13/2014
FFA Managers Approve RMD (DOE/LX/07-0107&D2/R3/V1)	7/17/2014
Quarterly Meeting (September)	9/10/2014

Quarterly meetings will be Web/teleconference 8:30 a.m.–11:00 a.m. (central), 9:30 a.m.–12:00 a.m. (eastern)

Approval of the revised Risk Methods Document (at least Appendix A) is needed by end of June (approximately) to support Programmatic QAPP revision.

3. Proposed Revisions to the 2013 Risk Methods Document for the 2014 Version re: Outdoor Worker. Text attached (from e-mail sent 6/27/2013).

<u>**Kentucky Division of Waste Management Comment:**</u>

The Division has discussed inconsistent language regarding the outdoor worker/gardener contained in the document (page 3-27 vs. page B-3 and B-4) with DOE and their contractors. Per our discussion, this issue will be placed on the next Risk Working Group meeting agenda.

Double-check that page 3-27 vs. page B-3 and B-4 **are the only locations in the RMD where there is inconsistent language regarding the outdoor worker/gardener.**

Comments on language included will be included with RAWG member comments to the meeting minutes.

4. Status of Lead-210 Paper

Comments on language included will be included with RAWG member comments to the meeting minutes.

Text attached (reworked from previous version)

<u>**Kentucky Cabinet for Health Services—Radiation Health Branch Comment:**</u>

This document does not yet contain a consistent and defensible <u>method for handling contaminants not on the sitewide COPC list</u>, but which may be present in a unit based upon new data and/or are found at unexpected levels during sampling efforts (e.g., Pb-210 contamination at SWMU 222). It would be in the best interest of all parties to develop such a method and integrate it into the document.

Write-up/flow chart of how the potential for additional COPCs are identified consistently during project scoping; possibly add to Section 2. The write-up/flow chart will be sent to RAWG for comments on October 15. Comments will be due with main text/Appendix B comments.

5. Background Groundwater

- Nickel value was updated for the 2013 RMD.
- No additional activity planned for FY 2014; plan to use existing values for now.
- Review addressing new values in FY 2015.

6. Update WKWMA/Wildlife and Hunting Information in Appendix E

Update Agricultural Extension Information in Appendix E

Provide RAWG a plan for update at December meeting. Work plan schedule revised to accommodate.

7. Revisit Qualitative Assessment of High Sample Quantitation Limits (Section 3.3.3.2, Step 3)

The subject matter expert raising the issue was not on the call, so discussion was postponed until the December quarterly meeting.

8. Revisit Use of Negative XRF Results

Currently these results are included for statistical calculations.

The RAWG will explore other options for use. RAWG will follow-up at December meeting. Any input should be given to LeAnne. See KRCEE paper regarding AOC 492 and the first soil piles report for background information. The EPA representative stated he was against using proxy values.

9. Deletion of Groundwater Exposure in Industrial Worker Scenario (Tables D.26 and D.27 in the Risk Methods Document)

Table D.26, “Reasonable Maximum Exposure Assumptions for Ingestion of Water by an Industrial Worker”

Table D.27, “Reasonable Maximum Exposure Assumptions for Inhalation of VOCs in Water while Showering by an Industrial Worker”

Table D.28, “Reasonable Maximum Exposure Assumptions for Dermal Contact with Water while Showering by an Industrial Worker”

Equations should be left in place for now, but they most likely will not be the driver for remedial action. Results could affect future land use control discussions.

Need to develop a footnote to these equations regarding their use. This will be submitted for review as part of the Risk Methods Document, Appendix D revision.

10. Round Table Issues/Comments

EPA is looking at making updates to the default exposure parameter handbook in February 2014. PRGs may be affected; will need to look at our site-specific parameters to see if we want to make changes.

On the December agenda, consider if there is anything that needs to be addressed in the Eco Risk Methods document. Invitee list will be checked to ensure Jeri Higginbotham is invited.

Proposed Text Revisions (Outdoor Worker-Gardener)

Footnote on page 3-27:

[7] A single set of exposure equations and parameters are provided for the outdoor worker/gardener scenario in Appendix D. The exposure parameters provided in Appendix D should be used without changes when assessing risk from exposure to surface soils in locations outside the industrialized area at the Paducah site. When assessing risk from exposure to both surface and subsurface soil in locations outside the industrialized areas, however, all exposure parameters, except exposure duration (ED) and exposure frequency (EF), should be used without changes to assess an outdoor worker. ED and EF for exposure by the outdoor worker/gardener to surface and subsurface soil in locations outside the industrialized area should be established considering guidance in the Exposure Factors Handbook (EPA 1997b), or similar sources, and be documented. Similarly, when assessing risk from exposure to either surface soil or subsurface soil or both in locations inside the industrialized area, all exposure parameters, except ED and EF, should be used without changes to assess both an outdoor worker and a construction/excavation worker. As above, ED and EF for exposure by the outdoor worker or a construction/excavation worker to surface soil or subsurface soil or both in locations inside the industrialized area should be established considering guidance in the Exposure Factors Handbook (EPA 1997b), or similar sources, and be documented.

Text on page B-3:

B.1.2.1 Receptors

Table B.1 provides a matrix showing the medium-receptor combinations for which PRGs were derived. As shown there, overall media, the receptors for which no action and action direct contact risk-based PRGs were derived, are the industrial worker, the resident, the recreational user, and the outdoor worker/gardener. These receptors were chosen because they represent the most likely current and future receptors for most areas and units at the Paducah Gaseous Diffusion Plant (PGDP). Also, it is believed that the PRGs derived for these receptors yield a range of values that are most useful for determining the cleanup priority for the various areas and units at PGDP. (Note: Outdoor worker/gardener PRGs can be used for a construction/excavation worker; however, because the duration and frequency of exposure for a construction/excavation worker would be markedly less than that for an outdoor worker/gardener, a better approach would be to derive scenario-specific PRGs for the construction/excavation worker based on site-specific conditions, as appropriate. See discussion in Section 3.3.4.3.)

Footnote to Table B.1. on page B-4:

3. Determining which soil and sediment screening value is appropriate is a location-specific decision. For all locations inside the industrialized area at PGDP where surface soil contamination is of concern, use of the industrial worker values is appropriate. For locations inside the industrialized area at PGDP where contact with surface soil and subsurface soil is of concern (e.g., soil from the surface down to 16 ft bgs), use of the outdoor worker/gardener values is appropriate for a construction/excavation worker. (A better approach, however, would be to derive scenario-specific PRGs for the construction/excavation worker based on site-specific conditions, as appropriate. See discussion in Section 3.3.4.3.) For locations outside the industrialized area where surface soil contamination is of concern, screening using the recreator and/or resident values is appropriate. As with the surface water values, the child resident values are the most "conservative (in terms of protecting human health)." Generally, the recreator values are more appropriate for areas along ditches and creeks (i.e., for bank soils), and the resident values are more appropriate for grassy fields. Finally, the outdoor worker/gardener values also can be considered for contact with soil in locations outside the industrialized area if this scenario is appropriate for the locations considered. (If screening considers both surface and subsurface soil in locations outside the industrialized area, however, development of scenario-specific PRGs for the outdoor worker based on site-specific conditions is a better approach. See discussion in Section 3.3.4.3.)

Deleted: Although a

Deleted: used

Deleted: , the gardener scenario

Deleted: only be considered

Deleted: be a reasonable scenario for areas

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Additional Information to RAWG Regarding Lead-210
(Revised September 2013)

In response to discussion during the December 2012 Risk Assessment Working Group, we researched the potential for reporting analytical results of lead-210 and the potential value of this information. The two action items for the Risk Assessment Working Group below were taken from that discussion.

- What is the risk for lead-210 at the minimum detectable concentration (MDC) with no special detector?

- Check to see if labs would need to recalibrate equipment to analyze lead-210 by gamma spectroscopy.

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 (see Web site http://www.lrb.usace.army.mil/Portals/45/docs/FUSRAP/DaytonIII/day3-si-2004-12.pdf, Table 2). See attached spreadsheets for the Radiation Health Branch (RHB) lead-210 analysis. Only data with a sample-specific 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., 10^{-6} values calculated using RAIS and Paducah-specific parameters) are as follows:

- Resident, 0.66 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, the MDC obtained by liquid scintillation counting (LSC) is approximately 5 pCi/g. TestAmerica indicates this is the target MDC by LSC; 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."

However, soil analysis by the Kentucky RHB using gamma spectroscopy and a thin window HPGe detector achieved a 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. Since 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. Since 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.

Since analysis of lead-210 by LSC 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 current equipment used by the USEC laboratory, gamma spectroscopy analysis for lead-210 is not possible because the primary energy line is below the analytical laboratory normal energy calibration range. It would require the purchase of a new calibration mixture to include the lead-210 line at 46 KeV. The analytical laboratory has only 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 10^{-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, the uranium enrichment processes at PGDP contribute to the presence of lead-210 as a potential contaminant/risk at PGDP; therefore, 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 a project-by-project basis.

Risk Assessment Working Group
Meeting Minutes—December 2013

Present:

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

1. Call for Issues from RAWG Members

No additional issues were raised from Risk Assessment Working Group (RAWG) members.

2. Remainder of Fiscal Year (FY) 2014 Schedule

One revision made to submittal date for Appendix E. The revised date is shown in the table.

Submit Suggested Deletions/Changes from Appendix E	12/4/2013
Comments Due for Appendix A	12/4/2013
Quarterly Meeting (December)	12/11/2013
Submit Revised Appendix B, D, and Main Text to RAWG for Review	12/11/2013
Submit Revised Appendix E	1/29/2014
RAWG Approve Appendix A	2/12/2014
Comments Due for Appendix B, D, and Main Text	2/12/2014
Comments Due for Appendix E	2/26/2014
Quarterly Meeting (March)	3/5/2014
RAWG Approve Appendix E Deletions/Changes	3/5/2014
RAWG Approve Appendix B, D, and Main Text	4/9/2014
Submit Entire Revised RMD to RAWG for Review	4/16/2014
Quarterly Meeting (June)	6/4/2014
Comments Due for Entire Revised RMD	5/16/2014
Submit RMD to FFA Managers (DOE/LX/07-0107&D2/R3/V1)	6/13/2014
FFA Managers Approve RMD (DOE/LX/07-0107&D2/R3/V1)	7/17/2014
Quarterly Meeting (September)	9/10/2014

Quarterly meetings will be Web/teleconference 8:30 a.m.–11:00 a.m. (central), 9:30 a.m.–12:00 a.m. (eastern)

An e-mail confirmation was requested from each RAWG member whether additional comments on Appendix A are expected.

3. Discussion of Outdoor Worker/Gardener Text (update) and Other Comments Received

KDWM requested the Risk Methods Document (RMD) be double-checked that page 3-27 vs. pages B-3 and B-4 are the only locations in the RMD where there is inconsistent language regarding the outdoor worker/gardener. One additional location for change was sent in October 15 e-mail to the RAWG.

The following was presented as a suggested response to comments that were received for the proposed text changes:

B.1.2.1 Receptors

"Note: Outdoor worker/gardener PRGs can be used for a construction/excavation worker; however, because the duration and frequency of exposure for a construction/excavation worker would be markedly less than that for an outdoor worker/gardener, ~~a better approach would be to derive~~ scenario-specific PRGs for the construction/excavation worker based on site-specific conditions should be derived, as appropriate."

Throughout the footnote on page 3-27, "risk," was replaced with "potential risk."

Additional editorial changes were made to provide clarity.

4. Status of Lead-210 Paper

No comments on language provided in previous meeting were made. The paper will be added to Appendix E. Comments can be made on Appendix E when it is submitted.

The write-up/flowchart of how the potential for additional chemicals of potential concern (COPCs) are identified consistently during project scoping was sent to RAWG for comment on October 15. Comments will be due with main text comments.

5. Risk Methods Document Appendix E Update

A proposal was made that Appendix E be put on compact disc (CD) or a separate volume; the group agreed.

The plan for updating Appendix E is as follows:

E.1. DATA AND DOCUMENTS USED TO ESTABLISH BACKGROUND CONCENTRATIONS: Leaving in 2014 RMD with no changes.

E.2. SITE-SPECIFIC EXPOSURE INFORMATION: Updating for the 2014 RMD with more current information, as follows.

- Letter and survey form used during the Phase I Site Investigation (CH2M Hill 1991) to determine groundwater use near PGDP:

  Clarify the purpose for having the survey forms in this document (i.e., to address the question of how groundwater would be used if municipal water were not provided for developing the exposure scenarios in the RMD).

- Summary of the interview with Mr. Kenny E. Perry, Agricultural Extension Agent, Ballard County, Kentucky, regarding agricultural practices in Ballard County held in February 1994:

  Update in 2014 RMD with revised interview/information for Ballard County.

- Summary of the interview with Mr. Douglas A. Wilson, Agricultural Extension Agent, McCracken County, Kentucky, regarding agricultural practices in McCracken County held in February 1994:

Update in 2014 RMD with revised interview/information for McCracken County.

- Letter dated February 24, 1994, from Mr. Douglas A. Wilson, Agriculture Extension Agent, McCracken County, Kentucky, to Mr. Fred Dolislager, Risk Analyst, Oak Ridge National Laboratory, regarding area of crop land in McCracken County:

  Update in 2014 RMD with revised information for McCracken County.

- Questionnaire dated October 26, 1995, sent to Mr. Charles Logsdon, Kentucky Department of Fish and Wildlife Resources (KDFWR), by FMSM Engineers, Inc., regarding recreational use of Little and Big Bayou Creeks near PGDP:

  Update in 2014 RMD with revised information from KDFWR.

- Facsimile dated November 8, 1995, sent to Mr. Stephen Scott, FMSM Engineers, Inc., containing responses from Mr. Charles Logsdon, KDFWR, to the aforementioned questionnaire:

  Update in 2014 RMD with revised information from KDFWR.

- Letter dated April 5, 1994, from KDFWR to Mr. Fred Dolislager, Risk Analyst, Oak Ridge National Laboratory, containing annual harvests of geese, ducks, turkeys, and deer in McCracken and Ballard Counties, Kentucky:

  Update in 2014 RMD with revised information from KDFWR (most information should be available from KDFWR Web site).

- 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:

  Leave in 2014 RMD. Attempt to find better quality copy.

E.3. KENTUCKY REGULATORY GUIDANCE: Leaving in 2014 RMD, especially if putting Appendix E on CD.

E.4. FLOWCHART FOR UNCERTAINTY MANAGEMENT FOR UNKNOWN AREAS OF CONTAMINATION: Leaving in 2014 RMD, especially if putting Appendix E on CD.
LATA Kentucky is checking into whether adding this flowchart to the RMD was a commitment for the Environmental Indicators (EI) project. A cover letter may be added indicating that. The main text also has flowcharts for scoping that could be used for other projects. Mike Guffey will check whether the existing flowcharts in the main text are adequate and sufficient for the uncertainty management of burial ground nature and extent identification.

E.5. DATA QUALITY OBJECTIVE MATERIALS: Removing material from 2014 RMD, but adding introductory information and Web link to Hanford information to the main text where DQOs are discussed.

E.6. COMPILED PARAMETERS FOR PROBABILISTIC RISK ASSESSMENTS: Leaving in 2014 RMD, especially if putting Appendix E on CD.

E.7. MEETING MINUTES FROM PADUCAH RISK ASSESSMENT WORKING GROUP: Leaving in 2014 RMD. This section will continue to be updated.

E.8. LEAD-210 AT PGDP: Leaving in 2014 RMD. Replace "placeholder" with information agreed to by RAWG; any comments to be made as part of this submittal.

E.9. PAH CONTAMINATION AND ESTABLISHMENT OF REMEDIAL GOALS: Leaving in 2014 RMD. Replace "placeholder" with information agreed to by RAWG; any comments to be made as part of this submittal.

6. Revisit Qualitative Assessment of High SQLs (Section 3.3.3.2, Step 3)

No changes were proposed to Human Health assessment as a result of using high sample quantitation limits (SQLs). Exposure point concentrations (EPCs) are calculated using ProUCL.

The issue may need to be addressed in an update to the Paducah Ecological RMD, because the Ecological RMD still uses one-half the detection limit to calculate EPC, while the ProUCL is used for EPCs for the human health evaluations.

It was noted that there is a new version of ProUCL (i.e., Version 5).

7. Revisit Use of Negative XRF Results

Following-up from previous quarterly meeting, use of negative X-ray fluoroscopy (XRF) results was discussed. No changes were proposed to their use. It is not anticipated that negative XRF results should occur in the future, due to changes in instrumentation; this issue affects only historical data (specifically soil piles data, such as chromium). The group believes that data should not be thrown out. The group needs to ensure this issue is documented as an uncertainty, if it applies to a project. EPA recently had XRF project at another site; Tim Frederick will share information at next RAWG quarterly meeting. Joe Towarnicky will review findings from XRF results in relation to laboratory results that were documented in the Soils Operable Unit Remedial Investigation on an element-by-element basis so that we know how to use XRF data (e.g., can XRF be used for selenium); these findings will be added to Appendix E.

8. Anything that needs to be addressed in the Eco Risk Methods document?

Brett Thomas needs to be added to meeting distribution. The Paducah Ecological RMD needs to be revised in FY 2015. See above regarding EPC calculation. Jeri Higginbotham will send additional changes for the Paducah Ecological RMD to LeAnne. These suggestions will be included in the next RAWG quarterly meeting agenda (to be held on March 5, 2014).

Risk Assessment Working Group
Meeting Minutes—March 2014

Present:

✓Gaye Brewer
✓Stephanie Brock
✓Nathan Garner
✓Mike Guffey
✓Jeri Higginbotham
✓Jerri Martin
✓Todd Mullins
✓Tim Frederick
✓Jon Richards
✓Brett Thomas
✓Rich Bonczek
✓Martin Clauberg
✓LeAnne Garner
✓Bobette Nourse
✓Joe Towarnicky

1. Call for Issues from RAWG Members

An electronic link for most recent Ecological Risk Methods Document (RMD) was sent to the Risk Assessment Working Group (RAWG). Any additional comments on the document will be sent in to the group. An explanation was provided that clarified that any changes to the current, approved Ecological RMD would be part of next year's work plan that will be developed in September and approved in October 2014.

2. Remainder of Fiscal Year 2014 Schedule

A proposal was made to postpone incorporation of recreational user lifetime excess lifetime cancer risk (ELCR) no action levels (NALs) and action levels (ALs) and excavation worker site-specific scenario until the next revision of the RMD.

The excavation worker site-specific scenario information would be adopted into the RMD from the Burial Grounds Operable Unit (BGOU) Solid Waste Management Units (SWMUs) 2, 3, 7, and 30 Feasibility Study (FS). The BGOU FS will use the "2 men and a backhoe" concept. The concept of how the individual units fit in with the whole site needs to be considered.

It was highlighted that the entire revised Human Health (HH) RMD will be sent for review on April 16 and that comments will be due May 16. This schedule needs to be met in order to incorporate HH RMD changes (including revised NALs) into the year's revision of the programmatic Quality Assurance Project Plan.

RAWG Approve Appendix E Deletions/Changes	3/5/2014
RAWG Approve Appendix B, D, and Main Text	4/9/2014
Submit Entire Revised RMD to RAWG for Review	4/16/2014
Comments Due for Entire Revised RMD	5/16/2014
Quarterly Meeting (June)	6/4/2014
Submit RMD to FFA Managers (DOE/LX/07-0107&D2/R3/V1)	6/13/2014
FFA Managers Approve RMD (DOE/LX/07-0107&D2/R3/V1)	7/17/2014
Quarterly Meeting (September)	9/10/2014

Quarterly meetings will be Web/teleconference 8:30 a.m.–11:00 a.m. (central), 9:30 a.m.–12:00 a.m. (eastern)

3. Summary of RAWG review and comments received.

All portions of the 2014 RMD with revisions have been sent. Due dates for comments for all sections have passed. Below is a summary of the comments received.

Main Text:

- Vapor intrusion analysis/scenario needs to be added to text—
  Add the guidance "2008 Brownfields Technology Primer: Vapor Intrusion Considerations for Redevelopment, EPA 542-R-08-001."
  A newer reference is expected soon from the U.S. Environmental Protection Agency (EPA). The current RMD should use the 2008 guidance, for now, and it will be replaced in the next version of the RMD.

- To keep in mind, default exposure parameters will be updated soon (likely in June 2014) for EPA's Regional Screening Levels. The Paducah RMD will, in turn, need to incorporate these changes in the next revision of the RMD.

- References to data quality assessment/data quality objectives and other items in Appendix E need revision. References will need to be made to EPA and U.S. Department of Energy (DOE) guidance instead of the Hanford example previously used.

- Based on discussion in the February 7, 2014, meeting, revise use of "outdoor worker/gardener" to "outdoor worker" and "excavation" to "site-specific."
  The word "gardener" will not be used. Additionally, the scenarios should be for the future outdoor and excavation workers. A follow-up e-mail will be sent to the group with details about how the term "site-specific" is to be used (i.e., with respect to "site-specific" and "unit-specific").

- Based on discussion in the February 7, 2014, meeting, revise previously agreed footnote for

  (1) "Outdoor worker" and associated soil depth to be evaluated.
  (2) "Excavation worker" and associated soil depth to be evaluated.
  (3) Site-specific excavation worker with respect to soil depth and the application of varying exposure durations (EDs) ("two men and a backhoe").

  This year's RMD will say the excavation worker will use site-specific parameters [e.g., depths, EDs, and exposure frequencies (EFs)]. All subsequent RMD revisions will adopt the agencies-approved BGOU SWMUs 2, 3, 7, and 30 FS project approach.
  A follow-up e-mail will be sent to the group with details about how the site-specific term is to be used.

Appendix A:
Recreational Scenario ELCR Preliminary Remediation Goals (PRGs) (i.e., NALs and ALs) need to be developed for a lifetime exposure. Subsequent RMD revisions will address this addition.

Appendix B:

- Table B.5. Toxicity Values and Information Used in PRG Derivation: Mercury, Inorganic Salts. Inhalation reference concentration 3.00E-05 was deleted, but no replacement value was given. The RSL table lists 3.0E-04 for RfC, and the key is marked "S" indicating that the User Guide, Section 5 should be seen, but there is nothing in the User Guide, Section 5 on mercury.
  As a follow-up, "Mercuric Sulfide" and "Mercury, Inorganic Salts" were removed from the table and "Mercuric Chloride" was renamed "Mercuric Chloride (and other Mercury salts)." EPA plans to correct the reference on their table.

- Based on discussion in the February 7, 2014, meeting, revise previously agreed text note and footnotes for outdoor worker/gardener for
  (1) "Outdoor worker" and associated soil depth to be evaluated.
  (2) "Excavation worker" and associated soil depth to be evaluated.
  (3) Site-specific excavation worker with respect to soil depth and the application of varying EDs ("two men and a backhoe").
  (See notes on main text, above, where this comment is discussed.)

- Based on discussion in the February 7, 2014, meeting, revise use of "outdoor worker/gardener" to "outdoor worker" and "excavation" to "site-specific." (See notes on main text, above, where this comment is discussed.)

Appendix D:
Add information for the excavation worker to the outdoor worker equations.
(See notes on main text, above, where this comment is discussed.)

Appendix E:

- **Section E.4: Flowchart for Uncertainty Management for Unknown Areas of Contamination**
  While the decision to proceed with a remedial investigation (RI) (including a baseline risk assessment), FS, proposed remedial action plan, etc., without source term data must be dealt with by risk and uncertainty managers; the RMD addresses risk assessment (communication) at these various stages. When the parties agree to proceed with remedy selection without source term data (i.e. without defined nature and extent), care should be taken not to present risk in accordance with protocol [e.g., no contaminants of concern (COCs)] developed under the assumption that nature and extent are defined. Any presentations of risk at the various stages must be strongly qualified and coupled with a firm bias (presumption?) for action. COC selection must be governed by conservatism.
  When projects have limited data, the baseline risk assessment needs to qualify information regarding the source term.
  See if text above can fit into the FS section of the main text referencing Risk Assessment Guidance for Superfund (RAGS). If possible, language from RAGS or other risk assessment guidance (e.g., DOE guidance on uncertainty) will be used as an addition to the main text.
  See if Site Management Plan has similar language.
  An opinion was expressed by DOE that the text above goes to risk management and not risk assessment. The HH RMD and its references include guidance on the need to address uncertainties in the risk characterization in the baseline human health risk assessment. How those uncertainties are addressed by the risk managers is a follow-up concern.

4. Revisit use of negative XRF results

Joe Towarnicky reviewed findings from X-ray fluorescence (XRF) results in relation to laboratory results that were documented in the Soils Operable Unit RI on an element-by-element basis so that we know how to use XRF data (e.g., can XRF be used for selenium); these findings will be added to Appendix E. Joe's findings are attached.
The group should send any comments they have to LeAnne. This information will be included in this Risk Methods Document, Appendix E.

5. **Excavation Worker Scenario (chronic versus subchronic toxicity values)**

Chronic toxicity values are more conservative, in terms of protecting human health, and not many subchronic values are available. The RAWG prefers to stay with chronic values.

Ensure the RMD states that we use chronic values as a layer of protectiveness even if subchronic values are available. The BGOU FS should not add a footnote to explain that subchronic values were not used.

6. **Topics that need to be addressed in the Eco Risk Methods document (Review of Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky. Volume 2. Ecological. DOE/LX/07-0107&D2/V2)**

Jeri Higginbotham had the following suggestions:

a. On page 2-9, Sample et al is cited with an incorrect date of 1998. The date is listed correctly (1997) in the reference section on page 4-2. Please correct.
b. On page 2-11, change "using one-half the reported detection limit for all results reported as nondetected concentrations." Methodology now available in Pro-UCL or an equivalent statistical package is preferable. An exception to this is when a sample contains a small fraction of non-detects (i.e., no more than 10-15%), simple substitution of half the reporting limit is generally adequate (USEPA 2009. *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance*. U.S. Environmental Protection Agency Office of Resource Conservation and Recovery, EPA 530/R-09-007).
c. On page 2-12, the sentence, "Toxicity profiles for COPCs should include a discussion of published data on the relative toxicity of various groups of organisms" should be changed to, "Toxicity profiles for COPCs should include a discussion of published data on the relative toxicity to various groups of organisms".
d. On page 2-19, there are 4 bullets, but the sentence preceding the bullets indicates there should be three. The second bullet may be more clearly treated as an if-then statement subsequent to the bulleted information.
e. On page A-9 in Table A.2, the no further action (NFA) screening values for sulfur, thiocyanates, benzene, ethylbenzene, toluene, and xylene are listed as 500, 1, 0.01, 0.03, 0.01, and 0.1, respectively. The source for all six values is listed as EPA Region 4. The screening values listed by EPA Region 4 are 2, 2, 0.05, 0.05, 0.05, and 0.05 respectively, as can be seen at http://www.epa.gov/region04/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf.
f. On page A-10 in Table A.2, the NFA screening values for carbon tetrachloride, 1,2-dichloroethane, 1,2-dichloropropane, chlorobenzene, chloroform, dichlorobenzene, dichloromethane, hexachlorobenzene, pentachlorobenzene, tetrachloroethylene, and aldrin are listed as 0.4, 0.02, 0.1, 0.1, 0.02, 0.1, 0.4, 0.05, 0.05, 0.002, and 0.0006 respectively. The source for all is listed as EPA Region 4. The screening values listed by EPA Region 4 are 1.0, 0.4, 700, 0.05, 0.001, 0.01, 2, 0.0025, 0.0025, 0.01, and 0.0025 respectively, as can be seen at http://www.epa.gov/region04/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf.
g. On page A-11 in Table A.2, the NFA screening values are 0.0002 for atrazine, 0.009 for BHC-beta, 0.00003 for carbaryl, 0.00002 for carbofuran, 0.0049 for dieldrin, 0.00004 for endrin, 0.002 for maneb, 0.000007 for acrylonitrile, 0.05 for catechol, 960 for ethylene glycol, and 0.3 for styrene. The source for all is listed as EPA Region 4. The screening values listed by EPA Region 4 are 0.00005, 0.001, 0.5, 0.2, 0.0005, 0.001, 3.5, 1000, 20, 97, and 0.1 respectively, as can be seen at http://www.epa.gov/region04/superfund/images/allprogrammedia/pdfs/tsstablesoilvalues.pdf.
h. On page A-11 in Table A.2, cresols has a b superscript, but there is no corresponding b footnote. Please add the b footnote.

i. In Table A.6, on page A-17, change the selenium NFA Screening Value Type from "Kentucky State 'warm water'" to "Region 4 Freshwater ESV."
j. On page A-19, change the Polychlorinated biphenyls Screening Value from "0.0014" to "0.014".

LeAnne will prepare a schedule for the Ecological RMD revision before the June 2014, quarterly meeting to include incorporation of the above-referenced revisions. The group should consider whether the Ecological RMD needs to include the revised guidance for the later steps of the ecological risk assessment methodology.

7. Validation needed for closure activities [CERCLA 120(h)]

Typical validation (i.e., 3rd party validation) currently is 10%. What is appropriate for closure activities? RAWG will develop a recommendation during the next quarterly meeting. Also, DOE agreed to ask the PGDP Site Manager about scheduling a CERCLA 120() training.

8. Derivation of Risk-based Surface Water Effluent Limits

Based upon the most recent resource use information developed for the revised Appendix E, in consideration of surface water, the recreational user wading, swimming, and fishing and outdoor worker exposure scenarios apply to Bayou and Little Bayou Creek. Of these, fishing is likely implausible for Little Bayou Creek due to the lack of catchable fish. Subsistence fishing is unlikely for Bayou Creek because the fishery is too small to allow subsistence catches without considering that many of the fish caught would be from the Ohio River. Wading and swimming are plausible but only swimming allows for derivation of a risk-based value for radionuclides (dose is from incidental ingestion of water). The RAWG needs to consider this and other information and develop a recommendation on how best to develop risk-based effluent limits.
Just because a scenario is not plausible, we don't need to do away with rad effluent limits.
RAWG will develop a recommendation during the next quarterly meeting.
Some inputs to consider are the following:

- How were NPDES limits developed? Are their scenarios reasonable to use at this site?
- Are there similar ways to calculate rad limits?
- Can we extrapolate 1E-04, 1E-05, and 1E-06 values for the Risk Methods Document?
- Does Oak Ridge have an ALARA implementation procedure that we could use here?
- What scenarios do we need to use to set limits?
- What are the risk-based inputs?

9. Status of RAWG SWMUs 2, 3, 7 and 30 FS Remedial Action Objective Revision Recommendation

The revision that was recommended by the RAWG during special-called meetings January 31 and February 7, has been incorporated into the draft document. This recommendation may be put into the comment resolution summary that includes the tables (comparing the outdoor worker and excavation worker numbers) presented during those meetings in January and February.

10. Poll RAWG Members/Open Discussion

It was highlighted that the next meeting will be on June 4. No additional discussion occurred.

DRAFT Discussion Concerning Use of XRF Data with Negative Values

Issue:

X-ray fluorescence (XRF) analyses for a few constituents (chromium, lead, and uranium) at the Paducah Gaseous Diffusion Plant (PGDP) historically have reported negative (less than zero) concentration values [See attached excerpt from Soils Operable Unit (OU) Remedial Investigation (RI) Report Comment Response Summary]. Because an element concentration cannot be less than zero, there is concern over how best to use the raw XRF data. In the Soils OU RI, the negative values were used in the calculation of the means and standard deviations.

Background:

- XRF data have been used at PGDP to supplement laboratory analyses of soil samples to define better the nature and extent of the presence of elements. Some of the reported results have been less than zero.

- ***The less-than-zero values for chromium, lead, and uranium all were from XRF analyses conducted in 2007.***

- The less-than-zero values had no detection limits reported in the database; however, 2010 XRF data report XRF detection limits of 85 mg/kg (chromium), 13 mg/kg (lead), and 20 mg/kg (uranium). The detection limit for lead (13 mg/kg) is less than the background concentration of lead at PGDP (per Table A.12 of the Risk Methods Document).

- The data set includes 590 less-than-zero chromium (~4794 total results), 27 lead (~4917 total results), and 129 uranium (~4,700 total results) results.

- The Soil Piles Investigation, Appendix B (Section 9.6) summarizes the data management for that project using Kaplan-Meier, the EPA recommended method of handling nondetects (Singh 2006) and compares that to using the raw values (including negative values) as reported from the XRF method.

- The Soil Piles Investigation compared the use of the raw data to the use of the Kaplan-Meier approach and found that for elements with most values above the detection limits, the means and standard deviations are comparable; however, for elements with few (or no) detects, the two methods yielded different results. For example, the chromium mean value for the concentration was negative (from the XRF data set with no detectable chromium results). As a result, the conclusions section of Section B.9.6 stated: "Thus, it is not recommended substituting the raw values in place of undetected values for computation of summary statistics and UCLs" (for those elements with few detected values).

Discussion:

Module 2 – Basic XRF Concepts XRF Web Seminar discusses the application of XRF analysis (http://www.clu-in.org/conf/tio/xrf_080408/prez/XRF_02pdf.pdf). The page reproduced (below) from this module discusses how negative values can be reported when there is none of the element present. Counting statistics will report values that cluster around zero, with half the results being positive and half the results being negative.

A second page (reproduced below) describes recommendations for use of data reported at concentrations below the detection limit. Some instruments do not report these data. Some manufacturers advise against using these data. These values can be valuable information if careful about its use…particularly true if one is trying to calculate average values over a set of measurements.

The XRF measurements represent concentrations near the surface of the sample, while laboratory results are volumetric in nature. Thus, one can expect some differences between the XRF and the lab results, except in those cases where the concentrations of elements are homogeneously dispersed in the soil.

Impacts on Soils OU RI Results:

1. The more recent XRF results did not have any negative results reported; thus, this may not be an issue going forward except when trying to use older historical results.

2. The less-than-zero results only occur when the true value is near zero.

3. The detection limit for the recent results is a more positive value than the average less-than-zero value. Thus, the use of negative values somewhat balances the positive bias introduced when using a detection limit (e.g., 85 mg/kg) as the nondetected value.

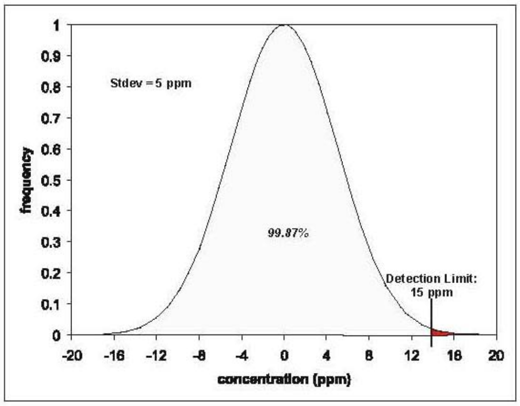
4. The 1,049 ***lab*** results (including one nondetect) had an average chromium concentration of 32 mg/kg.

5. The 4,794 lab and XRF results (including the 2,362 XRF nondetect results of which 590 were less-than-zero values) had an average concentration of 50 mg/kg. It appears that even when the negative values are used, the XRF results tend to yield a somewhat false positive result for chromium.

6. If remedial actions are taken for chromium, the use of XRF in confirmation sampling may need to be limited.

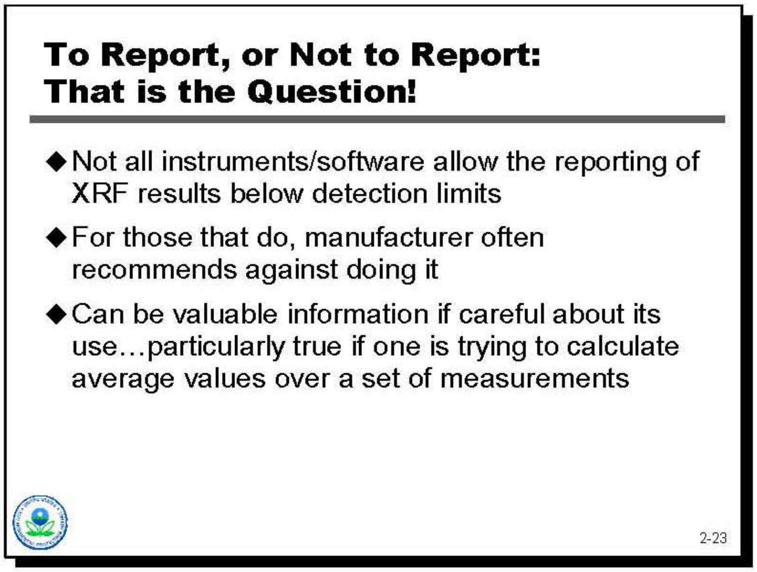
The 3 Standard Deviation Concept

Frequency of XRF Responses When Element Not Present



Notes

- The graphic above illustrates the frequency of XRF responses when the element is not present. Assume that a sample does not have an element present (or that it is present at trace levels). If one were to take a measurement of the sample with the XRF, the XRF would record a concentration present for that element just because of the random nature of x-ray counting statistics. If one did a large number of repeat measurements, one could generate a distribution or frequency plot of those “random” concentrations such as is shown here, with a measurable standard deviation. Notice that the frequency distribution is centered around zero, indicating that this instrument is providing an unbiased estimate of the concentration for the element of interest. Notice too that half the time the instrument would report positive values, and half the time it would report negative values…an important fact that will be discussed later. If one moves three standard deviations up from zero and calls that the detection limit (consistent with SW846 Method 6200), then almost 100% of the concentration values generated when the element is not present would be less than the detection limit. In other words, if the instrument records a result greater than this detection limit, then it is very likely that in fact the element is present.



To Report, or Not to Report: That is the Question!

- Not all instruments/software allow the reporting of XRF results below detection limits
- For those that do, manufacturer often recommends against doing it
- Can be valuable information if careful about its use…particularly true if one is trying to calculate average values over a set of measurements

Notes

- **Not all instruments/software allow the reporting of XRF results below detections limits:** Some instruments and associated software do not allow the reporting of measurement results that are below detection limits.
- **For those that do, manufacturer ofter recommends against doing it:** For those instruments that do allow reporting of results below detection limits, the manufacturer usually advises against it. Within the chemistry analytical world, the approach has been to not report values less than detection limits. Within the radionuclide analytical world, the approach has been to report values less than detection limits. The XRF is an analytical technique that has its roots in the radionuclide world (e.g., gamma and alpha spectroscopy), but has applications to the chemical world (e.g., elemental metals).
- **Can be valuable information if careful about its use . . . particularly true if one is trying to calculate average values over a set of measurements:** Values below detection limits can be useful when calculating average values over a set of measurements. If the instrument's calibration is unbiased for low levels of the element of interest, using measured values below the instrument's detection limits can yield more accurate assessments of average concentrations that flagging readings as non-detects and substituting some arbitrary value such as the detection limit, or half the detection limit, in average value calculations. Great care and full disclosure are necessary when using values below detection limits.

E.7. 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.6). 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.

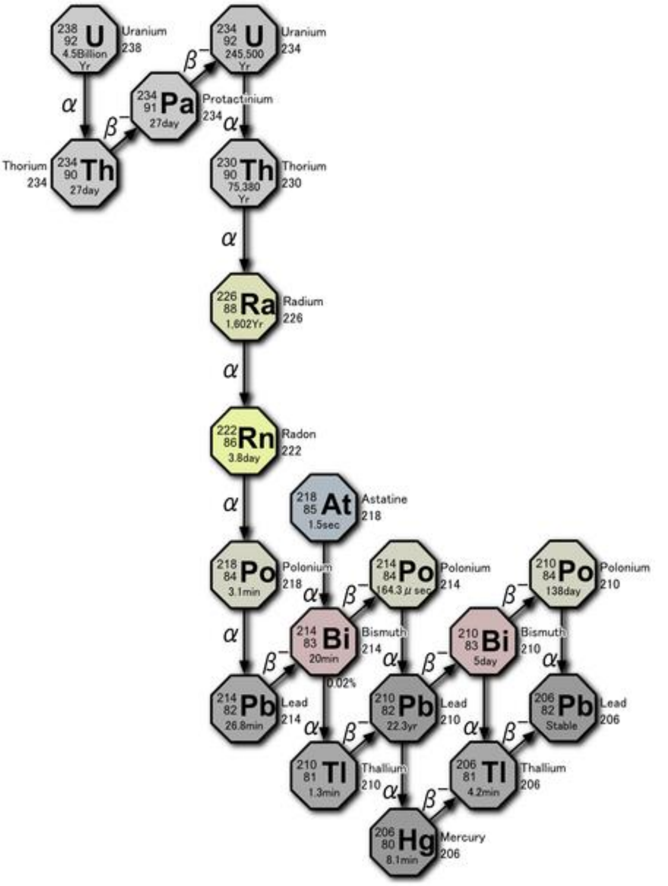


Figure E.6. Lead-210 Decay Chain

Available PGDP lead-210 data was plotted to estimate an approximate background value. This map is shown in Figure E.7. 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.

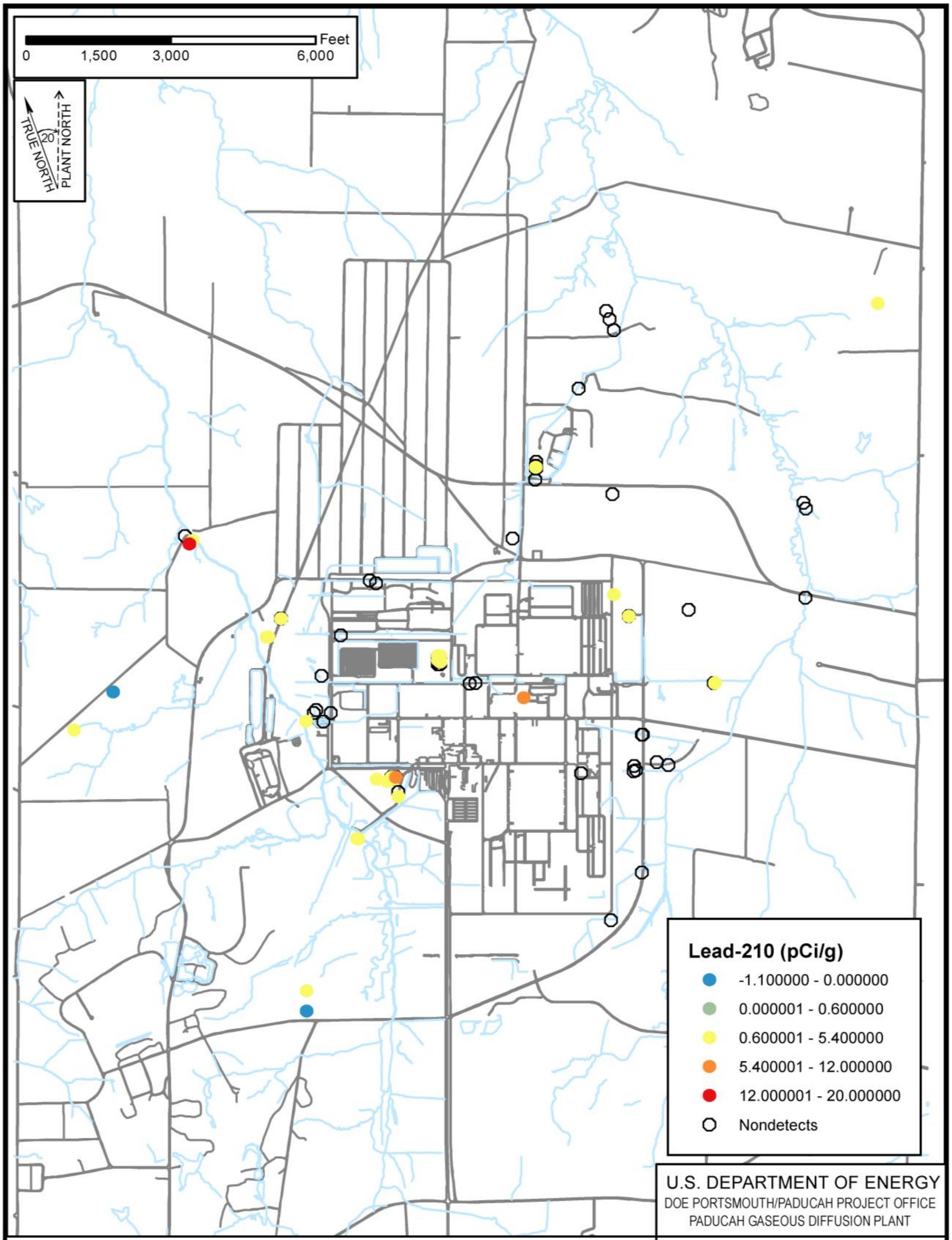


Figure E.7. Lead-210 Soil/Sediment Samples

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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.3. 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.4. Recent Soils Operable Unit (OU) soils data passed both checks.

Table E.3. 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.3. 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.3. 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.3. 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.4. 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.4. 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.4. 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.3 and E.4 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.8. PAH CONTAMINATION AND ESTABLISHMENT OF REMEDIAL GOALS

E.8.1. IDENTIFICATION OF THE PROBLEM

Due to the nature of polycyclic aromatic hydrocarbons (PAHs), as described in the Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs),[1] the presence of PAHs in Paducah Gaseous Diffusion Plant (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 (AOCs) 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]

E.8.2. 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 (TSD) activities; and (2) concentrations are sufficiently high that the acceptable risk range of 1E-4 to 1E-6 is exceeded.[5] Additionally, 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 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.

- Because of the many potential sources, 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. Alternatively, 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. At PGDP, there were 334 detected benzo(a)pyrene results, out of 4,544 analyzed soil and sediment samples. Table E.5 summarizes these benzo(a)pyrene results and indicates that the highest concentrations of the PAH are in surface soils.

Table E.5. 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 are used to calculate Total PAHs.[8] Factors utilize results from the carcinogen PAHs of 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.6 summarizes Total PAHs as they are found in surface (0–1 ft), subsurface (1–10 ft), and deep subsurface soils (> 10 ft) (as defined by the Paducah Risk Methods Document).[8]

Table E.6. 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

Figures E.8 through E.10 illustrate the location of these total PAHs by depth. Ranges of values are shown with respect to the no action level for the industrial worker (i.e., 1E-6) and action level for the industrial worker (i.e., 1E-4), 0.784 mg/kg and 78.4 mg/kg, respectively.

In conclusion, the Observations section of the BHHRA should address the uncertainties associated with the presence of PAHs, and the feasibility study (FS) should include discussions ensuring that remedial actions appropriately address the uncertainties associated with the presence of residual concentrations of PAHs.

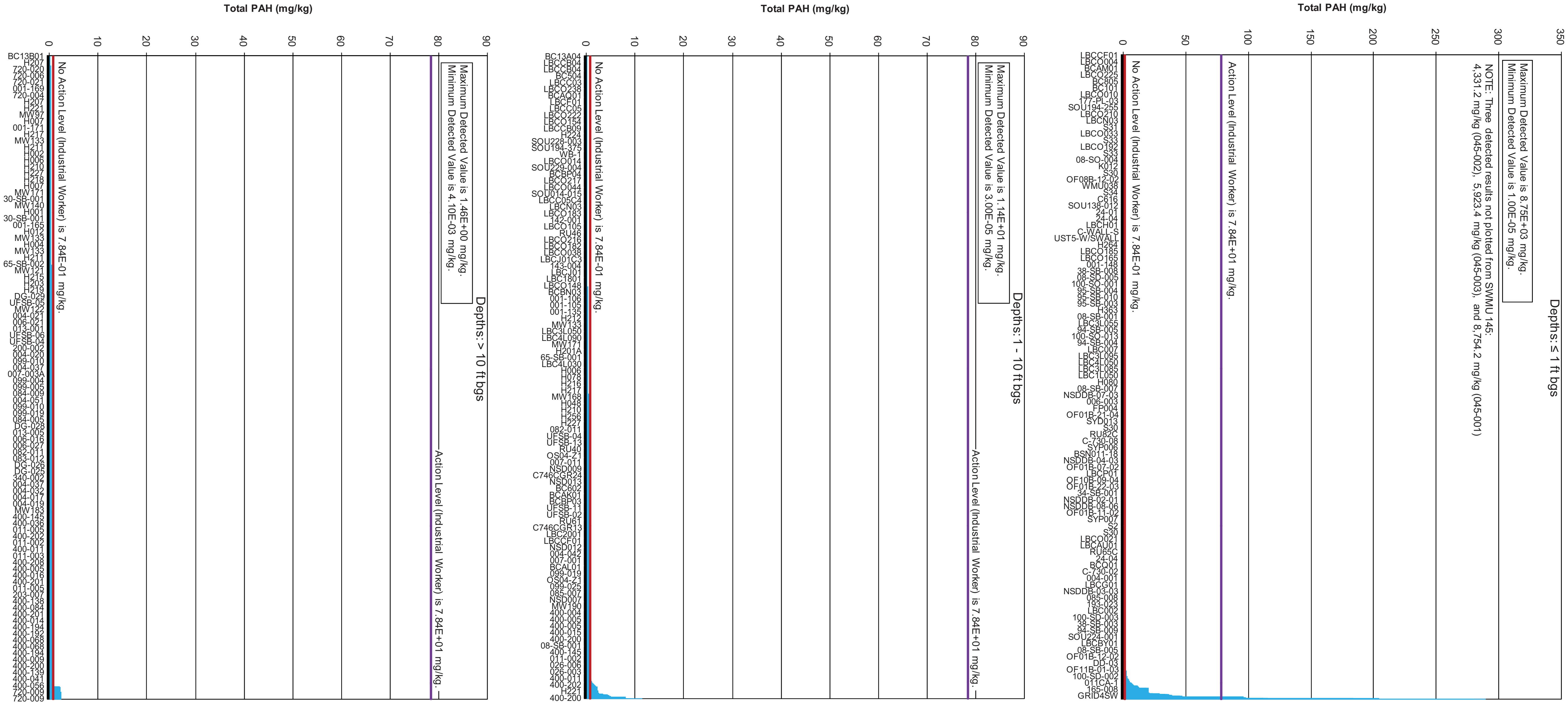

Figure E.8. Total PAH Concentrations by Depth

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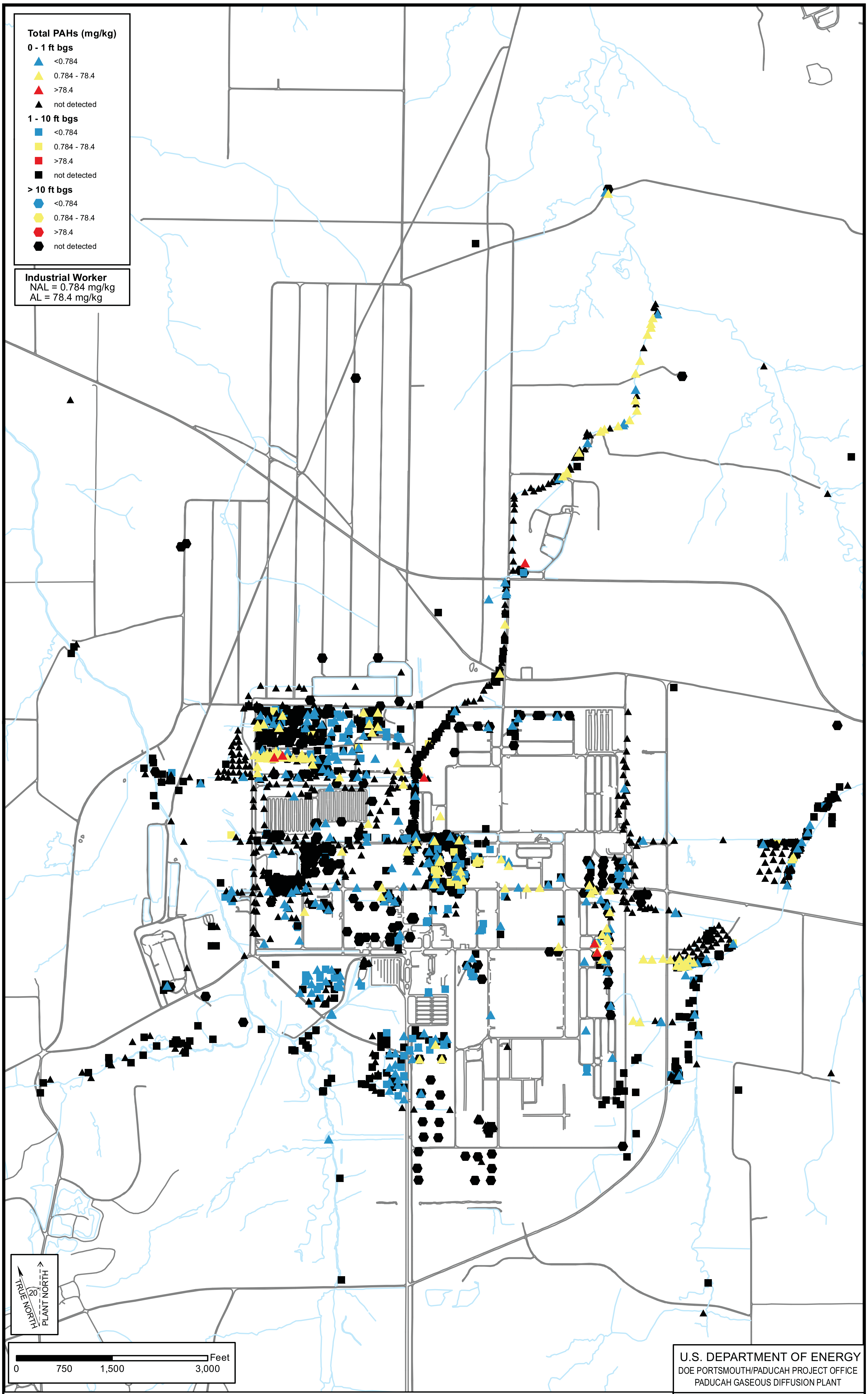

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PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

Figure E.9. Total PAH Soil/Sediment Samples

Figure No. 2012_Total PAHs in Soil-SedimentR1.mxd
DATE 12-19-2012

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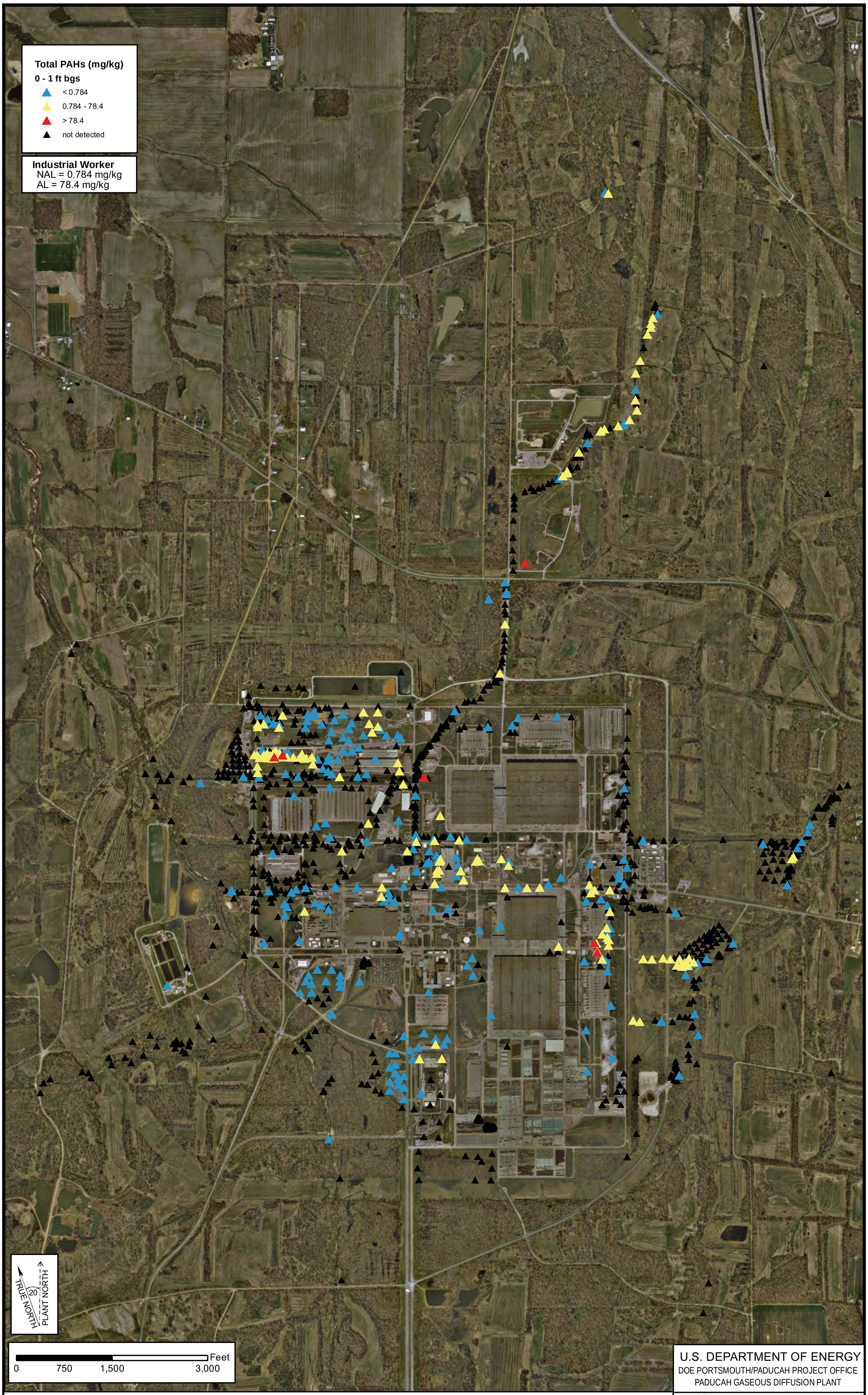

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

LATA Environmental Services of Kentucky, LLC

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

Figure No. 2012_Total PAHs in Soil-Sediment_SurfaceR1.mxd
DATE 12-19-2012

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E.8.3. SUMMARY

In evaluating risk/hazard at PGDP, PAHs will be evaluated 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, 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.

Because PAHs generally are not related to identifiable sources, sampling for PAHs at many SWMUs should be deferred to post-gaseous diffusion plant (GDP) activities; however, the need for sampling for PAHs would be appropriate during pre-GDP activities at SWMUs where PAHs release are potentially expected (e.g., SWMU 30, which contained an incinerator). The need for sampling for PAHs should be addressed during project scoping on a SWMU-specific basis.

[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.

[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] *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.

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ATTACHMENT E1

1995 QUESTIONAIRE AND RESPONSES REGARDING RECREATIONAL USAGE OF BAYOU AND LITTLE BAYOU CREEKS

1409
North Forbes Road
Lexington, Kentucky
40511-2050

606-233-0574
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Fuller
Mossbarger
Scott &
May
FMSM
ENGINEERS

October 26, 1995

O.1.1.94355L05

Mr. Charles Logsdon
Kentucky Department of Fish and Wildlife Resources
10535 Ogden Landing Road
Kevil, Kentucky 42053

Re: PCB Risk Calculations
Paducah Gaseous Diffusion Plant

Dear Mr. Logsdon:

FMSM is conducting a preliminary risk calculation for the Little Bayou and Big Bayou areas around the Paducah Gaseous Diffusion Plant. This subject was discussed at a meeting in which you attended on September 7, 1995. During that meeting you indicated that your office could provide information on the recreational use of these areas. In response to your suggestion, we have developed the following list of questions. Please try to research your site use data and answer as many of these questions as possible. If data is not directly available to answer these questions we would appreciate an estimate based on your best professional judgment.

Big Bayou

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

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

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

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

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

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

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

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

Little Bayou

I realize that during the September 7th meeting, you stated there is little to no recreational use of the Little Bayou areas. However, it would be helpful if you could answer the same questions about Little Bayou, as asked of Little Bayou. Therefore, we are repeating the following questions.

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

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

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

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

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

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

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

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

We appreciate your help in answering these questions. After you have reviewed these, if you have any questions, or if the questions need clarification, please call.

Sincerely,

FULLER, MOSSBARGER, SCOTT AND MAY
ENGINEERS, INC.

Stephen L. Scott, P.E.
Project Manager

/esh

c: David Asburn
Tom McGee
Bob Sneed
David Brancato

facsimile
TRANSMITTAL

to: Stephen Scott, P.E.
fax #: 606-254-4800
re: Big Bayou & Little Bayou
date: November 8, 1995
pages: 4, including this cover sheet.

From the desk of...

Charlie Logsdon
WMA Supervisor
Ky. Dept. Of Fish & Wildlife Resources
10535 Ogden Landing Rd.
Kevil, KY. 42053

(502)488-3233
Fax

Stephen Scott, P.E.
Fuller, Mossbarger, Scott and May
Engineers, Inc.
1409 North Forbes Road
Lexington, Ky. 40511-2050

Dear Mr. Scott:

I have answered these question as accurately as possible. If you have any other questions, or questions about my answers feel free to contact me. Sorry about the delay, but you're letter came during some of our deer hunting seasons.

Sincerely,

Charlie Logsdon

Charlie Logsdon

cc: Wayne Davis
Don Walker

Little Bayou

1. The number of people visiting Little Bayou is essentially zero, with the exception of PGDP personnel and a few fishermen(maybe, 20 visits annually) that fish a large beaver pond above the outfalls of the plant. A few people (bowhunters and dog trainers) may cross the creek occasionally, but these visits would be brief(the majority would be measured in seconds or minutes). Field trial galleries do cross the creek(over a large dirt-covered culvert) north of McCaw Road, however, they do not enter the creek and the whole process takes seconds.

2. The visitors would be adults.

3. Refer to Big Bayou question 3. Visitors to Little Bayou would be repeat users, probably less than 10 visits per year and most of them in the brief encounter scenario described in question 1.

4. Most encounters with Little Bayou would be measured in seconds. Fishermen that use the beaver pond above the outfalls, may fish on average 2 hours.

5. See Big Bayou question 5.

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

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

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

Big Bayou

Question 1: The number of visits by people using Big Bayou specifically, is estimated to be 150 visits. This is for a specific activity involving Big Bayou, such as fishing. More people may be in the vicinity while using the WKWMA, but their use of Big Bayou maybe for only an instant(i.e., using a log to cross Big Bayou to hunt on the other side of the creek).

Question 2: Of the 150 visits of people using Big Bayou, 100 are adults and 50 are children. This is an estimate based on our observations of people using the area.

Question 3: Most of these people would be one time users. However, 10% of the total number of users could be classified as repeat users. The highest number of visits by one person specifically using Big Bayou, would probably be <10.

Question 4: The average time spent in Big Bayou by users is unknown. However, I feel the amount of time spent/trip would be similar to other activities. During 1994, the average number of hours spent/trip for the following activities were: Quail hunting - 3.49 hrs/trip(n= 158), rabbit hunting - 3.25(n=168), bowhunting for deer - 3.48(n=1115), duck hunting - 2.4(n=69), and raccoon hunting - 2.63(n=20). Raccoon hunting and duck hunting would be the activities most likely associated with Big Bayou. There would be little, if any, difference between adult and child usage of the area.

Question 5: This question is difficult to answer. Do you mean for WKWMA or Big Bayou? WKWMA is heavily used by a wide variety of users. Annually, the estimated number of visits for the following activities are: fishing - 5000 visits/year, hunting and dog training 4-6000, field trials - 1500, hiking - 100, berry & nut picking - 200, driving through for a variety of reasons - 50,000.
For activities involving Big Bayou alone: fishing - 150, hunting - ?(explained in question 1).

Question 6: Refer to questions 3 and 4.

Question 7. Most, if not all would be bank fishermen. Most of the fishing would occur at 3 points: 1) where the iron bridge in tract 4 crosses Big Bayou, 2) where the collapsed bridge in tract 4 crosses Big Bayou(by weir constructed by PGDP), and 3) where the concrete crossing bridges Big Bayou in tract 6. While it may occur, no wade fishing has been observed. No actual data is available, but should be similar to the length of visits noted in question 4.

Question 8: There is a harvestable fish population in Big Bayou. A person could potentially expect to catch 0.284 kgs of fish on a regular basis(depending on the skill of the fisherman), however, this is assuming that the person is not culling(throwing back extremely small fish). The frequency of being able to catch 0.248 kgs of fish would increase as one approaches the mouth of Big Bayou. Also, the only way the creek could support 128 meals a year is if there was major influx of fish from the Ohio River. This does occur when there is a backwater. During the backwater periods catches of 50 to several hundred pounds of catfish can be taken(this has been observed) on trotlines. This would not be indicative of risks associated with the plant.

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

Used with permission for inclusion in *Methods for Conducting Risk Assessment and Risk Evaluation at the Paducah Gaseous Diffusion Plant Paducah, Kentucky, Volume 1. Human Health.*

Garner, Leanne K (YLN)

From:	Kreher, Timothy (FW) <Timothy.Kreher@ky.gov>
Sent:	Tuesday, January 21, 2014 11:41 AM
To:	Garner, Leanne K (YLN)
Subject:	RE: Update of Recreational Use of Bayou and Little Bayou Creeks near PGDP

LeAnne,

I would concur with the numbers and estimates originally provided by Charlie Logsdon for the most part. I would suggest that there are brief exposures to both Little Bayou and Bayou Creeks by dog trainers riding horses where they cross the creek via the method of the horse and dog wading through the creek while the rider is mounted (i.e., the riders does not have contact with the water for the most part). Such crossings are brief, less than 10 seconds at a time. I would also suggest that there may be cases where hunters cross one or both creeks by wading through shallow spots, but in most cases these people are wearing rubber boots or waders, and I would not consider this a major source of exposure (?). When hunters do wade through the creeks, it is again a brief exposure of less than 30 seconds each time.

I would suggest increasing the **frequency** of visits / exposures by a factor of 1.5 for all of Charlie's answers to factor in increased use of the WMA.

I almost never see fishing activity in the creeks outside of the portion that crosses through TVA-owned property near where the creeks join and meet the Ohio River (what we refer to as Tract 6 of the WKWMA). As Charlie mentioned, the great majority of this fishing activity occurs when the Ohio River levels are elevated and have the creeks "backed up" with water from the river. I assume this also decreases the effects of any particular exposure during these instances.

Tim Kreher
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Doug Travis, Obion Creek, and West Kentucky Wildlife Management Areas
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email Timothy.Kreher@ky.gov

From: Garner, Leanne K (YLN) [mailto:Leanne.Garner@lataky.com]
Sent: Tuesday, January 21, 2014 8:52 AM
To: Kreher, Timothy (FW)
Subject: RE: Update of Recreational Use of Bayou and Little Bayou Creeks near PGDP

Any thoughts on this, Tim?
If there are no updates, I can just use to older information.

Thanks.

LeAnne

From: Garner, Leanne K (YLN)
Sent: Tuesday, January 07, 2014 8:56 AM
To: 'Timothy.Kreher@ky.gov'
Subject: RE: Update of Recreational Use of Bayou and Little Bayou Creeks near PGDP

Good morning, Tim!
I hope you had a good holiday!

We are updating the Risk Methods Document (the *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant Paducah, Kentucky Volume 1. Human Health*) with more current information.

Some of the information we are updating is "Recreational Use of Bayou and Little Bayou Creeks near PGDP." I have attached that information.
The entire document can be found here:
http://www.paducaheic.com/media/112385/ENV1.A-00440-ARI41.pdf

If you could, please look at the attached and let me know if you think any of the information needs updating.
If so, do you have that information?

I would appreciate any help you could give.

Thank you.

LeAnne Garner
Scientist
LATA Kentucky
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