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Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant Paducah, Kentucky

Volume 2. Ecological

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PADUCAH REMEDIATION SERVICES, LLC
managing the
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Paducah Gaseous Diffusion Plant
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ACRONYMS

ADD	average daily dose
ASTM	American Society for Testing and Materials
AUF	area use factor
BAF	bioaccumulation factor
BCF	bioconcentration factor
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COC	contaminant of concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CSM	conceptual site model
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ERAWG	Ecological Risk Assessment Working Group
ESV	ecological screening values
FS	feasibility study
HQ	hazard quotient
KDEP	Kentucky Department for Environmental Protection
LOAEL	lowest observed adverse effect level
NFA	No Further Action
NOAEL	no observed adverse effect level
NSDD	North-South Diversion Ditch
OREIS	Oak Ridge Environmental Information System
PAH	polycyclic aromatic hydrocarbon
PGDP	Paducah Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act of 1976
RI	remedial investigation
ROD	record of decision
SAP	sampling and analysis plan
SMDP	Scientific/Management Decision Point
T&E	threatened and endangered
TCL	target cleanup level
TRV	toxicity reference value
UCL	upper confidence limit

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EXECUTIVE SUMMARY

An Ecological Risk Assessment Working Group (ERAWG) was chartered in April 2000 to develop effects-based threshold concentrations for no-action and action decisions and to develop risk assessment and analysis methods to support decision making for sites requiring further evaluation and to support verification that cleanup goals have been reached following implementation of a response action. In 2008, another ERAWG comprised of representatives from the Kentucky Department for Environmental Protection (KDEP), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE) was assembled to update the document in accordance with new guidance.

The ERAWG agreed that the overall process of designing and conducting ecological risk assessments (ERAs) would continue to follow an eight-step process concordant with current EPA Superfund guidance, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments*, *Interim Final*. This document is not intended to be prescriptive, rather it is meant to be a guidance document describing the ecological risk assessment (ERA) process for PGDP. The ERAWG agreed upon sources and types of published data, model parameters, and methods for obtaining site-specific data that are required in various steps of the ERA process, and these are described. Revision 1 of this document incorporates updates to the no-action levels and provides additional information on guidance from EPA and KDEP issued after the development of the initial version of this document.

This ERA guidance document describes the input from ecological risk assessors that is required for PGDP decision documents. Ecological risk input to decision documents includes summaries of ERA and screening results, evaluations of the adverse effects on ecological receptors of the proposed remedial actions and the effectiveness of proposed exposure controls, and the requirements of monitoring plans.

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1. INTRODUCTION

This document presents guidance for designing and conducting ecological risk assessments (ERAs) and related ecological risk analyses at the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. This ecological risk guidance reflects the consensus of the PGDP Ecological Risk Assessment Working Group (ERAWG). The original ERAWG chartered in April 2000, was comprised of representatives of the Kentucky Department for Environmental Protection (KDEP), Kentucky Department of Fish and Wildlife Resources, U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service, and U.S. Department of Energy (DOE). The charter directed the ERAWG to reach consensus on (1) criteria to support no-action and remedial action decisions and (2) risk assessment and analysis methods for sites requiring evaluation and verification. The ERAWG assembled to update this document in accordance with new guidance in 2008 was comprised of representatives of KDEP, EPA, and DOE. By documenting ERAWG consensus on decision criteria, guidelines, and methods, this guidance incorporates the requirements of the Commonwealth of Kentucky and EPA and promotes prompt approval of ecological risk plans and reports for PGDP sites.

This document is not intended to be prescriptive, rather it is meant to be a guidance document describing the ecological risk assessment (ERA) process for PGDP. This consensus guidance supplements existing guidance for conducting risk assessment activities at PGDP. For ERAs at PGDP sites, this ERAWG consensus guidance is similar in many areas to previous documents but takes precedence over these previous documents when they differ. The PGDP ERA method document supplements and is concordant with existing state and federal guidance documents. The methods in this PGDP ERA methods document apply to both source and integrator[1] units at PGDP and remedial activities being conducted under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Resource Conservation and Recovery Act of 1976 (RCRA) regulations. ERAs for PGDP source or integrator units that were or are currently being conducted according to earlier guidance are expected to be consistent with the initial steps of the ERA process as described in this PGDP ERA methods document. If additional evaluation is required for these sites to support risk-management decisions, those evaluations are expected to conform to this guidance.

This document presents the updated 2008 ERAWG-consensus criteria values as well as guidance for designing and conducting risk assessments and related ecological risk analysis activities supporting risk management decisions at PGDP. The eight-step process to be followed by ERAs for all PGDP sites is described in Chap. 2. Screening benchmarks for soil, surface water, and sediment are provided. These benchmarks are for use in all ERAs conducted in accordance with this guidance. Chapter 2 includes model receptors and values of exposure parameters for use at all PGDP sites and guidance on selecting toxicity reference values (TRVs). Guidance is also provided for the conduct, use, and reporting of each of the eight steps of PGDP ERAs. Chapter 3 describes the data, results, and information about ecological risk that should be included in CERCLA and RCRA decision documents for PGDP sites.

[1] Integrator units are those units or areas that accumulate contaminants from source units or areas.

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2. DESIGNING AND CONDUCTING ECOLOGICAL RISK ASSESSMENTS AT PGDP

The 2001 ERAWG reached consensus on specific elements potentially required for all ERAs at PGDP, including specific decision criteria, such as screening benchmarks; model receptors, exposure assumptions, and parameters for preliminary risk calculations; and formats for assessment endpoints and ERA reports. PGDP ERA rules are consensus statements clarifying potentially important guidelines. The ERAWG also agreed that ERAs at PGDP must follow an eight-step process concordant with the EPA eight-step process for designing and conducting ERAs at Superfund sites (EPA 1997a). The review by the 2008 ERAWG confirmed the use of the eight-step process and updated some aspects of this guidance with new ecological risk information and screening levels. The EPA eight-step ERA process is illustrated in Figure 1.

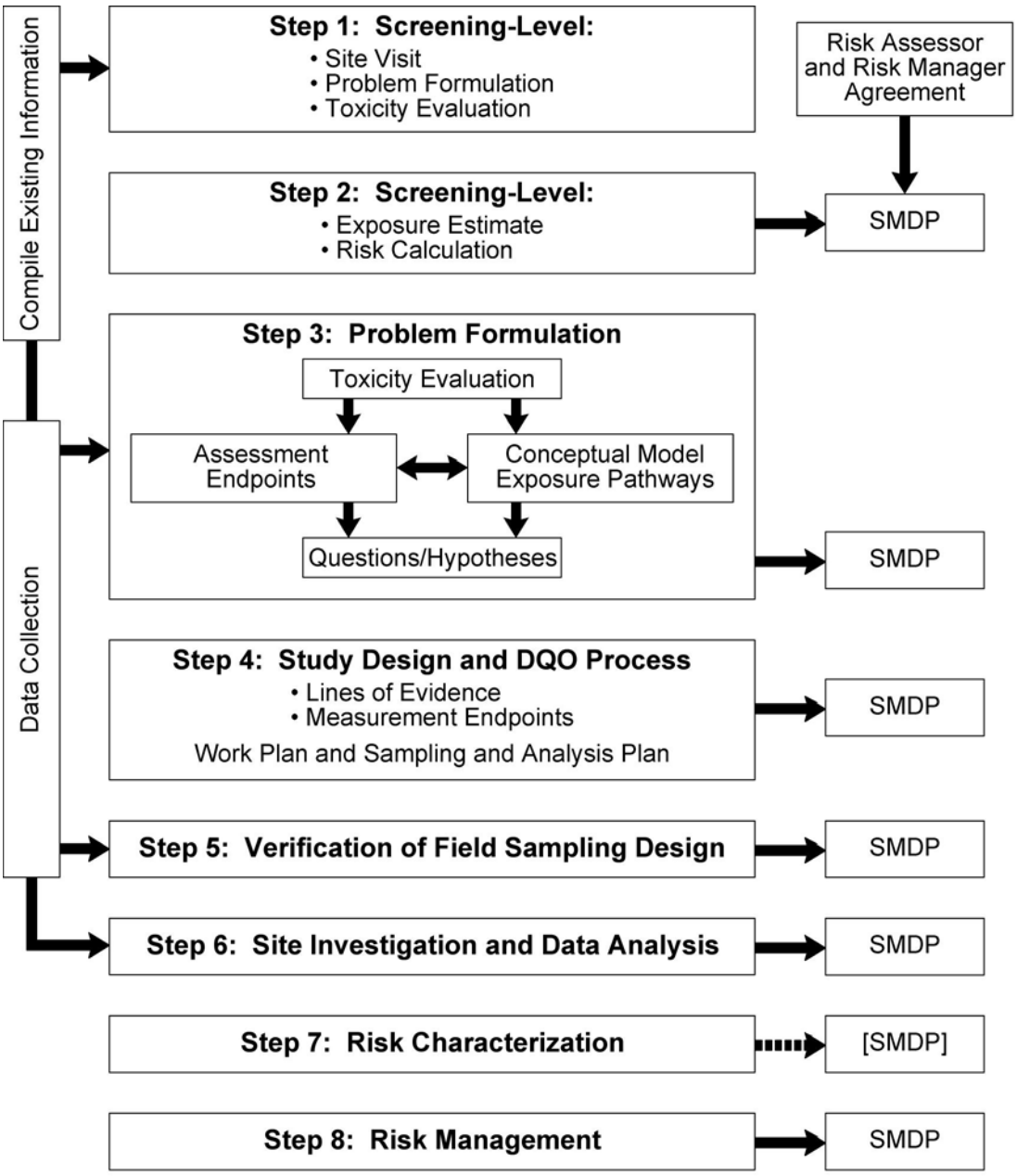
The eight-step process for ERAs at PGDP agreed upon by the ERAWG supplements the EPA's ERA process (EPA 1997a). Although the names of the eight steps are identical, some of the activities within the steps are different. This site-specific consensus document specifies where the PGDP process differs slightly from the EPA process in the sequencing of activities. Where this document is silent, EPA governs (EPA 1997a). A description of the eight-step process and directions for applying the process to ERAs at PGDP are given below.

The PGDP ERA process should be complete to justify a decision to remediate a site based on ecological risks alone. If a decision is made to remediate a site before the PGDP ERA process is complete, such as when high risk to human health has been established during scoping activities (DOE 2001), then evaluations of the protectiveness of proposed remedial actions for ecological receptors will be more uncertain. Given the greater uncertainty when proceeding with remediation before the PGDP ERA process is complete, remedial goal options will be based on more conservative exposure and effect assumptions, and site-specific target cleanup levels (TCLs) likely will be lower and more costly to achieve than would result following completion of the PGDP ERA process. A decision that no further action is necessary to protect ecological receptors, on the other hand, may be justified following the early steps of the PGDP ERA process (Steps 1, 2, and 3).

2.1 SCOPING FOR ECOLOGICAL EVALUATION

Prior to ecological evaluation of a site, a scoping meeting should be conducted with ecological risk assessors from the regulatory agencies. Some aspects of ecological evaluation, even at a screening level, are site-specific, and discussions regarding the site held prior to the evaluation will focus resources and efforts in the appropriate direction. The scoping meeting should include discussion of the presentation of the dataset for the ERA and the format for any requested electronic copies of the data to be included with the ERA.

The consensus of the ERAWG is that PGDP sites with any amount of vegetation are potential nesting or feeding habitat for ecological receptors and, thus, require at least a screening-level risk assessment. Some sites may not require a screening for ecological risk from soil because no habitat and no exposure pathways for ecological receptors currently exist at the site. Sites meeting the general guidelines here can be considered for exclusion from the screening process. Each site meeting the criteria still needs to be discussed with risk managers and regulators, as these criteria are not prescriptive and some sites meeting them still may need to undergo evaluation.



Source: EPA 1997a. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final*.
DQO = data quality objective
SMDP = Scientific/Management Decision Point

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Figure 1. EPA Eight-Step Process for Designing and Conducting ERAs

Sites considered for exclusion should have all of the following characteristics:

- All areas of soil contamination shallower than five feet are covered with concrete, pavement, or a building.

- Routes for off-site migration of soil also are incomplete due to the presence of concrete, pavement, or a building.

- Features and structures preventing the existence of complete pathways are reasonably expected to remain in place.

Groundwater at these sites still should undergo screening for ecological risk, as described in Section 2.3.

2.2 SCREENING-LEVEL RISK ASSESSMENT (STEPS 1 AND 2)

Steps 1 and 2 of the ERA process at PGDP constitute a screening-level 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. Because the consequences of incorrectly deciding that there is risk (further evaluation) when there is no risk are less severe than the consequences of incorrectly concluding there is no risk (not reducing or eliminating risk) when there is risk, the screening-level risk assessment is designed to minimize the likelihood of the latter, false negative error. That is, the screening-level risk assessment is intentionally conservative (EPA 1997a). If no potential for risk is identified in a conservative screening-level risk assessment, then risk managers can confidently conclude that no further action (i.e., investigation, remediation) is required at the site. A screening-level risk assessment is an appropriate risk analysis during scoping, prioritization, and work plan development activities prior to the remedial investigation (RI)/feasibility study (FS) or equivalent.

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

- Site visit (if needed),
- Screening-level problem formulation [preliminary conceptual site model (CSM)],
- Screening-level effects evaluation (toxicity threshold benchmarks),
- Screening-level exposure estimate (site maximum concentration data), and
- Screening-level risk calculation (site concentration data screens).

In Step 1 of ERAs for PGDP sites, ecological risk assessors use available information to develop a preliminary CSM. Available information includes observations made during site reconnaissance, historical documents, existing data, and professional judgment of other technical experts who are familiar with the site (e.g., biologists, hydrogeologists, chemists, and engineers). The preliminary CSM describes the environmental setting of the individual site, the site's immediate surroundings (as opposed to the larger PGDP), and the contaminants known to exist at the site. The preliminary CSM should identify fate and transport mechanisms by which site contaminants potentially move off-site, and briefly discuss the ways that site contaminants act on likely receptors.

Based on the preliminary CSM, the ecological risk assessors identify the potentially complete exposure pathways and endpoints for the screening assessment. The potentially contaminated source media at the site, such as soil, surface water, sediment, and groundwater, are described, and the classes of receptors potentially exposed to these media are identified. As determined in the scoping described in Section 2.1, only those source media that are potentially contaminated and to which receptors are potentially exposed

need to be screened in Steps 1 and 2. Subsurface soils to a depth of five feet should be screened if surface soil at a site likely will be removed and not replaced or if site-specific information indicates that ecological receptors are exposed to potentially significant levels of contamination (e.g., burial grounds and waste piles). For PGDP ERAs, surface soil is defined as no deeper than 0–1 ft below ground surface (bgs). For ERAs, use of samples collected in the 0-6-inch bgs depth is preferred over the 0-1-ft depth when those results are available. This shallower depth range should be considered when additional sampling of a unit is done for the purposes of ecological investigation.

The exposure pathways and endpoints for the site specify which ecological effects data are required. For PGDP ERAs, the screening-level effects data are screening-level benchmarks, which are concentrations of substances in abiotic media that are associated with little to no adverse ecological effect. The screening benchmarks used to make the screening-level risk calculations are the PGDP No Further Action (NFA) levels. There are NFA levels for substances in soil, sediment, and surface water. Screening benchmarks are also available for some classes of chemicals [e.g., total polycyclic aromatic hydrocarbons (PAHs)]. If groundwater potentially discharges to surface water, groundwater concentrations are compared to surface water screening benchmarks. There are not any NFA levels for constituents in air. PGDP NFA levels for soil, sediment, and surface water are described in Appendix A.

In Step 2 of ERAs at PGDP sites, the maximum site concentrations for substances in a given exposure medium are compared to the screening-level benchmarks for those substances [i.e., PGDP NFA levels (PGDP ERA Rule 2)]. For the NFA screen at PGDP sites, the maximum site concentration for a substance reported as detected in any sample is the larger of the maximum detected concentration and one half of the maximum reported detection limit for the substance in samples reported as nondetect. Therefore, it is highly recommended that there be some existing data with detection limits below the NFA values. If existing data do not have adequate detection limits, new data may be collected to replace them. Existing data should be considered valid until newer data are collected to replace them.

Site concentration data for PGDP sites are those data present in the Paducah Data Warehouse. All relevant concentration data for a site should be gathered and entered into Oak Ridge Environmental Information System (OREIS) before conducting the screen. Although data on the nature and extent of contamination need not be complete before screening, representative samples are required. If sampling results are suspected of not being representative of the site or data quality is unsatisfactory (e.g., detection limits routinely exceed NFA values), then additional data may be required for the screening evaluation needed to reach the Step 2 Scientific/Management Decision Point (SMDP). Data sets that have been evaluated and accepted for use in human health risk assessments for PGDP sites are acceptable for use in ERAs; however, these data should not be screened against background and human health preliminary remediation goals, and essential nutrients should not be eliminated before conducting the ecological NFA screen. If existing data are not used, the reasons for not using the data should be explained.

NFA levels are available for some groups of substances for some media. For Steps 1 and 2 of PGDP ERAs, the maximum concentrations for all members of a group detected at a site and the reported detection limits for all members of the group reported as nondetected are summed to give the group total concentration. The group total concentration is compared to the screening benchmark for the group (e.g., total PAHs) when at least one member of the group is detected. If toxicity equivalency factors for effects on ecological receptors are available for a group of related chemicals, then they should be used to adjust concentrations when calculating group totals or to compare individual chemicals against the standard benchmark.

PGDP ERA Rule 1—Assume shallow groundwater discharges to surface water. Provide justification that groundwater does not discharge to surface water if groundwater data are not screened in Steps 1 and 2.

Screens are conducted for surface soil, sediment, surface water, and groundwater (if groundwater potentially discharges to surface water) at the site if they potentially result in exposure to ecological receptors. The comparison of site concentrations to screening benchmarks for abiotic media assumes that the primary exposure routes for receptors at the site are the same as those for receptors at the test site or in the lab experiments that generated the data used to derive the screening benchmarks. These screens constitute the screening-level risk calculations and should include calculation of the screening hazard quotient (screening HQ). If the site maximum concentration (the numerator) is greater than the screening benchmark (the denominator), then the substance has an HQ > 1 for that medium. Due to the conservative nature of the NFA levels and their relationship to more general endpoints than may exist at the site, the HQs generated during the screening step should be referred to as screening HQs to distinguish them from the receptor-specific HQs generated during a baseline ERA.

PGDP ERA Rule 2—In Step 2, compare the maximum site concentrations for substances in a given exposure medium to the screening-level benchmarks and generate screening HQs. If detected in at least one sample, the maximum site concentration is the larger of the maximum detected concentration and one-half of the maximum reported detection limit.

Chemicals with known additive synergistic effects or that bioaccumulate are retained as chemical of potential ecological concern (COPECs) and evaluated further in Step 3. The list of bioaccumulating compounds is based on the list developed for the Great Lakes and is presented in Appendix A.

2.2.1 Steps 1 and 2 Uncertainties

At Steps 1 and 2 of the ERA process, information will not be complete, and some constituents will not have NFA levels. There may not be site chemistry data for all classes of constituents. There may be incomplete information about what animal and plant species actually or potentially occur at the site, including threatened and endangered (T&E) species. The document recording the results of Steps 1 and 2 should discuss these uncertainties.

2.2.2 Use of Steps 1 and 2

The screening results and site information for the given unit are used at the SMDP 1 to support a decision whether to continue evaluating ecological risk. If any constituent in an abiotic medium to which organisms are potentially exposed is present at a concentration exceeding the PGDP NFA level or if there is not an NFA level for a constituent, then further evaluation of the potential for risk will be required unless the decision to take an action (such as soil or sediment removal) has been made. At SMDP 1, the results of the screening evaluation should be discussed with the regulatory agencies. If constituents exceed NFA levels, there are critical data gaps, or other uncertainties at this point in the process are large enough, then additional data could be required for decision making even though no constituent exceeds an NFA level.

Another important piece of information risk managers need at the first SMDP is the nature of the habitat and ecological setting of the site. At SMDP 1, risk managers may decide that sites do not require additional evaluation, even though one or more substances are identified as chemicals of potential concern (COPCs), if exposure pathways are not complete or actions will be taken to eliminate the exposure pathway.

2.2.3 Reporting Steps 1 and 2

The documentation of Steps 1 and 2 for PGDP sites should include the following:

- Brief habitat description and map, if appropriate;
- Preliminary CSM;
- Discussion of all changes to the dataset made to refine the raw data to that used in the risk assessment;
- Tables of screening results;
- List of wildlife species actually or potentially occurring at the site, including T&E plant and animal species; and
- Discussion of uncertainties.

The discussion of the uncertainties should identify constituents for which there are not NFA levels or analytical chemistry data. The decision whether to collect additional data for screening, proceed with the ERA, or conduct no further evaluation or other action can be documented in the report.

When reporting risks from PGDP sites at which no surface soil samples were collected, the report needs to state the following: "The potential risk from exposure to surface soil was not quantified in this risk assessment and is, therefore, unknown. The risk from exposure to this medium was not quantified because the investigation of this medium falls outside the scope of the current investigation." (Note that a similar caveat also will apply when considering risk from potential exposure to groundwater when data are not available because of the scope of the investigation.) Ecological assessment does not move beyond Step 2, if maximum site concentrations do not exceed their NFA levels.

2.3 ERA PROBLEM FORMULATION (STEP 3)

The purpose of Problem Formulation (Step 3) is to provide sufficient information to support a risk management decision concerning the need for additional evaluation of ecological risk. Important inputs to this decision (SMDP 2) are the identification of COPCs that warrant further evaluation, an understanding of the effects of COPCs on ecological receptors, identification of complete exposure pathways by which COPCs are brought into contact with ecological receptors, and identification of assessment endpoints. The outputs of the Problem Formulation step are the final list of COPCs, assessment endpoints, and questions and hypotheses potentially requiring further evaluation in an ERA. In support of the Step 3 SMDP, the risk assessors provide their conclusions and recommendations based on professional judgment.

2.3.1 Reevaluation of COPCs (Step 3a)

The further evaluation of COPCs identified in Steps 1 and 2 of the EPA eight-step process is called the "Refinement of COPCs," and it occurs after the screen. Some evaluation of COPCs beyond the comparison with screening values appears with the results of the screening, as described in previous sections. Those evaluations should be repeated as part of the Problem Formulation step (Step 3) for the baseline risk assessment (BRA). According to EPA's amended guidance, Step 3a of the process represents an opportunity to present a "reasoned toxicological approach for the elimination of one or more COPCs from future consideration" (EPA 2000a). The purpose of this step is to sharpen the focus of the evaluation on those COPCs that can and should be evaluated because of the potentially significant risk they pose to ecological receptors at the site.

Step 3a of ERAs for PGDP sites include the following activities:

- Compare site and background concentrations;
- Evaluate frequency and distribution of concentrations exceeding benchmarks and/or referenced site values;
- Evaluate site-specific tissue concentrations against benchmarks for direct risk to organism sampled (if available);
- Calculate preliminary HQs for bioaccumulating constituents and for selected PGDP wildlife receptors;
- Evaluate site-specific exposure data and assumptions [e.g., area use factor (AUF), ingestion rates, and diet];
- Consider alternative toxicity data and benchmarks for receptors exposed by direct contact;
- Compare site and reference concentrations; and
- Evaluate site-specific tissue concentrations (if available) to calculate risk from food chain uptake.

In contrast to the eight activities potentially included in Step 3a for PGDP ERAs, EPA explicitly identifies only one activity in this step: review and consideration of "realistic conservative" exposure assumptions (EPA 1997a). **The first four activities listed for Step 3a may be included as part of the uncertainty evaluation of the screening assessment, if this is appropriate based on the site and information available**. The last four of the eight activities generally require input from regulators and should be completed after regulatory review of the results of the screening. The eight activities potentially included in Step 3a for PGDP ERAs are briefly described here.

Comparison of site and background. Consistent with the revised Human Health Risk Methods Document, the maximum detected concentration of inorganic chemicals and naturally occurring radionuclides may be compared to twice the mean value of the background dataset for that chemical or radionuclide. Constituents with maximum detected concentrations less than twice the mean value of background can be eliminated from further consideration as COPCs after the initial screening.

Frequency and Distribution. The frequency of occurrences in site samples of concentrations exceeding background criteria may be used to evaluate the extent of contamination. The representativeness of the site data set, including the number and spatial distribution of samples, should be evaluated if the frequency of exceedances is considered in Step 3a of PGDP ERAs.

Site-Specific Tissue Concentrations-direct risk. If data is available on the concentrations in tissues within species found at a site, that data may be compared to available tissue residue benchmarks to provide a refined screen for direct risk to that organism.

Preliminary HQs. Preliminary HQs are calculated for individual wildlife receptors when those receptors are present at PGDP sites. This set of preliminary HQs is based on individual receptors differs from the screening HQs based on general endpoints that were generated during Steps 1 and 2. For ERAs at PGDP sites, the ERAWG has selected the following model wildlife receptors: arboreal insectivorous mammal, insectivorous bird, ground-dwelling insectivorous/vermivorous mammal, piscivorous mammal, piscivorous bird, granivorous mammal, granivorous bird, predatory mammal, predatory bird, and

carnivorous fish. Preliminary HQs are required only for those wildlife receptor groups that occur or potentially occur at a given site. If the preliminary HQs are presented in the same document as screening Steps 1 and 2, the receptors listed in Table 1 must be used for the calculations. If the preliminary HQs are calculated during the beginning of the BRA, the receptors and parameters for the site should be scoped with the regulators prior to performing the HQ calculations to ensure that appropriate receptors are selected for the site under consideration. Preliminary HQs for model wildlife receptors are required only for COPCs that bioaccumulate in prey tissue. Preliminary HQs for COPCs that do not bioaccumulate in tissues (biotransfer factor < 1) are optional for PGDP ERAs. If preliminary HQs are not calculated, the decision to continue evaluating a COPC will be based on the screening-level risk assessment (Steps 1 and 2), which screens for risk to receptors exposed primarily by direct contact with the contaminated medium.

The parameters for the receptor model species used to calculate preliminary HQs are given in Table 1. Parameters for model species [i.e., body weights, specific ingestion rates (kg/kg body weight/day), AUFs, and diets] should be conservative because the risk assessment for model species is meant to protect all species in the group. It is assumed that model receptors spend their entire lives and obtain 100% of their diet or drinking water at the facility (i.e., AUF equals 1). Ground-dwelling insectivorous/vermivorous mammals and insectivorous/vermivorous birds are assumed to eat only soil-dwelling invertebrates that bioaccumulate contaminants from soil. Predatory mammals and birds are assumed to eat only small mammals such as shrews that bioaccumulate contaminants from ingested soil or biota. Mammalian piscivorous predators and carnivorous fish are assumed to eat only fish. Avian piscivorous predators are assumed to eat only fish for evaluations of surface water and groundwater, and only sediment-dwelling invertebrates for evaluations of sediment. The sources of values in Table 1 are provided in Appendix B.

Preliminary HQs for wildlife receptors are calculated using the maximum detected concentrations and the appropriate benchmarks associated with no effect. Published, observed, or estimated no observed adverse effect levels (NOAELs) for test species are the benchmarks for all model receptors except carnivorous fish (PGDP ERA Rule 3). Benchmarks for carnivorous fish are body burdens (tissue concentrations) associated with no adverse effect (Jarvinen and Ankley 1999). ERAs for PGDP sites will need to explain how all benchmarks are derived and selected, including NOAELs estimated from other benchmarks [e.g., lowest observed adverse effect levels (LOAELs)]. Equations for calculating preliminary HQs are presented in Appendix C.

If site-specific tissue data or appropriate biotransfer factors derived from PGDP data are not available, conservative biotransfer factors should be compiled from sources selected in cooperation with KDEP. The ERAWG has not identified preferred biotransfer factors, but a list of bioaccumulating substances and biotransfer factors is available from the KDEP. Other possible sources of bioaccumulation factors (BAFs) are Sample *et al.* (1998), HAZWRAP (EPA 1995), and the LANL Ecorisk database (LANL 2005). EPA has published biotransfer factors (EPA 1999a), and the PGDP ERAWG has used these values, or values derived as specified therein, for use in deriving site-specific cleanup goals for the PGDP North-South Diversion Ditch (NSDD). Table C.1 lists BAFs and bioconcentration factors (BCFs) provided by KDEP and other sources. These values should be considered as example only and not as approved values. Biotransfer factors used in PGDP ERAs should be fully documented.

PGDP ERA Rule 3—When calculating preliminary HQs, do not scale TRVs for body weight of model receptors.

Site-Specific Exposure Assumptions. Site-specific exposure assumptions also may be considered in Step 3a. Preliminary HQs calculated using conservative exposure assumptions likely overestimate risk. If site-specific data are available, they can provide a more accurate preliminary risk assessment. Alternative HQs may be calculated using site-specific values for exposure parameters and compared to preliminary

HQs. Site-specific exposure data include estimates of central tendency [e.g., mean and 95% upper confidence limit (UCL)].

Table 1. Model Parameters for Calculating Preliminary Hazard Quotients for PGDP ERAs

PGDP Model Receptor Group (PGDP Species Model)	Model Body Weight (kg)	Model Feeding Rate (kg/kg/day)	Model Diet
Arboreal insectivorous mammal (Little Brown Bat)	0.0075	0.9	Adult aquatic insects
Ground-dwelling insectivorous/vermivorous mammal (Short-tailed shrew)	0.015	1.7	Earthworms, soil-dwelling insects
Insectivorous/vermivorous bird (American woodcock)	0.15	0.77	Earthworms, soil-dwelling insects
Insectivorous/vermivorous bird (American robin)	0.0773	1.52	Earthworms, soil-dwelling insects
Insectivorous/vermivorous bird (Marsh wren)	0.0094	0.67	Earthworms, adult aquatic insects
Piscivorous mammal (Mustelid)	0.78	0.46	Fish, crayfish, etc.
Piscivorous bird (Belted kingfisher)	0.136	0.5	Fish, crayfish, etc.
Granivorous mammal (*Microtus spp*.)	0.02	0.3	Seeds
Granivorous bird (Bobwhite quail)	0.16	0.078	Seeds
Predatory mammal (Long-tailed weasel)	0.14	0.46	Small mammals
Predatory bird (Screech owl)	0.14	0.385	Small mammals, flying insects
Carnivorous fish (Smallmouth bass)	0.086	2.0	Invertebrates, fish

ERA = ecological risk assessment
PGDP = Paducah Gaseous Diffusion Plant

Alternative Benchmarks. Alternative toxicity data and benchmarks include such values as LOAELs for wildlife receptors, National Oceanic and Atmospheric Administration and Ontario Ministry of Environment effects-based values for sediment, and lowest chronic values for aquatic biota for surface water.

Reference Site Comparison. The reference site comparison evaluates the relationship between COPC site and reference site concentrations primarily for aquatic systems. Both the choice of reference site and the types of studies to be conducted should be scoped with regulators prior to collection of any data for toxicity and population studies. The reference site comparison is not a background screen because the reference site is used primarily for collecting media for comparison of toxicity test results between the site and the reference site and as a reference site for field data such as population studies.

The site and reference site data presented for comparison include minimum, maximum, mean, and 95% UCL concentrations; frequency of detect; detection limits; and distribution type. Because the comparison

to a reference site or sites is not a strict screen, concentration data for organic compounds detected in reference site samples can be compared to site data.

Site-Specific Tissue Concentrations-bioaccumulation. Site-specific data that are available should be considered in Step 3a. If data are available for the concentration of constituents in plant or animal tissues, then those data may reduce the uncertainties in preliminary HQs calculated using abiotic site concentration data and generic BAFs.

Site-Specific Effects Data. Other potentially useful data are TRVs derived from *in situ* toxicity and laboratory toxicity test results for site media. Toxicity data for standard laboratory test species are of limited value because these species are not necessarily as sensitive to contaminants as are native species.

For all activities conducted as part of Step 3a of PGDP ERAs, mean and 95% UCL concentrations for detected substances are calculated using one-half the reported detection limit for all results reported as nondetected concentrations. Site concentration data for PGDP sites are those data present in OREIS. All relevant concentration data for a site should be gathered and entered into OREIS before conducting Step 3a. Site concentration data used in ERAs and other ecological risk activities must be qualified as valid. An important consideration is the relationship between detection limits and benchmarks. Also, the appropriateness of using statistical manipulation of data must be considered in relation to the number of samples.

2.3.2 ERA Study Focus and Scope (Step 3b)

If any COPCs are identified at a PGDP site, the ERA process continues with Step 3b, ERA Study Focus and Scope. This is the problem formulation step for the site-specific assessment of ecological risk and should be included with the baseline ERA. Where Step 3a focuses the ERA on the subset of COPCs at a site that more likely poses a risk to ecological receptors, Step 3b narrows and sharpens the focus of the required site investigation onto the important exposure pathways and receptors that are potentially exposed to these COPCs. Step 3b of the ERA process includes the following activities:

- Summarizing ecotoxicity of COPCs,
- Identifying assessment endpoints,
- Describing habitat,
- Presenting the CSM, and
- Specifying risk questions and hypotheses for the site.

These elements are common to the EPA eight-step ERA process (EPA 1997a; EPA 2000a).

Ecotoxicity Summaries. Ecotoxicity summaries of COPCs in Step 3b are meant to be brief profiles. These profiles support the selection of assessment endpoints; therefore, they should briefly describe the toxicity of the COPCs to groups of organisms (communities, guilds) and the COPCs' bioaccumulation potential. Toxicity profiles for COPCs should include a discussion of published data on the relative toxicity of various groups of organisms when exposed by the same routes. There are two primary exposure routes of interest for potential receptor groups at PGDP sites:

- Direct contact for plants, soil-dwelling invertebrates, sediment-dwelling invertebrates, and aquatic biota; and

- Ingestion by consumers, such as granivorous (seed-eating) birds, and carnivorous birds and mammals.

Predators include arboreal insectivorous mammals, insectivorous birds, ground-dwelling insectivorous/ vermivorous mammals, piscivorous mammals, piscivorous birds, predatory mammals, predatory birds, and carnivorous fish.

Assessment Endpoints. Assessment endpoints are valued ecological resources that are potentially exposed and susceptible to the COPCs at a site. Policy goals are given in Table 2, along with generic assessment endpoints. Assessment endpoints are the species populations or communities at a site that are investigated to evaluate the risk from exposure to the COPCs. Resources that are not at risk because they are not exposed or not susceptible to the adverse effects of the COPCs should not be assessed. Because not all populations or communities at a site can be evaluated in an ERA, care must be taken in selecting assessment endpoints. Assessment endpoints for PGDP sites should be selected after consulting members of the ERAWG and other stakeholders to ensure that the site investigation addresses the important risk questions. This is one of the critical decisions made at the SMDP following Step 3b, and concurrence on the assessment endpoints for PGDP sites should be obtained from natural resources trustees and parties to the Federal Facility Agreement.

The assessment endpoints for PGDP sites are stated in terms of the survival and successful reproduction of guilds or communities at the site. For example,

Protection of carnivorous mammal populations at the site from negative impact on survival and reproduction from exposure to the COPCs in surface soil.

Assessment endpoints can be stated as in terms of adverse effects on populations or on communities. Adverse effects on populations can be inferred from measures related to impaired reproduction, growth, and survival. Adverse effects on communities can be inferred from changes in community structure or function. The measures used in BRAs for wildlife receptors at PGDP are TRVs, laboratory toxicity tests, and tissue residue concentrations related to impaired reproduction, growth, and survival. These measures reflect assessment endpoints for populations. If a T&E or otherwise legally protected species is an assessment endpoint, then the endpoint should be stated in terms of survival and reproduction of receptors.

If an individual COPC or class of COPCs can be identified as the potential cause of risk to an endpoint receptor, then the COPC can be explicitly named in the assessment endpoint. The ERAWG recommends that the assessment endpoint explicitly name the source medium or media containing the COPCs so as to link the assessment endpoint to potential remedial action decisions, because remedial actions are applied to source media.

Assessment endpoints for ERAs at PGDP sites must be justified on the basis of the following factors:

- The COPCs that are present and their concentrations,
- Mechanisms of toxicity of the COPCs to different groups of organisms,
- Ecologically relevant receptor groups that are potentially sensitive or highly exposed to the COPCs, and
- Potentially complete exposure pathways from source to receptor.

Table 2. Generic Assessment Endpoints for PGDP ERAs

Policy Goals	Assessment Endpoints
The conservation of threatened and endangered species and their habitats.	No adverse impact to any federal- or state-designated threatened or endangered species[2] (flora and fauna) and no adverse impacts to their critical habitats.
The protection of terrestrial populations, communities, and ecosystems.	Protection of soil-invertebrate populations from negative impacts on nutrient cycling resulting from exposure to COPCs in surface soil.
	Protection of omnivorous mammal populations from negative impact on survival and reproduction resulting from exposure to COPCs in surface soil.
	Protection of herbivorous mammal populations from negative impact on survival and reproduction resulting from exposure to COPCs in surface soil.
	Protection of carnivorous mammal populations from negative impact on survival and reproduction resulting from exposure to COPCs in source media.
	Protection of amphibian and reptile populations from negative impact on survival and reproduction resulting from exposure to COPCs in source media.
	Protection of herbivorous bird populations from negative impact on survival and reproduction resulting from exposure to COPCs in source media.
	Protection of omnivorous bird populations from negative impact on survival and reproduction resulting from exposure to COPCs in source media.
	Protection of carnivorous bird populations from negative impact on survival and reproduction resulting from exposure to COPCs in source media.
The protection of aquatic populations, communities, and ecosystems.	Protection of benthic invertebrate populations from negative impact on survival and reproduction resulting from exposure to COPCs in sediment and surface water.
	Protection of amphibian and reptile populations from negative impact on survival and reproduction resulting from exposure to COPCs in sediment and surface water.
	Protection of fish populations from negative impact on survival and reproduction resulting from exposure to COPCs in sediment and surface water.
	Protection of mammal populations that feed on aquatic organisms from negative impact on survival and reproduction resulting from exposure to COPCs in sediment and surface water.
	Protection of bird populations that feed on aquatic organisms from negative impact on survival and reproduction resulting from exposure to COPCs in sediment and surface water.
	Protection of bird populations that feed on aquatic vegetation from negative impact on survival and reproduction resulting from exposure to COPCs in sediment and surface water.

COPC = chemical of potential concern
ERA = ecological risk assessment
PGDP = Paducah Gaseous Diffusion Plant

The assessment endpoint receptors must be present at, or must potentially occur at, the site. Because endpoints should be natural components of the ecosystem at the site, nonnative species [e.g., English

[2] If threatened and endangered species not included on the federal list are listed by the Commonwealth of Kentucky.

sparrows (*Passer domesticus*)] are not appropriate assessment endpoints at PGDP sites. Endpoint receptors must be exposed to COPCs, and they must be susceptible to the adverse effects of the COPCs when exposed at low doses relative to other potential endpoints.

Habitat Description. The habitats occurring at, or potentially occurring at, PGDP sites are important factors to consider in selecting assessment endpoints and developing the CSM for the site. The description of the habitats at PGDP sites should include general information about the site and specific information about terrestrial and aquatic habitats at the site. EPA provides a useful form (provided in Appendix E) for recording habitat characteristics during a site visit (EPA 1997a). The use of photographs, as well as maps and written site descriptions, is recommended. Photographs of sites should be taken when feasible and made available in association with ERAs and decision documents for PGDP sites.

Conceptual Site Model. A CSM is a written or pictorial representation of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system (ASTM 1995). The CSM for PGDP sites must define the potential pathways of exposure from source media to assessment endpoint receptors. The CSM should distinguish potential exposure pathways from those pathways that are evaluated in the ERA for the site. A diagram of the exposure pathways, including source media, fate and transport mechanisms, exposure media, exposure routes and receptors, is an expected element of all PGDP ERAs. Figure 2 is an example of a CSM exposure pathways diagram, and it is not representative of any site at PGDP. Food web diagrams are useful and should be included in the report if wildlife receptors are potentially exposed by ingestion at the site. Figure 3 is an example of a foodweb; however, it is not representative of any site at PGDP.

2.3.3 Step 3 Uncertainties

The uncertainties in Step 3 of the ERA process are primarily associated with the COPCs that remain following the reevaluation (Step 3a). As with Steps 1 and 2, there will not be site concentration data or alternative benchmarks for all constituents. The potential adverse effects of COPCs on some classes of receptors may be unknown. Data gaps must be clearly identified so that the site investigation can be designed to collect the data necessary to answer the risk questions.

2.3.4 Use of Step 3

The results of the refinement of COPCs and the problem formulation (Step 3) for the given site are used to support the decision at SMDP 2 whether to continue evaluating ecological risk. Generally, if any constituent in an abiotic medium to which organisms potentially are exposed is judged to be a COPC in Step 3a, then further evaluation of the potential for risk to ecological receptors will be required. The results of Step 3a should be communicated in a technical memorandum, and the SMDP it triggers should occur before submittal of the work plan for the site investigation. Thus, Step 3a supports the decision about what assessment endpoints will be evaluated further in the ERA. Further evaluation means site-specific ecological investigation, which requires a work plan documenting Steps 3b and 4 of the process and describing how the data collected will be used in Step 7 to make a remedial decision for the site.

2.3.5 Reporting Step 3

The documentation of Step 3 for PGDP sites should include the following:

- Site and, if available, reference site concentration data;
- Preliminary HQs, BAFs, and ingestion rates for wildlife receptors;
- Discussion of alternative benchmarks;

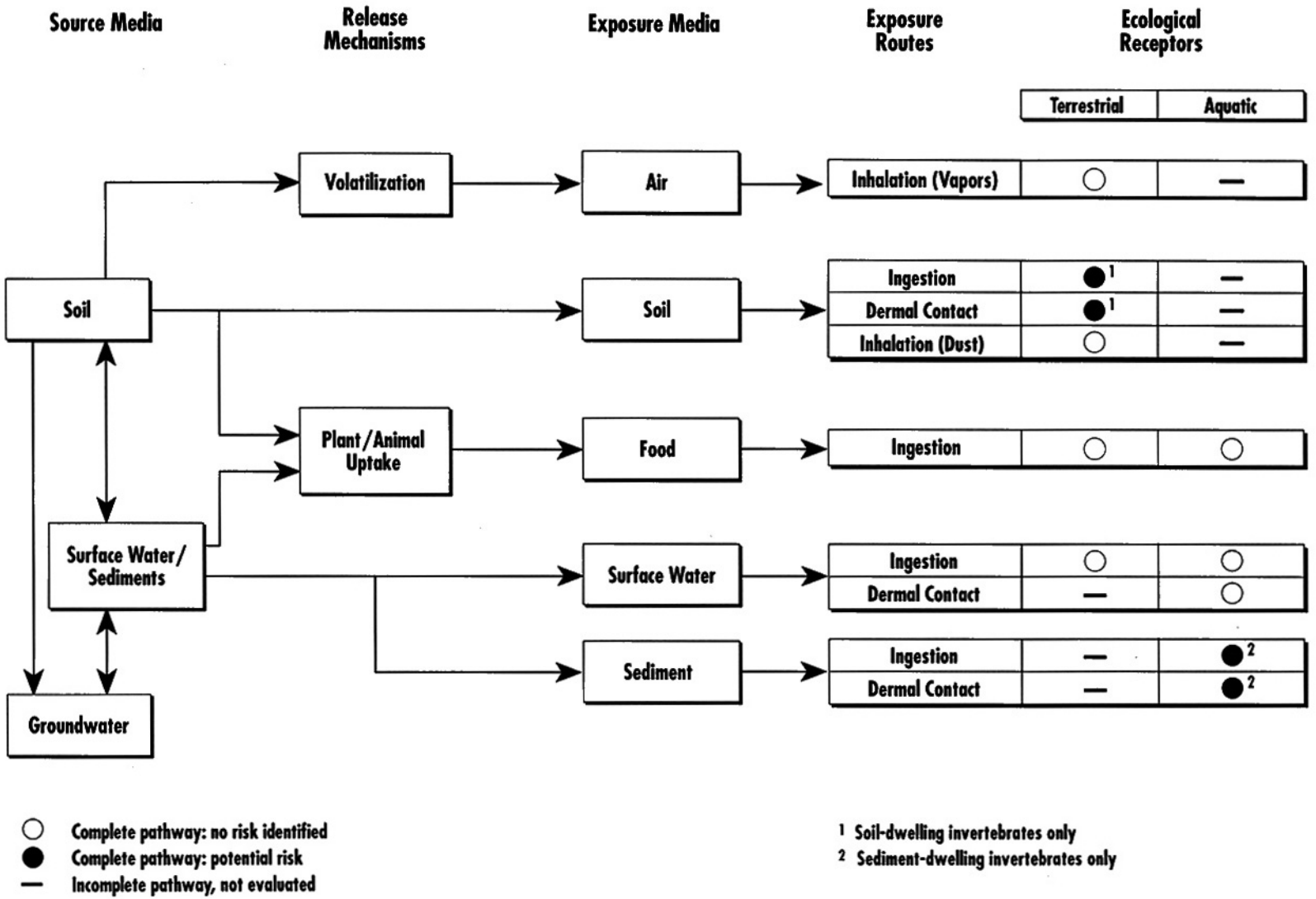

Figure 2. Example of a Conceptual Site Model of Exposure Pathways for Ecological Receptors

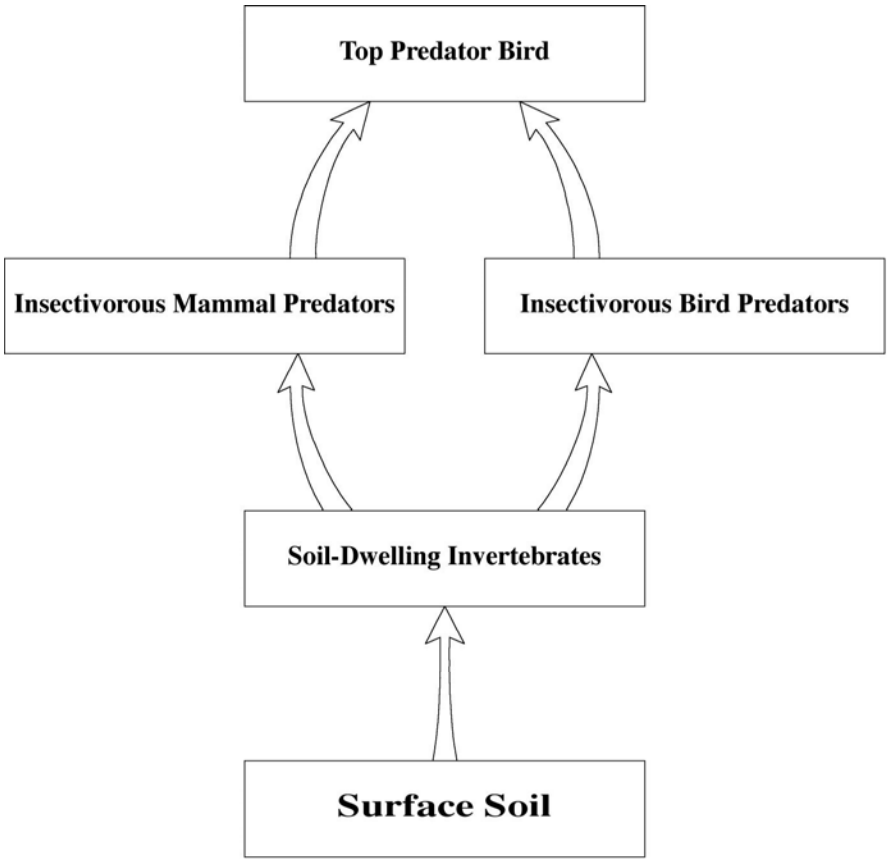

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Figure 3. Example of a Foodweb for Wildlife Receptors

- Discussion of site-specific data and exposure assumptions;
- Ecotoxicity profiles for COPCs following reevaluation;
- Assessment endpoints and justification;
- Habitat descriptions;
- Conceptual site model;
- Risk questions and hypotheses; and
- Discussion of uncertainties.

The documentation of Step 3a results should include tables that compare side-by-side site and reference site concentrations, benchmark concentrations, preliminary HQs, and other data used to reevaluate COPCs. The discussion of uncertainties should include the lack of site concentration or toxicity data for COPCs. The results of Step 3a may be provided in the same document as screening Steps 1 and 2. The decision about whether to conduct a site investigation or to conduct no further evaluation or other action can be documented in the same report. If further evaluation is required, the additional elements of Step 3a and the problem formulation (Step 3b) can be incorporated into the work plan for the site investigation. Concurrence on assessment endpoints and risk questions should be obtained and documented before completion of Step 4, ERA Study Design and Data Quality Objectives (DQOs).

2.4 ERA STUDY DESIGN AND DATA QUALITY OBJECTIVES (STEP 4)

Step 4 of the ERA process identifies the study design and DQOs for the site investigation. For PGDP sites, the ERA work plan and the sampling and analysis plan (SAP) are the primary products of Step 4. The work plan and SAP must specify the study design in sufficient detail for risk managers to evaluate its adequacy for collecting the data necessary to answer the risk questions with sufficient confidence to support remedial action decisions for the site. Final regulatory approval of the work plan and SAP represents the outcome of the Step 4 SMDP.

2.4.1 Study Design—Exposure and Effects Measurements

A site-specific study is designed in Step 4 of the ERA process to answer the risk questions defined in Step 3. Site investigations for ERAs at PGDP sites are required to measure exposure, effects, or both. The measurements specified in the study design must be directly relevant to evaluating exposure of or effects on the assessment endpoints defined in Step 3. Most of the lines of evidence described below assume consideration of contaminant levels present at the site.

For ERAs at PGDP sites with wildlife receptors that are potentially exposed through ingestion of contaminated media, measurements must be made of the concentrations of COPCs in the tissues of organisms that those receptors potentially eat (PGDP ERA Rule 4). Contaminant body burdens in prey are expected to be the primary and most typical exposure measurements used in ERAs at PGDP sites. Particular attention should be given to detection limits when establishing the DQOs for tissue analysis. Abiotic media sample collocated with tissue samples should be collected because they may be helpful in developing remedial goals, if required later in the remedial process.

Concentration measurements for endpoint-receptor tissues (e.g., organ, muscle, bone, feather, eggshell, or hair) may be used to confirm or monitor exposure to specific COPCs. If appropriate concentration-effects data are available for the COPC and the endpoint receptor from the ongoing monitoring programs at PGDP, then exposure measurements should include concentrations in appropriate receptor tissues. Receptor-tissue sampling should be designed not to adversely impact the receptor populations. Particular attention should be given to detection limits when establishing DQOs for analysis of receptor tissues.

Organisms living in direct contact with contaminated media are assumed to be exposed to the COPCs present. For these receptors, the concentrations in the abiotic media to which they are exposed at the site must be measured. Toxicity tests reduce the uncertainty about bioavailability of COPCs, as quantified by analytical chemistry data for abiotic media. Special sampling and analytical techniques may be required to measure the exposure concentrations of COPCs in some media for some endpoint receptors. Particular attention should be given to sampling design and analytical detection limits when establishing DQOs for abiotic exposure media.

PGDP ERA Rule 4—For the study design for PGDP sites with wildlife receptors exposed to COPCs, include the collection and chemical analysis of prey tissue from the site.

There are numerous types of measurements of effects on various biological levels from the chromosome to the community. While measures of suborganismal effects on receptors exposed to COPCs at PGDP sites are possible, the most likely effects measurements for PGDP ERAs are measures of survival and reproduction of organisms: toxicity tests and measures of population/community abundance.

Analytical chemistry data provide estimates of current exposure concentrations and are essential to the interpretation of the toxicity tests and population/community studies. PGDP ERAs that include measures of effect must also include chemical analysis of collocated samples (PGDP ERA Rule 5). Collocated analyses are important to the interpretation of the toxicity test and population/community study results even though analytical data overestimate the bioavailability of some COPCs.

PGDP ERA Rule 5—For the study design for PGDP sites with receptors exposed by direct contact to COPCs, include collocated analytical chemistry data where *in situ*, laboratory toxicity tests, or population/community studies are specified.

Toxicity Tests. For ERAs at PGDP sites with endpoint receptors that are potentially exposed by direct contact with contaminated media, direct tests must be made of the toxicity of the exposure media (PGDP ERA Rule 6). Toxicity tests on abiotic media should use organisms that are representative of the endpoint receptors. Standardized toxicity tests using commercially supplied test species are available for soil, sediment, and surface water (see the following text box). The selection of standardized tests instead of *in situ* tests using local species should be justified and the differences between local and test species in their sensitivity to COPCs discussed. Samples from reference locations are required to identify impacts due to COPCs present at the site, and these locations need to be carefully selected.

STANDARDIZED TOXICITY TESTS

Examples of standardized toxicity tests for surface soil, sediment, and surface water are, respectively, as follows:

- American Society for Testing and Materials (ASTM) E 1676-97, Standard guide for conducting laboratory soil toxicity or bioaccumulation tests with the Lumbricid earthworm, *Eisenia fetida* (ASTM 1998);
- EPA Test Method 100.0, *Hyalella azteca* 10-day survival test for sediments (EPA 1994a); and
- Fathead minnow, *Pimephales promelas*, larval survival and growth test, EPA Method 1000.0 (EPA 1994b).

PGDP ERA Rule 6—For the study design for PGDP sites with endpoint receptors exposed by direct contact to COPCs, include *in situ* or laboratory toxicity tests.

Laboratory tests indicate whether the media collected from the site cause toxicity to the test organisms and quantify the magnitude of the toxic effect relative to media from reference locations. Screening toxicity tests do not produce definitive benchmark concentrations associated with specific levels of adverse effects. Screening toxicity tests are considered to be chronic tests (EPA 1994a; EPA 1994b; ASTM 1998), and test durations are believed to be sufficiently long for adverse effects on sensitive life stages to be observed at concentrations exceeding ecological screening values (ESVs).

The measurement endpoints in toxicity tests used in PGDP ERAs will typically be survival, reproduction, growth, emergence, or combinations of these endpoints. Survival and reproduction are the primary effects of interest because they are directly related to the assessment endpoints, which are stated in terms of survival of the population and survival of individuals, in the case of T&E species. Reduced growth as a result of chronic exposure to contaminants can have ecological significance in some circumstances, such as when a population experiences severe size-based predation pressure or when overwinter survival depends on achieving a certain pre-winter size. Growth effects indicate only the possibility of adverse effects on a population, so toxicity tests with growth as the only measurement endpoint must be carefully justified. Likewise, emergence is an indirect measure of potential adverse effects on a population (e.g., aquatic insects). Because reduced emergence potentially leads to reduced survival and population size, reliance on emergence as the only measurement endpoint must be justified.

Using toxicity tests as a line of evidence in the risk characterization for PGDP sites assumes three things:

- Effects observed in laboratory tests of site media using surrogate species, beyond those observed in tests of reference site media, will represent effects on assessment endpoints occurring at the site.

- The substances responsible for any observed toxicity above reference site levels are those COPCs present at concentrations above reference site levels and above benchmarks associated with adverse effects.

- Effects on the test species are caused by contaminants in the tested medium and not artifacts of the test conditions or test organisms.

If these assumptions make toxicity tests unacceptable to risk managers as a basis for remedial decisions, then toxicity tests should not be selected, and population/community studies must be designed to answer the risk questions.

Population/Community Measures. If ERAs at PGDP sites require population/community studies to evaluate effects of COPCs on receptors, then the work plan must provide a detailed description and justification of the study. The EPA DQO process should be implemented (EPA 2000b; DOE 1993b). Preliminary data on population variability, both temporally and spatially, is a prerequisite to establishing DQOs for population studies. Standardized methods of evaluating whether benthic invertebrate communities and fish have been impacted are available, but these methods do not define the cause of the impacts (EPA 1990). Therefore, careful selection of metrics and reference sites is required to ensure that the results of population/community studies will answer the risk questions.

2.4.1 DQO Process

According to the EPA process document, Steps 3 and 4 of the eight-step ERA process comprise the DQO process (EPA 1997a). The final COPCs, the nature of their effects on biota, the exposure pathways, the assessment endpoints, questions to be answered, and the measurements to be used to answer the ERA

questions define the data requirements for the site investigation. The study design, approved at the Step 4 SMDP, defines the acceptable level of decision error. Guidance for sampling design is available from EPA, Kentucky state agencies, and the U.S. Geological Survey. The basic elements of the DQO process are described in EPA's *Guidance for the Data Quality Objectives Process* (EPA 2000b).

2.4.2 Uncertainties of Step 4

The uncertainties in Step 4 of the ERA process relate to the efficacy of the study as designed to answer the risk questions. Tests can confirm or deny toxicity from site media in excess of the reference site, but uncertainty remains about the ecological significance of observed levels of effect. Natural variability makes short-term field studies of effects difficult to interpret. Most native species are difficult to rear successfully in the laboratory, and laboratory test species may not be as sensitive to contaminants as are native species. Site-specific tissue concentration data reduce the uncertainty associated with modeling uptake and bioaccumulation. Accurate site-specific exposure parameters, such as ingestion rates and foraging areas, are also difficult to obtain, so there is uncertainty about risk estimates even when exposure estimates are based on site-specific tissue concentration data. Multiple lines of evidence are useful and recommended for reducing the uncertainty of ERAs at PGDP sites.

2.4.3 Use of Step 4

The work plan, including the SAP and quality assurance/quality control plan, for PGDP sites must prescribe the site investigation required to complete the ERA and answer the risk questions. The numbers and types of measurements specified in the work plan are made according to the procedures detailed in the SAP. The work plan should describe precisely how the resulting data will be used in the risk characterization for the site and will constitute the basis for a conclusion about risk at the site. Approval of the work plan at the Step 4 SMDP signifies that the proposed field investigation design and methods provide acceptable data and levels of decision error to support the risk management decisions for the site.

2.4.4 Reporting Step 4

The ERA work plan and its appendices are the expected mechanism for recording and seeking approval of the DQOs and study design for the site investigation. The methods for collecting and controlling samples for toxicity tests and analytical chemistry are described in the RI work plan and field sampling plan for the site. The work plan 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, and
- a description of how the results of site investigations will be used in the risk characterization (Step 7) to answer risk questions.

Neither the ERAWG nor EPA has specific requirements about the timing of the document other than it must follow Steps 1 through 3 and precede the ecological site investigation (EPA 1997a).

2.5 VERIFICATION OF FIELD SAMPLING DESIGN (STEP 5)

Verification of Field Sampling Design, Step 5 of the ERA process, evaluates the probability of successfully completing the study as designed. In this step, measurement endpoints are evaluated for

appropriateness and implementability. The work plan or SAP for the ERA should describe the methods for verifying the study design. A memorandum from the ecological risk assessor to the risk manager should describe the outcome of the verification. If the design is verified, then the risk manager must approve the site investigation. If the design cannot be verified, the memorandum should describe the revised study design and how it was verified. The verification process and any remaining uncertainties about the study design should be discussed when the results of the site investigation are reported.

2.6 SITE INVESTIGATION AND DATA ANALYSIS (STEP 6)

Site Investigation and Data Analysis, Step 6 of the ERA process, is the implementation of the site investigation designed in Step 4 and verified in Step 5. An SMDP during or following the site investigation and data analysis is only required if changes to the SAP are required following approval of the work plan. Approved alterations in the work plan for PGDP sites are documented in the report containing the risk characterization (i.e., the baseline ERA report).

2.7 RISK CHARACTERIZATION (STEP 7)

Risk Characterization, Step 7 of the ERA process, 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.

2.7.1 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 are abiotic medium and tissue concentration data, toxicity test results, and population/community data.

The weight given to the different lines of evidence is established in the DQOs (Step 4); thus, the inferences made from the measurements are briefly described in Step 7. Factors confounding the results of the site investigation should be discussed. Any alterations to the study design during Field Verification (Step 5) and Site Investigation (Step 6) should be described.

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 the HQ equations (Appendix C) with appropriate exposure estimates and TRVs. In Step 7, the full range of risk estimates can be provided by calculating HQs using the central tendency and maximum tissue concentrations to estimate exposure and TRVs associated with a range of adverse effect from NOAELs to LOAELs.

ERAs for PGDP sites will not present only probabilistic estimates of exposure; point estimates are required. The ERAWG concurs that probabilistic methods of quantifying risk are expected to be of limited value for ERAs at PGDP sites because adequate data are typically lacking. If sufficient data exist to calculate probabilistic risk estimates, they can be reported and used in PGDP ERAs to address the uncertainty of point estimates of risk. ERAs presenting probabilistic risk estimates must have an approved work plan and include the documentation specified in EPA guidance on probabilistic risk assessments (EPA 1997b).

2.7.2 Risk Description

For PGDP ERAs, 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. EPA indicates that the range of potential effects be bounded by threshold concentrations associated with no effect and probable effect (EPA 1997a). As discussed in Steps 1 and 2, PGDP NFA levels bound the range at the lower end for receptors exposed by direct contact. Lower bound threshold concentrations for wildlife receptors are calculated using the conservative assumptions used to calculate preliminary HQs in Step 3a. All site-specific parameter values used to calculate HQs must be described and the source of the values identified. The HQ equations (Appendix C) can be used to calculate threshold concentrations by setting the HQ equal to 1 [average daily dose (ADD) = TRV] and solving for the medium concentration.

ERAs for PGDP sites should include estimates for the upper bound on the threshold concentrations for adverse ecological effects, i.e., those concentrations in environmental media that are associated with a probable effect (EPA 1997a). These upper-bound threshold concentrations are calculated using the site-specific exposure assumptions identified in Step 3a, Reevaluation of COPCs, and toxicity benchmarks associated with potential adverse effects on test species (e.g., LOAELs). Upper-bound thresholds must be calculated on a site-specific basis and presented in the ERA report.

2.7.3 Step 7 Uncertainties

At Step 7 of the ERA process for PGDP sites, 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. Uncertainty will, however, remain at the risk characterization step. The actual cause of observed toxicity and reductions in populations may be unknown, and the actual expected level of exposure of wildlife receptors to contaminated site media may be inaccurate or imprecise. Nevertheless, if the DQOs for the site investigation were achieved, risk managers should have sufficient confidence in the conclusions of the ERA to make a risk management decision.

2.7.4 Use of Step 7

The risk characterization provides information to judge the ecological significance of the estimated risk to assessment endpoints in the absence of any remedial action. In the final step of the EPA eight-step ERA process, risk managers use the results of the risk characterization and the conclusions of the professional ecological risk assessor to determine whether remedial action is required.

2.7.5 Reporting Step 7

Step 7 of the ERA process for PGDP sites is reported in the ERA, which may be included in the RI/FS, or as a separate document. Neither the ERAWG nor EPA has specific requirements about the timing of the document, other than it must follow Steps 1 through 6 (EPA 1997a).

2.8 RISK MANAGEMENT (STEP 8)

Step 8 of the ERA process is Risk Management. The role of ecological risk assessors in Step 8 for PGDP sites is to advise risk managers during the final SMDP. EPA provides additional guidance on risk management (EPA 1999b). If the risk characterization (Step 7) concludes there is risk to ecological receptors, the risk management decision is whether to remediate the site or to leave contaminants of concern (COCs) in place with controls on exposure and monitoring. This decision can be documented in

the ERA report. If the risk assessment concludes there is no risk to ecological receptors, then the results of the ERA can be summarized in the decision documents, justifying no further evaluation or other actions to address ecological risk. If the ecological assessment concludes that there is unacceptable risk, then the ecological risk assessors continue to provide input as part of the decision making process. If the risk managers conclude there is unacceptable risk, then ecological risk assessors continue to provide input to risk management decisions following the completion of the RI.

2.9 SUMMARY OF ERA PROCESS

The ERA process for PGDP sites includes up to eight steps and five SMDPs. Several documents report the results of these steps and the decisions made by risk managers at the SMDPs. Decisions whether to continue the ERA process occur after the screening-level ERA (Steps 1 and 2) and again after Step 3, Problem Formulation. The ecological risk assessment input (Step 8) to the risk management decision to remediate the site should occur after the risk characterization (Step 7).. Ecological risk assessors for PGDP sites continue to support the risk management decision making process by providing input to decision documents.

3. INPUT TO DECISION DOCUMENTS

Ecological risk assessors should provide input to CERCLA and RCRA decision documents for sites with ecological resources. This input includes summaries of ERAs and screenings; evaluations of the adverse effects on habitats, ecological receptors, and the effectiveness of proposed exposure controls; and the requirements of monitoring plans. Decision documents and documents supporting the selection of response actions include FSs, proposed plans, records of decision (RODs), their corresponding RCRA documents, and other remedy selection decision documents, such as those documenting NFA decisions, engineering evaluation/cost assessments, and site management plans (EPA 1999c). Ecological risk analyses for, and inputs to, FSs, NFA decision documents, proposed plans, RODs, and 5-year review documents are discussed in the following subsections.

3.1 FEASIBILITY STUDY

The FS for a PGDP site requires input from ecological risk assessors. Typically, the FS for a PGDP site will include a summary of the findings of the ERA for the site, TCLs for COCs identified in the ERA for the site, and qualitative evaluation of impacts on ecological resources and effectiveness of alternative response actions.

Site-specific TCLs should be derived in the FS for each site considered for remedial action. TCLs for PGDP sites should be reported in the FS for the site, as well as later decision documents. Ecological TCLs for sites having an ERA are typically the highest concentration of a substance in an environmental medium that is protective of assessment endpoints. The assumptions and data used to derive cleanup levels must be justified in the FS. If an FS is produced for sites that have been selected for remedial action before an ERA, then the ecological TCLs for the site should be reported as part of the development of remedial goal options in the FS, and the assumptions and data used to derive them should be discussed.

Until PGDP develops a substantial body of relevant published and site-specific data on natural attenuation, degradation should not be included in the calculation of cleanup goals. Radioactive decay, on the other hand, should be considered when developing cleanup goals for radionuclides at PGDP sites.

The detailed evaluation of alternative response actions in the FS for PGDP sites with ecological COCs should include a qualitative evaluation of impacts on ecological resources. Impacts on the ERA assessment endpoints must be evaluated so that risk managers will be able to compare, on an equivalent basis, the risks of cleanup alternatives and the NFA alternative. Ecological resources that are not assessment endpoints but which are potentially impacted by response actions also must be evaluated. Evaluating all identifiable impacts to all ecological resources for each alternative will allow those alternatives to be compared.

3.2 NO FURTHER ACTION DECISION DOCUMENTS

NFA decision documents will generally require a summary of site risks. Two of the three CERCLA NFA decision documents identified by EPA guidance on RODs require risk summaries: those where remedial action is not necessary for protection because there is no risk and those where no action is necessary because previous response actions at the site have reduced or eliminated risk (EPA 1999c). According to EPA, NFA decision documents for sites where there is “No CERCLA authority to take action” do not include a summary of site risks (EPA 1999c).

The summary of site risks in NFA decision documents must include a summary of risks to ecological receptors. The summary should provide sufficient information to support the determination that no remedial action is needed to ensure protection of ecological receptors. The summary should explain the basis for concluding that ecological receptors will not experience unacceptable exposures to, and effects from, hazardous substances. The summary should correlate with current and potential future site conditions and uses of resources at the site.

3.3 PROPOSED PLAN

Proposed plans for PGDP sites and the equivalent for early actions should include a summary of the ecological risk findings (EPA 1999c). The proposed plan facilitates public involvement in the remedy selection process. Among other things, the document explains the reasons why the lead agency recommends the preferred alternative for addressing contamination at the site. A major section of the plan is the Summary of Site Risks, including risks to the environment (i.e., ecological risk).

The Summary of Site Risks section of the proposed plan for PGDP sites should provide a brief, descriptive narrative summary regarding the nature and extent of risk to ecological receptors. The proposed plan is targeted to the general public. Therefore, the proposed plan should not include extensive tables of risk calculations, which are more appropriate to the ROD. If ecological risks are a basis for the selected remedy at a PGDP site, then the proposed plan should include streamlined risk summary tables like those suggested by EPA (1999c) (Appendix D).

The summary of the ERA in the proposed plan for PGDP sites should include the following:

- Ecological COCs in each medium,
- Current and reasonably anticipated future habitats and land use,
- Assessment endpoints,
- Exposure pathways for ecological receptors, and
- Summary of risk characterization.

The summary of the risk characterization should address the basis for the conclusions concerning ecological risk for receptors exposed to each medium and the potential for risk to T&E species.

For sites that have been selected for remedial action before an ERA is conducted, site-specific TCLs should be reported in the proposed plan or ROD for the site. TCLs must be conservative estimates of concentrations in environmental media that will protect all or most ecological receptors potentially exposed at the site. Site-specific TCLs may be larger than the corresponding PGDP NFA values. PGDP NFA values are not site-specific and, therefore, must be sufficiently conservative to protect all potential receptors at PGDP sites. Site-specific TCL values may be based on a more limited set of receptors, and more sensitive receptors protected by NFA values may not occur at the site.

3.4 RECORD OF DECISION

The Summary of Site Risks section of RODs for PGDP sites should include a summary of risks to ecological receptors (EPA 1999c). The ROD should summarize the ERA at an appropriate level of detail for the complexity of the site and the risks identified. Each of the eight steps of the ERA process for PGDP sites should be summarized.

The summary of the ERA in RODs for PGDP sites will contain tables of risk assessment parameters and results. The summary of the screening-level risk assessment (Steps 1 and 2) should include tables of screening-level benchmarks (PGDP NFA levels) and COPCs identified in the screen. Tables of site concentrations (range, mean, and 95% UCLs) should be included in support of the summary of Steps 1 through 3. Tables clearly summarizing preliminary HQs, TRVs, alternative benchmarks, relevant site-specific exposure parameters and effects data, and the conclusions of the reevaluation of COPCs (Step 3a) should be included in the ROD. The summary of the problem formulation should include, as tables or text, brief descriptions of site habitats, the CSM, exposure pathways, assessment endpoints, and the basis for their selection. The types, number, and DQOs of samples and analyses for the site investigations conducted to answer ecological risk questions should be summarized. Tables of results of site-specific studies on effects (e.g., toxicity tests) and risk calculations based on site-specific tissue concentration data will support the summary of the risk characterization.

When calculating residual risks for a group of units, there is no need to include calculations for units previously agreed to be NFA based upon an approved risk assessment (or alternative calculation, such as a screening assessment); however, the documentation should include by reference the NFA site's risk results.

The site-specific TCLs for ecological receptors at a PGDP site should be reported in the ROD as well as in the FS and proposed plan for the site. For sites that have been selected for remedial action before an ERA, these TCLs will be conservative estimates of concentrations of substances present in environmental media that will protect ecological receptors potentially exposed at the site. As discussed above for proposed plans, TCLs are often equal to PGDP screening NFA values, but also may be higher than NFA values.

Input from ecological risk assessors to monitoring plans will be required if RODs for PGDP sites with ecological risk specify monitoring as part of the selected response action. The monitoring required to address ecological risk must address the assessment endpoints and risk questions selected in Step 3 of the ERA process. The work plan for monitoring programs should repeat PGDP ERA Step 4, Study Design and DQO Process, to ensure that the measurements will answer the risk questions being addressed by the monitoring with sufficient confidence to support risk management decisions during 5-year reviews.

3.5 FIVE-YEAR REVIEW

According to EPA and DOE guidance, 5-year reviews at PGDP sites should identify, collect, and compile the necessary information and data to determine whether remedies continue to be fully protective of human health and the environment (EPA 1999c; DOE 2001). For PGDP sites remediated under CERCLA authorities and monitored under the DOE's Long-Term Stewardship Program, information and data collected to assess remedy performance will be based primarily on monitoring requirements established during the implementation and closeout phases of the CERCLA process. In general, these data will be collected under the auspices of the stewardship program and the five-year review requirement incorporated into this program as a reporting tool.

According to DOE, five-year reviews at PGDP sites will include the following actions

- Evaluate whether the remedy is operational and functional;

- Evaluate those assumptions critical to the effectiveness of remedial measures or the protection of human health and the environment (made at the time of the remedial decision) to determine, given current information, whether these assumptions are still valid;

- Determine whether “fixes” are required to address any identified deficiencies; and

- Evaluate whether there are opportunities to optimize the long-term performance of the remedy or reduce life-cycle costs.

Each of these four review activities must consider ecological risk at the site. An evaluation of those parameters established as appropriate indicators of performance at the site serves as the basis for the determination of whether remedies are operational and functional. Performance indicators, therefore, must include measures relevant to the exposure of ecological receptors identified in the ERA as being at risk from COCs in one or more medium at the site.

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APPENDIX A

PGDP NO FURTHER ACTION LEVELS

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PGDP NO FURTHER ACTION LEVELS

No Further Action (NFA) levels for chemicals are concentrations in abiotic media used to screen constituents detected at a site to identify those constituents that require further evaluation [i.e., chemicals of potential concern (COPCs)]. NFA levels are generally conservative estimates of chemical concentrations that will not adversely affect ecological receptors with high probability. NFA levels are not necessarily acceptable cleanup goals because of their potentially extreme conservatism.

The NFA level for radionuclides is a threshold "no effect" dose. The threshold dose is for the combined exposure to all radionuclides present at a site. NFA levels cannot be derived for individual radionuclides unless a relative abundance of radionuclides is specified and the relative abundance of radionuclides is a site-specific property. For any specified distribution of radionuclides at a site, NFA levels resulting in the threshold dose can be derived using DOE Standard 1153-2002 (DOE 2002) and the associated RESRAD-BIOTA software (available at http://web.ead.anl.gov/resrad/home2/biota.cfm).

NFA levels for soil, sediment, and surface water are provided for a limited number of chemical constituents. The available NFA levels come from various sources, which were identified and unanimously agreed upon by the members of the Ecological Risk Assessment Working Group (ERAWG). Representatives of Kentucky Department for Environmental Protection (KDEP), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy developed the hierarchy of sources and the selected values. The agreed-upon NFA levels are briefly described here.

The ERAWG agreed that for PGDP ecological risk assessment (ERA) substances that potentially bioaccumulate will be considered in Step 3 of the ERA, whether or not they exceed NFA levels. As part of Step 3a, these substances that bioaccumulate will be evaluated through food-chain modeling. The list of substances that bioaccumulate is based on the list developed for the Great Lakes Water Quality Initiative. The list of substances that bioaccumulate for PGDP appears in Table A.1. NFA levels are based on the risk to organisms that are exposed to single constituents by direct contact with the medium. NFA levels do not protect receptors potentially exposed by ingestion to substances that have accumulated in the tissue of their food items. The presence of substances that bioaccumulate is not sufficient to trigger Step 3 of the ERA process for PGDP sites, but these substances should be considered if the ERA proceeds to Step 3.

Soil NFA levels—The soil NFA levels for chemicals (Table A.2) are selected based on the following hierarchy:

1. EPA Eco-SSLs;

2. EPA Region 4 screening values for soil;

3. Values selected from among KDEP screening values, LANL soil screening values (minimum ESL), Oak Ridge soil screening values, and values in EPA's Hazardous Waste Combustor Guidance based on professional judgement.

The NFA value for any particular chemical may be chosen from a lower tier if the value from the higher tier is not appropriate for use at PGDP. Chemicals for which a lower tier value was selected over a value available from a higher tier are footnoted with the rationale for the selection. The source for each value is noted in the screening table next to the value.

The soil NFA levels for radionuclides (Table A.3) are calculated from the NFA dose. The ERAWG consensus NFA dose for receptors exposed to radionuclides in PGDP soil is 0.1 rad/day, which is the recommended National Council on Radiation Protection (NCRP) threshold dose for soil invertebrates (1 rad/day) times a safety factor of 0.1 (NCRP 1991). In lieu of site-specific radionuclide relative abundance data, the PGDP NFA levels for soil are radionuclide soil-screening benchmarks for terrestrial plants and animals using RESRAD-BIOTA, Version 1.21, for soil for the terrestrial animal and plant receptors with the default dose adjusted to the ERAWG consensus value of 0.1 rad/day. The calculated PGDP soil NFA levels for radionuclides are used in the same way as soil NFA levels for chemicals.

Sediment NFA levels—The sediment NFA levels (Table A.4) for chemicals come from the following hierarchy of sources:

1. EPA Region 4 values and

2. Values selected from among KDEP screening values, Oak Ridge sediment screening values, consensus TECs, and values in EPA's Hazardous Waste Combustor Guidance based on professional judgment

The ERAWG consensus NFA dose for receptors exposed to radionuclides in the aquatic environment is 0.1 rad/day. The sediment NFA levels for radionuclides are calculated from the NFA dose (Table A.5). The ERAWG consensus NFA dose for receptors exposed to radionuclides in PGDP sediment is 0.1 rad/day, which is the recommended NCRP threshold dose for aquatic receptors (1 rad/day) times a safety factor of 0.1 (NCRP 1991). In lieu of site-specific radionuclide relative abundance data, the PGDP NFA levels for sediment are generated using RESRAD-BIOTA, Version 1.21, for sediment for the aquatic and riparian animal receptors with the default dose adjusted to the ERAWG consensus value of 0.1 rad/day. The calculated PGDP sediment NFA levels for radionuclides are used in the same way as sediment NFA levels for chemicals.

Surface water NFA levels—The surface water NFA levels (Table A.6) come from the following hierarchy of sources:

1. The Kentucky Warm Water Aquatic Habitat criterion

2. The federal NRWQC chronic CCC

3. EPA Region 4 values

4. Values selected from among KDEP screening values, Oak Ridge surface water screening values, and values in EPA's Hazardous Waste Combustor Guidance based on professional judgement

The surface water NFA levels for radionuclides are calculated from the NFA dose (Table A.7). The ERAWG consensus NFA dose for receptors exposed to radionuclides in PGDP surface water is 0.1 rad/day, which is the recommended NCRP threshold dose for aquatic receptors (1 rad/day) times a safety factor of 0.1 (NCRP 1991). In lieu of site-specific radionuclide relative abundance data, the PGDP NFA levels for surface water are generated using RESRAD-BIOTA, Version 1.21, for surface water for the riparian animal receptor with the default dose adjusted to the ERAWG consensus value of 0.1 rad/day to correspond to PGDP surface water NFA radiological doses of 0.1 rad/day. The radionuclide screening benchmarks are derived for parent isotopes and all short-lived daughter products using the radionuclide exposure model of Blaylock *et al.* (1993), thus, including internal and external exposures from all major alpha, beta, and gamma emissions for each isotope. Screening benchmarks for small fish are used because vertebrates are thought to be more sensitive than invertebrates (NCRP 1991). The calculated PGDP

surface water NFA levels for radionuclides are used in the same way as surface water NFA levels for chemicals.

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Table A.1 List of Substances that Bioaccumulate[1]

Chemical Class	Chemical
Metals	Mercury
Dioxins/Furans	2,3,7,8-TCDD
	2,3,7,8-TCDF
Semivolatile Organics	1,2,4,5-Tetrachlorobenzene
	Hexachlorobenzene
	Hexachlorobutadiene
	Hexachlorocyclohexane
	Pentachlorobenzene
Pesticides/PCBs	4,4'-DDD
	4,4'-DDE
	4,4'-DDT
	Alpha-BHC
	Beta-BHC
	Delta-BHC
	Gamma-BHC
	Alpha-Chlordane
	Chlordane
	Gamma-Chlordane
	Aroclor-1016
	Aroclor-1221
	Aroclor-1232
	Aroclor-1242
	Aroclor-1248

Table A.1 List of Substances that Bioaccumulate[1] (Continued)

Chemical Class	Chemical
	Aroclor-1254
	Aroclor-1260
	Polychlorinated biphenyls (PCBs)
	Dieldrin
	Toxaphene

[1] Source July 8, 2008 email from Brett Thomas, Region 4

Table A.2. PGDP Soil NFA Screening Values

Analyte	PGDP NFA Screening Value (mg/kg)	Source for Screening Value
Inorganics		
Aluminum	**If soil pH is less than 5.5, use 50; otherwise no evaluation needed**	**Eco-SSL; EPA Region 4**
Antimony	**0.27**	**Eco-SSL**
Arsenic	**18**	**Eco-SSL**
Barium	**330**	**Eco-SSL**
Beryllium[a]	**2.5**	**LANL ESL**
Boron	0.5	**EPA Region 4**
Cadmium	**0.36**	**Eco-SSL**
Chromium (III)	26	**Eco-SSL**
Chromium (VI)	**130**	**Eco-SSL**
Chromium (total)	**0.4**	**EPA Region 4**
Cobalt	**13**	**Eco-SSL**
Copper	**28**	**Eco-SSL**
Iron	**200**	**EPA Region 4**
Lanthanum	50	**EPA Region 4**
Lead	**11**	**Eco-SSL**
Lithium	2	**EPA Region 4**
Manganese	**220**	**Eco-SSL**
Mercury	0.1	**EPA Region 4**
Molybdenum	2	**EPA Region 4**
Nickel	**38**	**Eco-SSL**
Selenium	**0.52**	**Eco-SSL**
Silver	**4.2**	**Eco-SSL**
Technetium	0.2	**EPA Region 4**
Thallium	1	**EPA Region 4**
Tin	**53**	**EPA Region 4**
Titanium	1,000	**EPA Region 4**
Tungsten	400	**EPA Region 4**
Uranium	5	**EPA Region 4**
Vanadium	7.8	**Eco-SSL**
Zinc	**46**	**Eco-SSL**
Mineral pollutants		
Bromine	10	**EPA Region 4**
Cyanide, complex	5	**EPA Region 4**
Cyanide, free	0.9	**EPA Region 4**

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Table A.2. PGDP Soil NFA Screening Values (Continued)

Analyte	PGDP NFA Screening Value (mg/kg)	Source for Screening Value
Fluorine	30	**EPA Region 4**
Iodine	4	**EPA Region 4**
Sulfur	2	**EPA Region 4**
Thiocyanates	2	**EPA Region 4**
Aromatic hydrocarbons		
Benzene	0.05	**EPA Region 4**
Biphenyl	60	**EPA Region 4**
Ethylbenzene	0.05	**EPA Region 4**
Toluene	0.05	**EPA Region 4**
Xylene	0.05	**EPA Region 4**
Total cyclic aromatic hydrocarbons	0.1	**EPA Region 4**
Phenolic compounds		
2,3,4,5-Tetrachlorophenol	20	**EPA Region 4**
2,4,5-Trichlorophenol	4	**EPA Region 4**
2,4,6-Trichlorophenol	10	**EPA Region 4**
2,4-Dinitrophenol	20	**EPA Region 4**
3,4-Dichlorophenol	20	**EPA Region 4**
3-Chlorophenol	7	EPA Region 4
4-Nitrophenol	7	EPA Region 4
Chlorophenol	0.01	EPA Region 4
Dichlorophenols (total)	0.003	EPA Region 4
Monochlorophenols (total)	0.0025	EPA Region 4
Pentachlorophenol	2.1	Eco-SSL
Phenol	0.05	EPA Region 4
Tetrachlorophenols (total)	0.001	EPA Region 4
Trichlorophenols (total)	0.001	EPA Region 4
Polycyclic aromatic hydrocarbons		
Acenaphthene	20	EPA Region 4
LMW PAHs	29	Eco-SSL
HMW PAHs	1.1	Eco-SSL
Substituted hydrocarbons		
Carbon tetrachloride	**1,000**	EPA Region 4
1,2-Dichloroethane	0.4	EPA Region 4
1,2-Dichloropropane	700	EPA Region 4
2,3,5,6-Tetrachloroaniline	20	EPA Region 4
2,4,5-Trichloraniline	20	EPA Region 4

Table A.2. PGDP Soil NFA Screening Values (Continued)

Analyte	PGDP NFA Screening Value (mg/kg)	Source for Screening Value
2,4-Dichloroaniline	100	EPA Region 4
3,4-Dichloroaniline	20	EPA Region 4
3-Chloroaniline	20	EPA Region 4
Aliphatic chlorinated hydrocarbons (total)	0.1	EPA Region 4
Chlorinated hydrocarbons (total)	0.1	EPA Region 4
Chloroacetamide	2	EPA Region 4
Chlorobenzene	0.05	EPA Region 4
Chloroform	0.001	EPA Region 4
cis-1,4-dichloro-2-butene	1000	EPA Region 4
Dichlorobenzene	0.01	EPA Region 4
Dichloromethane	2	EPA Region 4
Hexachlorobenzene	0.0025	EPA Region 4
Hexachlorocyclopentadiene	10	EPA Region 4
Nitrobenzene	40	EPA Region 4
N-nitrosodiphenylamine	20	EPA Region 4
PCBs (total)	0.02	EPA Region 4
Pentachloroaniline	100	EPA Region 4
Pentachlorobenzene	0.0025	EPA Region 4
Polycyclic chlorinated hydrocarbons (total)	0.1	EPA Region 4
Tetrachlorobenzene	0.01	EPA Region 4
Tetrachloroethylene	0.01	EPA Region 4
trans-1,4-Dichloro-2-butene	1000	EPA Region 4
Trichlorobenzene	0.01	EPA Region 4
Trichloroethylene	0.001	EPA Region 4
Vinyl chloride	0.01	EPA Region 4
Pesticides		
Sum of 4,4'-DDT/4,4'-DDD/4,4'-DDE	0.021	Eco-SSL
Aldrin	0.0025	EPA Region 4
Atrazine	0.00005	EPA Region 4
BHC, alpha	0.0025	EPA Region 4
BHC, beta	0.001	EPA Region 4
Carbaryl	0.5	EPA Region 4
Carbofuran	0.2	EPA Region 4
Dieldrin	0.0049	Eco-SSL
Endrin	0.001	EPA Region 4

Table A.2. PGDP Soil NFA Screening Values (Continued)

	Analyte	PGDP NFA Screening Value (mg/kg)	Source for Screening Value
	gamma-BHC (lindane)	0.00005	EPA Region 4
	Maneb	3.5	EPA Region 4
	Organochlorinated pesticides (total)	0.1	EPA Region 4
	Total pesticides	0.1	EPA Region 4
Other pollutants			
	Acrylonitrile	1,000	EPA Region 4
	Catechol	20	EPA Region 4
	Cresols[b]	0.5	EPA Region 4
	Cyclohexane	0.1	EPA Region 4
	Diethylphthalate	100	EPA Region 4
	Dimethylphthalate	200	EPA Region 4
	Di-n-butylphthalate	200	EPA Region 4
	Ethylene glycol	97	EPA Region 4
	Furan	600	EPA Region 4
	Phthalates (total)	0.1	EPA Region 4
	Pyridine	0.1	EPA Region 4
	Styrene	0.1	EPA Region 4
	Tetrahydrofuran	0.1	EPA Region 4
	Tetrahydrothiophene	0.1	EPA Region 4

[a]Eco-SSL for beryllium was reviewed but lower LANL value which considers toxicity to plants was considered more appropriate for PGDP screening.
BHC = benzene hexachloride
DDT = dichlorodiphenyl trichloroethane
HMW=high molecular weight
LMW=low molecular weight
mg/kg = milligrams per kilograms
NFA = No Further Action
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant

Table A.3 PGDP Soil NFA Screening Values for Radionuclides

Radionuclide	NFA (pCi/g soil)
Americium-241	2.16E+03
Cesium-137	2.08E+01
Cobalt-60	6.13E+02
Neptunium-237	8.14E+02
Plutonium-238	5.27E+03
Plutonium-239	1.27E+03
Plutonium-240	1.27E+03
Technetium-99	2.19E+03
Thorium-230	9.98E+03
Uranium-234	5.13E+03
Uranium-235	2.75E+03
Uranium-238	1.57E+03

NFA = activity (pCi/g) resulting in dose of 0.1 rad/day assuming secular equilibrium of parent and daughter products.
NFA values from RESRAD-BIOTA, Version 1.21, Report for Level 2 (default values except dose for plant adjusted to 0.1 rad/day)
pCi/g = picocuries per gram

Table A.4. PGDP Sediment NFA Screening Values

	Analyte	PGDP NFA Screening Value	Units	Source for Screening Value
Inorganics				
	Aluminum	25,000	mg/kg	KDEP[a]
	Antimony	12	mg/kg	EPA Region 4[b]
	Arsenic	7.24	mg/kg	EPA Region 4
	Cadmium	1	mg/kg	EPA Region 4
	Chromium	52.3	mg/kg	EPA Region 4
	Cobalt	50	mg/kg	KDEP
	Copper	18.7	mg/kg	EPA Region 4
	Iron	200[b]	mg/kg	KDEP
	Lead	30.2	mg/kg	EPA Region 4
	Manganese	1,673	mg/kg	Oak Ridge[c]
	Mercury	0.13	mg/kg	EPA Region 4
	Methylmercury	0.0000245	mg/kg	KDEP
	Nickel	15.9	mg/kg	EPA Region 4
	Selenium	0.1	mg/kg	EPA Haz[d]
	Silver	2	mg/kg	EPA Region 4
	Vanadium	0.2	mg/kg	KDEP
	Zinc	124	mg/kg	EPA Region 4
Organic compounds				
	Anthracene	57.2	µg/kg	TEC[e]
	Acenaphthene	6.7	µg/kg	EPA Region 4
	Acetone	453	µg/kg	KDEP
	Benzene	57	µg/kg	KDEP
	Benzo(a)anthracene	108	µg/kg	TEC
	Benzo(a)pyrene	150	µg/kg	TEC
	Benzo(k)fluoranthene	655	µg/kg	KDEP
	Benzo(b)fluoranthene	655	µg/kg	KDEP
	Bis(2-ethylhexyl)phthalate	182	µg/kg	EPA Region 4
	Carbon disulfide	134	µg/kg	KDEP
	Carbon tetrachloride	35.7	µg/kg	KDEP
	Chlordane	1.7	µg/kg	EPA Region 4
	Chloroform	27	µg/kg	KDEP

Table A.4 PGDP Sediment NFA Screening Values (Continued)

Analyte	PGDP NFA Screening Value	Units	Source for Screening Value
Chrysene	57.1	µg/kg	KDEP
4,4'-DDD	3.3	µg/kg	EPA Region 4
4,4'-DDE	3.3	µg/kg	EPA Region 4
4,4'-DDT	3.3	µg/kg	EPA Region 4
Total 4,4'-DDT	3.3	µg/kg	EPA Region 4
Diazinon	1.9	µg/kg	KDEP
Dibenzo(a,h)anthracene	33	µg/kg	TEC
1,2-Dichlorobenzene	50	µg/kg	KDEP
1,3-Dichlorobenzene	170	µg/kg	KDEP
1,4-Dichlorobenzene	12	µg/kg	KDEP
1,1-Dichloroethane	0.1	µg/kg	KDEP
1,2-Dichloroethane	54.2	µg/kg	KDEP
1,1-Dichloroethene	23.3	µg/kg	KDEP
Dieldrin	3.3	µg/kg	EPA Region 4
Diethylphthalate	61	µg/kg	KDEP
Dioxins, total equivalent	0.0025	µg/kg	EPA Region 4
Endrin	3.3	µg/kg	EPA Region 4
Endosulfan (mixed)	0.0358	µg/kg	KDEP
Ethylbenzene	3,600	µg/kg	KDEP
Fluoranthene	42.3	µg/kg	TEC
Fluorene	77.4	µg/kg	TEC
gamma-BHC (Lindane)	3.3	µg/kg	EPA Region 4
Heptachlor epoxide	2.47	µg/kg	TEC

Table A.4 PGDP Sediment NFA Screening Values (Continued)

Analyte	PGDP NFA Screening Value	Units	Source for Screening Value
Indeno(1,2,3-cd)pyrene	655	µg/kg	KDEP
Malathion	6.7	µg/kg	EPA Region 4
Naphthalene	176	µg/kg	TEC
Phenanthrene	204	µg/kg	TEC
Total PAHs	1,680	µg/kg	EPA Region 4
Total PCBs	33	µg/kg	EPA Region 4
Pyrene	53	µg/kg	KDEP
Tetrachloroethene	32	µg/kg	KDEP
Toluene	500	µg/kg	KDEP
Toxaphene	2.2	µg/kg	KDEP
Toxaphene	2.2	µg/kg	KDEP
1,1,1-Trichloroethane	96	µg/kg	KDEP
1,1,2-Trichloroethane	98	µg/kg	KDEP
TCE	52	µg/kg	KDEP
2,3,7,8-TCDD	0.00001	µg/kg	KDEP
Xylenes (total)	0.0016	µg/kg	KDEP

[a] value from KDEP (KRAGS Appendix D, 2002)
[b] value is from EPA Region 4
[c] value from Oak Ridge 1997
[d] value from EPA Hazardous Waste Combustor guidance 1994
[e] value is consensus TEC
BHC = benzene hexachloride
DDT = dichlorodiphenyl trichloroethane
mg/kg = milligrams per kilogram
NFA = No Further Action
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant
TCDD = tetrachlorodibenzo-p-dioxin
TCE = trichloroethylene
(g/kg = micrograms per kilogram

Table A.5 PGDP Sediment NFA Screening Values for Radionuclides

Radionuclide	PGDP Sediment NFA level Based on Riparian Animal (pCi/g)
Americium-241	5.16E+03
Cesium-137	3.13E+03
Cobalt-60	1.46E+03
Neptunium-237	7.61E+03
Technetium-99	4.23E+04
Thorium-230	1.04E+04
Plutonium-238	5.73E+03
Plutonium-239	5.87E+03
Plutonium-240	—
Uranium-234	5.27E+03
Uranium-235	3.73E+03
Uranium-238	2.49E+03

Table A.6. PGDP Surface Water NFA Screening Values

Analyte	PGDP NFA Screening Value (μg/L)	Type
	Inorganics	
Aluminum	87	Region 4 Freshwater ESV
Antimony	160	Region 4 Freshwater ESV
Arsenic	50	Kentucky State "warm water"
Arsenic (III)	150	Kentucky State "warm water"
Arsenic (V)	3.1	Tier II (Suter and Tsao 1996)
Barium	4	Tier II (Suter and Tsao 1996)
Beryllium	0.53	Region 4 Freshwater ESV
Boron	1.6[a]	Tier II (Suter and Tsao 1996)
Cadmium	0.147[b]	Kentucky State "warm water"
Chloride	230,000	Kentucky State "warm water"
Chlorine	11	Region 4 Freshwater ESV
Chromium (III)	43.8[b]	Kentucky State "warm water"
Chromium (VI)	11	Kentucky State "warm water"
Cobalt	23	Tier II (Suter and Tsao 1996)
Copper	4.62[b]	Kentucky State "warm water"
Cyanide, free	5.2	Kentucky State "warm water"
Hydrogen sulfide	2	Kentucky State "warm water"
Iron	1,000[c]	Kentucky State "warm water"
Lead	1.12[b]	Kentucky State "warm water"
Manganese	120	Tier II (Suter and Tsao 1996)
Mercury	0.77	Kentucky State "warm water"
Mercury, methyl	0.0028	Tier II (Suter and Tsao 1996)
Molybdenum	370	Tier II (Suter and Tsao 1996)
Nickel	26.04[b]	Kentucky State "warm water"
Selenium	5	Kentucky State "warm water"
Silver	0.012	Region 4 Freshwater ESV
Strontium	1,500	Tier II (Suter and Tsao 1996)
Sulfide	2	Region 4 Freshwater ESV
Thallium	4	Region 4 Freshwater ESV
Tin	73	Tier II (Suter and Tsao 1996)
Uranium	2.6	Tier II (Suter and Tsao 1996)
Vanadium	20	Tier II (Suter and Tsao 1996)
Zinc	59.71[b]	Kentucky State "warm water"
Zirconium	17	Tier II (Suter and Tsao 1996)
	Organic compounds	
Acenaphthene	17	Region 4 Freshwater ESV
Acetone	1,500	Tier II (Suter and Tsao 1996)
Acrolein	2.1	Region 4 Freshwater ESV
Acrylonitrile	75.5	Region 4 Freshwater ESV
Aldrin	0.3	Region 4 Freshwater ESV
Anthracene	0.73	Tier II (Suter and Tsao 1996)
Benzene	53	Region 4 Freshwater ESV
Benzidine	25	Region 4 Freshwater ESV
Benzo(a)anthracene	0.027	Tier II (Suter and Tsao 1996)

Table A.6 PGDP Surface Water NFA Screening Values (Continued)

Analyte	PGDP NFA Screening Value (μg/L)	Type
Benzo(a)pyrene	0.014	Tier II (Suter and Tsao 1996)
Benzoic acid	42	Tier II (Suter and Tsao 1996)
Benzyl alcohol	8.6	Tier II (Suter and Tsao 1996)
BHC, alpha	500	Region 4 Freshwater ESV
BHC, beta	5,000	Region 4 Freshwater ESV
bis(2-Chloroethyl) ether	2,380	Region 4 Freshwater ESV
bis(2-Ethylhexyl)phthalate	0.3	Region 4 Freshwater ESV
Bromoform	293	Region 4 Freshwater ESV
4-Bromophenyl phenyl ether	12.2	Region 4 Freshwater ESV
2-Butanone	14,000	Tier II (Suter and Tsao 1996)
Butylbenzylphthalate	22	Region 4 Freshwater ESV
Carbon disulfide	0.92	Tier II (Suter and Tsao 1996)
Carbon tetrachloride	352	Region 4 Freshwater ESV
Chlorobenzene	195	Region 4 Freshwater ESV
Chlordane	0.0043	Kentucky State “warm water”
Chloroform	289	Region 4 Freshwater ESV
Chloropyrifos	0.041	Kentucky State “warm water”
2-Chloroethylvinyl ether	3,540	Region 4 Freshwater ESV
2-Chlorophenol	43.8	Region 4 Freshwater ESV
3-Methyl-4-Chlorophenol	0.3	Region 4 Freshwater ESV
Decane	49	Tier II (Suter and Tsao 1996)
Demeton	0.1	Region 4 Freshwater ESV
4,4'-DDD	0.0064	Region 4 Freshwater ESV
4,4'-DDE	10.5	Region 4 Freshwater ESV
4,4'-DDT	0.001	Kentucky State “warm water”
Dibenzofuran	3.7	Tier II (Suter and Tsao 1996)
1,2-Dichlorobenzene	15.8	Region 4 Freshwater ESV
1,3-Dichlorobenzene	50.2	Region 4 Freshwater ESV
1,4-Dichlorobenzene	11.2	Region 4 Freshwater ESV
1,1-Dichloroethane	47	Tier II (Suter and Tsao 1996)
1,2-Dichloroethane	2,000	Region 4 Freshwater ESV
1,1-Dichloroethylene	303	Region 4 Freshwater ESV
1,2-*Trans*-Dichloroethylene	1,350	Region 4 Freshwater ESV
1,2-Dichloroethene (total)	590	Tier II (Suter and Tsao 1996)
2,4-Dichlorophenol	36.5	Region 4 Freshwater ESV
1,2-Dichloropropane	525	Region 4 Freshwater ESV
1,3-Dichloropropylene	24.4	Region 4 Freshwater ESV
Dieldrin	0.056	Kentucky State “warm water”
Diethylphthalate	521	Region 4 Freshwater ESV
Dimethylphthalate	330	Region 4 Freshwater ESV
2,4-Dimethylphenol	21.2	Region 4 Freshwater ESV
Di-n-butylphthalate	9.4	Region 4 Freshwater ESV
2-Methyl-4,6-Dinitrophenol	2.3	Region 4 Freshwater ESV
2,4-Dinitrophenol	6.2	Region 4 Freshwater ESV
2,4-Dinitrotoluene	310	Region 4 Freshwater ESV
Endosulfan, alpha	0.056	Kentucky State “warm water”
Endosulfan, beta	0.056	Kentucky State “warm water”
Endosulfan, mixed isomers	0.051	Tier II (Suter and Tsao 1996)
Endrin	0.036	Kentucky State “warm water”

Table A.6 PGDP Surface Water NFA Screening Values (Continued)

Analyte	PGDP NFA Screening Value (μg/L)	Type
Ethylbenzene	453	Region 4 Freshwater ESV
Fluoranthene	39.8	Region 4 Freshwater ESV
gamma-BHC (lindane)	0.08	Region 4 Freshwater ESV
Guthion	0.01	Kentucky State "warm water"
Heptachlor	0.0038	Kentucky State "warm water"
Heptachlor epoxide	0.0038	Kentucky State "warm water"
Hexachlorobutadiene	0.93	Region 4 Freshwater ESV
Hexachlorocyclopentadiene	0.07	Region 4 Freshwater ESV
Hexachloroethane	9.8	Region 4 Freshwater ESV
Hexane	0.58	Tier II (Suter and Tsao 1996)
2-Hexanone	99	Tier II (Suter and Tsao 1996)
1,2-Diphenylhydrazine	2.7	Region 4 Freshwater ESV
Isophorone	1,170	Region 4 Freshwater ESV
Malathion	0.1	Kentucky State "warm water"
Methoxychlor	0.03	Kentucky State "warm water"
Methyl bromide	110	Region 4 Freshwater ESV
Methyl chloride	5,500	Region 4 Freshwater ESV
Methylene chloride	1,930	Region 4 Freshwater ESV
1-Methylnaphthalene	2.1	Tier II (Suter and Tsao 1996)
2-Methylphenol	13	Tier II (Suter and Tsao 1996)
Mirex	0.001	Kentucky State "warm water"
Naphthalene	62	Region 4 Freshwater ESV
Nitrobenzene	270	Region 4 Freshwater ESV
2-Nitrophenol	3,500	Region 4 Freshwater ESV
4-Nitrophenol	82.8	Region 4 Freshwater ESV
N-nitrosodiphenylamine	58.5	Region 4 Freshwater ESV
2-Octanone	8.3	Tier II (Suter and Tsao 1996)
Parathion	0.013	Kentucky State "warm water"
1-Pentanol	110	Tier II (Suter and Tsao 1996)
Pentachlorophenol	9.05[d]	Kentucky State "warm water"
Pentachlorobenzene	50	Region 4 Freshwater ESV
Phthalate esters	3	KRAGs Appendix D value
Phenol	256	Region 4 Freshwater ESV
Polychlorinated biphenyls	0.014	Kentucky State "warm water"
2-Propanol	7.5	Tier II (Suter and Tsao 1996)
1,2,4,5-Tetrachlorobenzene	50	Region 4 Freshwater ESV
Tetrachloroethylene	84	Region 4 Freshwater ESV
2,3,7,8-TCDD-Dioxin	0.00001	Region 4 Freshwater ESV
1,1,2,2-Tetrachloroethane	240	Region 4 Freshwater ESV
Toluene	175	Region 4 Freshwater ESV
Toxaphene	0.0002	Kentucky State "warm water"
Tributyltin	0.072	Kentucky State "warm water"
Trichloroethene	47	Tier II (Suter and Tsao 1996)
1,2,4-Trichlorobenzene	44.9	Region 4 Freshwater ESV
1,1,1-Trichloroethane	528	Region 4 Freshwater ESV
1,1,2-Trichloroethane	940	Region 4 Freshwater ESV
2,4,6-Trichlorophenol	3.2	Region 4 Freshwater ESV
Vinyl acetate	16	Tier II (Suter and Tsao 1996)

Table A.6 PGDP Surface Water NFA Screening Values (Continued)

Analyte	PGDP NFA Screening Value[a] (μg/L)	Type
m-Xylene	1.8	Tier II (Suter and Tsao 1996)
Xylenes (total)	13	Tier II (Suter and Tsao 1996)

Source: Suter, G. W. II and C. L. Tsao 1996. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota*, ES/ER/TM-96/R2, Oak Ridge National Laboratory, Oak Ridge, TN.

[a]Tier II value chosen over EPA Region 4 value of 750; EPA value based on crop irrigation

[b]Hardness dependent, uses minimum hardness value from Bayou Creek system, 44 (mg/L as $CaCO_3$) from source: Birge, W. J. and D. J. Price 2002. *Analysis of Polychlorinated Biphenyl Mixtures (PCB) and Metals in Water Samples Collected from the Bayou Creek System on August 13-14, 2001. Final Report.* Division of Waste Management, Kentucky Department for Environmental Protection.

[c]The chronic criterion for iron shall not exceed three and five-tenths (3.5) mg/L if aquatic life has not been shown to be adversely affected.

[d]pH dependent, assumes a pH of 7.3 (average of values from Birge and Price, 2002)

BHC = benzene hexachloride
DDT = dichlorodiphenyl trichloroethane
ESV = ecological screening value
KDEP Kentucky Department for Environmental Protection
NFA = No Further Action
TCDD = tetrachlorodibenzo-p-dioxin
(g/L = micrograms per liter

Table A.7. PGDP NFA Surface Water Values for Radionuclides

Radionuclide	PGDP Surface Water NFA level Based on Aquatic Animal (pCi/L)
Americium-241	4.38E+01
Cesium-137	1.05E+02
Cobalt-60	3.76E+02
Neptunium-237	6.85E+00
Technetium-99	2.47E+05
Thorium-230	2.57E+02
Plutonium-238	1.76E+01
Plutonium-239	1.87E+01
Plutonium-240	—
Uranium-234	2.02E+01
Uranium-235	7.37E+02
Uranium-238	2.24E+01

PGDP Surface Water NFA = Surface water benchmark for small fish (0.1. Surface water benchmark for small fish is from Bechtel Jacobs Company LLC 1998. *Radiological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota at Oak Ridge National Laboratory, Oak Ridge, Tennessee*, BJC/OR-80, Environmental Management and Enrichment Facilities, Oak Ridge, TN.
NFA = No Further Action
pCi/L = picocuries per liter
PGDP = Paducah Gaseous Diffusion Plant

APPENDIX B

EXPOSURE PARAMETERS FOR PGDP MODEL RECEPTORS

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Table B.1. Exposure Parameters for PGDP Model Receptors

Receptor	Parameter	Value	Details and Sources
Little brown bat	Body weight	0.0075 kg	Gould 1955 Sample and Suter 1994
	Food ingestion rate	0.9 kg/kgBW/day	KDFWR, personal communication, lactating female
Short-tailed shrew	Body weight	0.015 kg	15 g; both sexes, New Hampshire Schlesinger and Potter 1974, EPA 1993
	Food ingestion rate	1.7 kg/kgBW/day	KDFWR, personal communication, 0.0255 kg/d
American woodcock	Body weight	0.15 kg	154.6 g; arithmetic mean of juveniles, both sexes, central Massachusetts Sheldon 1967, EPA 1993
	Food ingestion rate	0.77 kg/kgBW/day	Both sexes, winter earthworm diet), Louisiana (captive) Stickel *et al.* 1965, EPA 1993
American robin	Body weight	0.0773 kg	77.3 g; arithmetic mean, adult, both sexes, all seasons, Pennsylvania Clench and Leberman 1978, EPA 1993
	Food ingestion rate	1.52 kg/kgBW/day	Arithmetic mean, both sexes, all ages, free living, Kansas Hazelton *et al*., 1984, EPA 1993
Marsh wren	Body weight	0.0094 kg	9.4 g; juvenile, both sexes, Georgia Kale 1965, EPA 1993
	Food ingestion rate	0.67 kg/kgBW/day	Adult, both sexes, free living, Georgia (captive) Estimated from Kale 1965, EPA 1993
Mustelid (Mink)	Body weight	0.78 kg	781.6 g; arithmetic mean, both sexes, all ages, Montana Mitchell 1961, EPA 1993
	Food ingestion rate	0.46 kg/kgBW/day	Mature male, farm raised NRC 1982
Belted kingfisher	Body weight	0.136 kg	136 g; adult, both sexes, Pennsylvania Brooks and Davis 1987, EPA 1993
	Food ingestion rate	0.5 kg/kgBW/day	Adult, both sexes, north central lower Michigan Alexander 1977, EPA 1993
Green Heron	Body weight	0.2 kg	EPA Region 4
	Food ingestion rate	0.12 kg/kgBW/day	EPA Region 4
Microtus spp. (Meadow Vole)	Body weight	0.02 kg	21.2 g; adult, both sexes, all seasons, south Indiana Myers and Krebs 1971, EPA 1993
	Food ingestion rate	0.3 kg/kgBW/day	No sex or age given, Russia Ognev 1950, EPA 1993

Table B.1 Exposure Parameters for PGDP Model Receptors (Continued)

Receptor	Parameter	Value	Details and sources
Bobwhite quail	Body weight	0.16 kg	157.25 g; arithmetic mean, adult, both sexes, winter and summer, west Rio Grande, Texas Guthery *et al.* 1988, EPA 1993
	Food ingestion rate	0.078 kg/kgBW/day	Arithmetic mean, adult, both sexes, all seasons, southern Texas (captive) Koerth and Guthery 1990
Screech owl	Body weight	0.14 kg	From range of males (0.088 to 0.178 kg) and females (0.092 to 0.22 kg) Earhart and Johnson 1970
	Food ingestion rate	0.385 kg/kgBW/day	Eq. (3-3) EPA 1993, 0.016 kg/d (dry matter) 70% water content

EPA = U.S. Environmental Protection Agency
KDFWR = Kentucky Department of Fish and Wildlife Resources
kg/kg/day = kilograms food per kilogram body weight per day
Sources:

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APPENDIX C

CALCULATING PRELIMINARY HAZARD QUOTIENTS

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CALCULATING PRELIMINARY HQS

Preliminary hazard quotients (HQs) for ecological risk assessments (ERAs) at Paducah Gaseous Diffusion Plant (PGDP) sites are calculated in Step 3a for wildlife receptors potentially exposed indirectly (via the food web) to chemicals of potential concern (COPCs) in surface soil, surface water, sediment, or groundwater potentially discharging as surface water. The equations used to calculate preliminary HQs are presented below. These equations may also be used to calculate HQs in Step 7 with the appropriate toxicity reference value (TRV).

An HQ is the ratio of the average daily dose (ADD) and the TRV. The ADD (mg COPC/kg receptor/day) is an estimate of how much COPC is ingested per day over the period of exposure. The TRV for preliminary HQs for wildlife receptors at PGDP sites is the no observed adverse effect level (NOAEL). The NOAEL (mg COPC/kg receptor/day) is an estimate of the highest average amount of COPC that the receptor can ingest per day over a relatively long period without experiencing an adverse effect. Thus,

$$HQ = ADD/NOAEL$$

The ADD for wildlife receptors exposed directly by ingestion to COPCs in an environmental medium at a site is calculated as the product of the ingestion rate (IR) for that medium and the maximum measured medium concentration at the site:

$$ADD\ (mg/kg/day) = medium\ concentration\ (mg/kg\ or\ \mu g/L) \times IR\ (kg/kg/day\ or\ L/kg/day)$$

The ADD for wildlife receptors exposed indirectly to COPCs in an environmental medium at a site is calculated as the product of the IR (kg tissue/kg receptor/day) and the maximum measured tissue concentration (mg COPC/kg tissue) in food organisms exposed to the medium at the site:

$$ADD\ (mg/kg/day) = food\ tissue\ concentration\ (mg/kg) \times IR\ (kg/kg/day)$$

If site-specific tissue data are not available, the ADD is calculated as the product of the maximum detected concentration in the abiotic medium, the appropriate biotransfer factor for the food organisms exposed to that medium, and the IR for the receptor.

For wildlife receptors exposed to COPCs in soil-dwelling invertebrates, the biotransfer factor is the unitless soil-to-invertebrate tissue bioaccumulation factor (BAF_i), and the ADD is calculated as:

$$ADD = soil\ concentration\ (mg/kg) \times BAF_i \times IR$$

For wildlife receptors exposed to COPCs in small vertebrate prey, such as small mammals and birds, the biotransfer factor is the unitless prey tissue BAF_v, and the ADD is calculated as:

$$ADD = soil\ concentration\ (mg/kg) \times BAF_v \times IR$$

For wildlife receptors exposed indirectly to COPCs in surface water and groundwater through ingestion of aquatic biota (e.g., fish and crayfish), the biotransfer factor is the BCF for the contaminant in fish tissue (BCF_{fish}), and the ADD is calculated as:

$$ADD = water\ concentration\ (\mu g/L) \times 0.001\ (mg/\mu g) \times BCF\ (L/\mu g) \times IR$$

For wildlife receptors exposed indirectly to COPCs in sediment through ingestion of sediment-dwelling biota (e.g., crayfish and benthic insect larvae), the biotransfer factor is the unitless BAF for the contaminant in invertebrate tissue (BAF_i), and the ADD is calculated as:

$$ADD = sediment\ concentration\ (mg/kg) \times BAF_i \times IR$$

When a wildlife receptor is exposed directly and indirectly by ingestion, the ADD for direct consumption of the abiotic medium is added to the ADD for indirect consumption (ingestion of food).

Table 1 in the main text (Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky) presents the values of IR for calculating preliminary HQs for model receptors exposed to substances in food at PGDP sites. EPA (1993) and other sources give ingestion rates for abiotic media. Table C.1 presents a list of substances with published BAFs or BCFs, including values for substances considered by KDEP to be bioaccumulative. Values for BAFs and BCFs for radionuclides can be obtained from Baes *et al.* 1984, PNNL 2003, or other literature sources.

For carnivorous fish, the HQ is calculated as the ratio of the estimated body burden for fish at the site and the TRV body burden for fish. Fish body burdens can be estimated as the product of the average concentration of matter ingested by the fish and the biotransfer factor for fish (BAF) plus the component from water, which is estimated as the product of the water concentration and the BCF for fish.

REFERENCES

Baes, C.F., R. Sharp, A. Sjoreen, and R. Shor 1984. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture.* ORNL-5786, Oak Ridge National Laboratory, Oak Ridge, TN, September.

PNNL (Pacific Northwest National Laboratory) 2003. *Literature Review and Assessment of Plant and Animal Transfer Factors Used in Performance Assessment Modeling. NUREG/CR-6825, PNNL-1432.*Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC, August.

Table C.1. Example Soil-to-Invertebrate and Water-to-Fish Bioaccumulation Factors

Analyte	Soil-to-Invertebrate Animal (BAF_i) (kg_{soil}/kg_{tissue})	Reference	Water-to-Fish Bioconcentration Factors (BCF) (L/kg)	Reference
	INORGANICS			
Aluminum	2.20E-01	EPA 1999	2.70E+00	EPA 1999
Antimony	$C_e = C_s$	EPA 2007	4.00E+01	EPA 1999
Arsenic	$\ln(C_e) = 0.706 * \ln(C_s) - 1.421$	EPA 2007	1.14E+02	EPA 1999
Arsenic (III)	1.10E-01	EPA 1999	—	—
Arsenic (V)	1.10E-01	EPA 1999	—	—
Barium	$C_e = 0.091 * C_s$	EPA 2007	6.33E+02	EPA 1999
Beryllium	$C_e = 0.045 * C_s$	EPA 2007	6.20E+01	EPA 1999
Cadmium	$\ln(C_e) = 0.795 * \ln(C_s) + 2.114$	EPA 2007	5.00E+03	KDEP
Chromium	$C_e = 0.306 * C_s$	EPA 2007	5.50E+02	KDEP
Cobalt	$C_e = 0.122 * C_s$	EPA 2007	3.00E+02	DOE 1994
Copper	$C_e = 0.515 * C_s$	EPA 2007	5.89E+03	KDEP
Cyanide	1.12E+00	EPA 1999	6.33E+02	EPA 1999
Fluoride	1.00E+00	DOE 1994	—	—
Fluorine	1.00E+00	DOE 1994	—	—
Iodine	1.00E+00	DOE 1994	—	—
Lanthanum	1.00E+00	DOE 1994	—	—
Lead	$\ln(C_e) = 0.807 * \ln(C_s) - 0.218$	EPA 2007	1.41E+05	KDEP
Lithium	1.00E+00	DOE 1994	—	—
Manganese	$\ln(C_e) = 0.682 * \ln(C_s) - 0.809$	EPA 2007	4.00E+02	DOE 1994
Mercury	3.30E+01	KDEP	6.30E+04	DOE 1994
Methyl mercury	8.50E+00	EPA 1999	2.51E+06	KDEP
Nickel	2.00E-02	EPA 1999	7.80E+01	EPA 1999
Selenium	$\ln(C_e) = 0.733 * \ln(C_s) - 0.075$	EPA 2007	1.29E+02	EPA 1999
Silver	$C_e = 2.045 * C_s$	EPA 2007	8.77E+01	EPA 1999
Thallium	2.20E-01	EPA 1999	1.00E+04	EPA 1999
Tin	—	—	2.57E+03	KDEP
Vanadium	$C_e = 0.042 * C_s$	EPA 2007	1.00E-02	DOE 1994
Uranium	2.20E-01	EPA 1999	—	—
Zinc	$\ln(C_e) = 0.328 * \ln(C_s) + 4.449$	EPA 2007	2.06E+03	EPA 1999
	ORGANICS			
Volatile organic compounds				
Acetone	5.00E-02	EPA 1999	1.00E-01	EPA 1999
Benzene	5.00E-02	DOE 1994	3.20E+01	DOE 1994
Carbon tetrachloride	1.20E+01	EPA 1999	3.00E+01	EPA 1999
Chlorobenzene	5.00E-02	DOE 1994	4.50E+02	DOE 1994
Chloroform	2.82E+00	EPA 1999	3.59E+00	EPA 1999
1,1,2,2-Tetrachloroethane	—	—	8.00E+00	DOE 1994
1,2-Dichloroethane	5.00E-02	DOE 1994	2.00E+00	DOE 1994
1,2-Dichloroethene	5.00E-02	DOE 1994	8.60E-01	DOE 1994
1,4-Dichlorobenzene	—	—	1.80E+03	KDEP
Ethylbenzene	5.00E-02	DOE 1994	2.90E+02	DOE 1994
Methylene chloride	5.00E-02	DOE 1994	4.00E+00	DOE 1994
Methyl ethyl ketone	5.00E-02	DOE 1994	—	—
4-chloro-3-methylphenol	—	—	1.10E+02	DOE 1994
4-Methyl-2-pentanone	5.00E-02	DOE 1994	6.00E+00	DOE 1994
Pentachlorobenzene	—	—	2.60E+05	KDEP
Tetrachloroethene	5.00E-02	DOE 1994	4.40E+01	DOE 1994
Toluene	5.00E-02	DOE 1994	8.30E+01	DOE 1994
Trichloroethene	5.00E-02	DOE 1994	1.70E+01	DOE 1994
Vinyl chloride	6.20E-01	EPA 1999	1.81E+00	EPA 1999
Xylene, total	5.00E-02	DOE 1994	1.70E+01	DOE 1994

Table C.1 Example Soil-to-Invertebrate and Water-to-Fish Bioaccumulation Factors (Continued)

Analyte	Soil-to-Invertebrate Animal (BAF_i) (kg_{soil}/kg_{tissue})	Reference	Water-to-Fish Bioconcentration Factors (BCF) (L/kg)	Reference
Semivolatile organic compounds				
Acenaphthene	$C_e = 1.47 * C_s$	EPA 2007	3.89E+02	KDEP
Acenaphthylene	$C_e = 22.9 * C_s$	EPA 2007	6.90E+02	DOE 1994
Anthracene	$C_e = 2.42 * C_s$	EPA 2007	1.68E+04	KDEP
Benzo(a)anthracene	$C_e = 1.59 * C_s$	EPA 2007	3.57E+04	KDEP
Benzo(a)pyrene	$C_e = 1.33 * C_s$	EPA 2007	5.00E+02	EPA 1999
Benzo(b)fluoranthene	$C_e = 2.60 * C_s$	EPA 2007	5.00E+02	EPA 1999
Benzo(g,h,i)perylene	$C_e = 2.94 * C_s$	EPA 2007	6.50E+04	DOE 1994
Benzo(k)fluoranthene	$C_e = 2.60 * C_s$	EPA 2007	5.00E+02	EPA 1999
Bis(2-ethylhexyl)phthalate	1.31E+03	EPA 1999	7.00E+01	EPA 1999
Butylbenzylphthalate	5.00E-02	DOE 1994	6.60E+02	DOE 1994
Carbazole	5.00E-02	DOE 1994	3.70E+02	DOE 1994
Chrysene	$C_e = 2.29 * C_s$	EPA 2007	5.00E+02	EPA 1999
Dibenzo(a,h)anthracene	$C_e = 2.31 * C_s$	EPA 2007	5.00E+02	EPA 1999
Dibenzofuran	5.00E-02	DOE 1994	6.90E+02	DOE 1994
3,3'-Dichlorobenzidine	—	—	6.10E+02	KDEP
Diethylphthalate	5.00E-02	DOE 1994	1.20E+02	DOE 1994
Di-n-butylphthalate	5.00E-02	DOE 1994	5.10E+03	DOE 1994
Di-n-octylphthalate	3.13E+06	EPA 1999	9.40E+03	EPA 1999
Fluoranthene	$C_e = 3.04 * C_s$	EPA 2007	1.74E+04	KDEP
Fluorene	$C_e = 9.57 * C_s$	EPA 2007	8.30E+02	DOE 1994
Indeno(1,2,3-cd)pyrene	$C_e = 2.86 * C_s$	EPA 2007	5.00E+02	EPA 1999
2-Methylnaphthalene	5.00E-02	DOE 1994	4.30E+02	DOE 1994
4-Chloro-3-methylphenol	2.00E-02	DOE 1994	1.10E+02	DOE 1994
4-Methylphenol	5.00E-02	DOE 1994	1.30E+01	DOE 1994
Naphthalene	$C_e = 4.40 * C_s$	EPA 2007	4.30E+02	DOE 1994
2-Nitrophenol	5.00E-02	DOE 1994	1.30E+01	DOE 1994
4-Nitrophenol	5.00E-02	DOE 1994	1.30E+01	DOE 1994
N-Nitrosodiphenylamine	5.00E-02	DOE 1994	8.10E+01	DOE 1994
Octachlorostyrene	—	—	3.30E+02	KDEP
Pentachlorophenol	$C_e = 14.63 * C_s$	EPA 2007	1.05E+03	KDEP
Phenanthrene	$C_e = 1.72 * C_s$	EPA 2007	1.12E+04	KDEP
Phenol	5.00E-02	DOE 1994	7.80E+02	DOE 1994
Pyrene	$C_e = 1.75 * C_s$	EPA 2007	6.10E+03	DOE 1994
Total LMW PAHs	$C_e = 3.04 * C_s$	EPA 2007		
Total HMW PAHs	$C_e = 2.6 * C_s$	EPA 2007	—	—
Pesticides and PCBs				
Aldrin	5.60E-01	DOE 1994	1.10E+04	DOE 1994
Aroclor-1254	1.13E+00	EPA 1999	2.30E+05	EPA 1999
Aroclor-1260	5.80E+00	DOE 1994	1.00E+07	DOE 1994
Total PCBs	2.80E+02	KDEP	—	—
alpha-BHC	2.60E+00	DOE 1994	7.10E+02	DOE 1994
beta-BHC	2.60E+00	DOE 1994	7.20E+02	DOE 1994
delta-BHC	2.60E+00	DOE 1994	6.90E+02	DOE 1994
gamma-BHC (Lindane)	2.00E-02	DOE 1994	1.00E+03	DOE 1994
alpha-Chlordane	1.60E+00	DOE 1994	1.40E+06	DOE 1994
gamma-Chlordane	1.60E+00	DOE 1994	7.60E+04	DOE 1994

Table C.1 Example Soil-to-Invertebrate and Water-to-Fish Bioaccumulation Factors (Continued)

	Soil-to-Invertebrate Animal (BAF_i)		Water-to-Fish Bioconcentration Factors (BCF)	
Analyte	**(kg_{soil}/kg_{tissue})**	**Reference**	**(L/kg)**	**Reference**
4,4'-DDD	$\ln(C_e) = 0.6975 * \ln(C_s) + 1.1613$	EPA 2007	5.65E+05	KDEP
4,4'-DDE	$\ln(C_e) = 0.8804 * \ln(C_s) + 2.4771$	EPA 2007	1.81E+05	KDEP
4,4'-DDT	$\ln(C_e) = 0.8689 * \ln(C_s) + 2.1247$	EPA 2007	5.88E+04	KDEP
Total 4,4'-DDT	$C_e = 11.2 * C_s$	EPA 2007	—	—
Dieldrin	$C_e = 14.7 * C_s$	EPA 2007	6.76E+04	KDEP
Endrin	1.90E+00	DOE 1994	1.30E+04	KDEP
Endrin aldehyde	1.90E+00	DOE 1994	1.20E+02	DOE 1994
Endrin ketone	1.90E+00	DOE 1994	1.20E+02	DOE 1994
Heptachlor	1.40E+00	EPA 1999	2.18E+19	KDEP
Heptachlor epoxide	1.00E+00	DOE 1994	2.18E+19	KDEP
Methoxychlor	5.70E-01	DOE 1994	8.30E+03	DOE 1994
Mirex	3.00E+01	KDEP	1.80E+04	KDEP
Toxaphene	9.00E-01	KDEP	7.60E+04	KDEP
Dioxins and furans				
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	8.10E-02	EPA 1999	2.16E+02	EPA 1993
1,2,3,4,6,7,8-Heptachlorodibenzofuran	1.70E-02	EPA 1999	4.66E+01	EPA 1993
1,2,3,4,7,8,9-Heptachlorodibenzofuran	6.20E-01	EPA 1999	1.65E+03	EPA 1993
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	1.90E-01	EPA 1999	5.08E+02	EPA 1993
1,2,3,6,7,8-Hexachlorodibenzofuran	3.00E-01	EPA 1999	8.05E+02	EPA 1993
1,2,3,7,8,9-Hexachlorodibenzofuran	1.00E+00	EPA 1999	2.67E+03	EPA 1993
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	4.90E-01	EPA 1999	1.31E+03	EPA 1993
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	2.20E-01	EPA 1999	5.93E+02	EPA 1993
1,2,3,4,7,8-Hexachlorodibenzofuran	1.21E-01	EPA 1999	—	—
2,3,4,6,7,8-Hexachlorodibenzofuran	1.07E+00	EPA 1999	2.84E+03	EPA 1993
2,3,4,7,8-Pentachlorodibenzofuran	2.54E+00	EPA 1999	6.78E+03	EPA 1993
Octachlorodibenzo-p-dioxin	1.90E-02	EPA 1999	5.08E+01	EPA 1993
Octachlorodibenzofuran	2.50E-02	EPA 1999	6.78E+01	EPA 1993
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	1.46E+00	EPA 1999	6.17E+04	KDEP
1,2,3,7,8-Pentachlorodibenzofuran	3.20E-01	EPA 1999	9.32E+02	EPA 1993
2,3,7,8-Tetrachlorodibenzo-p-dioxin	4.21E+01	KDEP	4.24E+03	EPA 1993

Table C.1 Example Soil-to-Invertebrate and Water-to-Fish Bioaccumulation Factors (Continued)

Analyte	Soil-to-Invertebrate Animal (BAF_i) (kg_{soil}/kg_{tissue})	Reference	Water-to-Fish Bioconcentration Factors (BCF) (L/kg)	Reference
2,3,7,8-Tetrachlorodibenzofuran	1.27E+00	EPA 1999	3.39E+03	EPA 1993
Dioxins, total equivalent	1.59E+00	EPA 1999	—	—
Explosives				
1,3-Dinitrobenzene	1.19E+00	EPA 1999	7.40E+01	EPA (1999)
2,4-Dinitrotoluene	3.08E+00	EPA 1999	2.10E+01	EPA (1999)
2,6-Dinitrotoluene	2.50E+00	EPA 1999	2.10E+01	EPA (1999)
Nitrobenzene	2.26E+00	EPA 1999	2.10E+01	EPA (1999)

DOE (U.S. Department of Energy) 1994. *Loring Air Force Base Risk Assessment Methodology*, Hazardous Waste Remedial Actions Program, Martin Marietta Energy Systems, Oak Ridge, TN, August, Final.

EPA 1993. *Wildlife Exposure Factors Handbook*, Vol. 1, EPA/600/R-93/187a, Office of Research and Development, Washington, DC, December

EPA (U.S. Environmental Protection Agency) 1999. Screening-Level Ecological Risk Assessment Protocol, Center for Combustion Science and Engineering, EPA Region 4.

EPA (U.S. Environmental Protection Agency) 2007. *Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs), Attachment 4-1 Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs.* OSWER Directive 9285.7-55, Office of Solid Waste and Emergency Response, Washington, DC, April.

— = no value

BAF_i = Bioaccumulation factor for invertebrate (kg_{soil}/kg_{tissue}).

BCF = Bioconcentration factor for transfer from water to fish and other aquatic biota (L/kg).

BHC = benzene hexachloride

DDT = dichlorodiphenyl trichloroethane

KDEP = Kentucky Department of Environmental Protection

PAH = polycyclic aromatic hydrocarbon

PCB = polychlorinated biphenyl

C_s = Concentration in soil (mg/kg)

C_e = Concentration in earthworm (mg/kg dry weight)

APPENDIX D

EPA STREAMLINED RISK SUMMARY TABLES

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Table D.1. Occurrence, Distribution, and Selection of Chemicals of Concern

Exposure Medium: Sediment									
Chemical of Potential Concern	**Minimum Conc.[a] (ppm)**	**Maximum Conc.[a] (ppm)**	**Mean Conc. (ppm)**	**95% UCL of the Mean[b] (ppm)**	**Background Conc. (ppm)**	**Screening Toxicity Value (ppm)**	**Screening Toxicity Value Source**	**HQ Value[c]**	**COC Flag (Y or N)**
Aluminum	2,419	12,800	9,808	10,400	3,010	NA	NA	NA	Y
Arsenic	3	69	12	21	3	6	Ont LEL	11.5	Y
Dieldrin	0.01	0.01	0.01	0.01	NA	0.052	EPA SQC	0.19	N
Lead	29	82	50	56	28	47	NOAA ER-L	1.75	Y
Methoxychlor	0.01	0.01	0.01	0.01	NA	0.019	EPA SQB	0.53	N

Source: EPA 1999, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Documents*, EPA 540-R-98-031, Washington, DC, July.

[a]Minimum/maximum detected concentration above the sample quantitation limit (SQL).

[b]The 95% upper confidence limit (UCL) represents the reasonable maximum exposure concentration.

[c]Hazard quotient (HQ) is defined as maximum concentration/screening toxicity value.

COC = contaminant of concern

Conc. = concentration

NA = not applicable

NOAA ER-L = National Oceanic and Atmospheric Administration effects range–low

Ont LEL = Ontario lowest effects level; *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario*; D. Persuad, R. Jaagumagi, and A. Hayton; Ontario Ministry of the Environment; Ontario; August 1993.

SQB = sediment quality benchmark

SQC = sediment quality criteria

Table D.2. Ecological Exposure Pathways of Concern

Exposure Medium	Sensitive Environment Flag (Y or N)	Receptor	Endangered/ Threatened Species Flag (Y or N)	Exposure Routes	Assessment Endpoints	Measurement Endpoints
Sediment	N	Benthic organisms	N	Ingestion, respiration, and direct contact with chemicals in sediment	Benthic invertebrate community species diversity and abundance	• Toxicity of soil to *Hyallela* • Species diversity index
Surface water	N	Fish	N	Ingestion, respiration, and direct contact with chemicals in surface water	Maintenance of an abundant and productive game fish population	• Toxicity of surface water to *Pimephales promelas* • Species diversity index
Soil	N	Terrestrial invertebrates	N	Ingestion and direct contact with chemicals in wetland soils	Survival of terrestrial invertebrate community	• Toxicity of sediment to *Lumbricus terrestris*
		Terrestrial plants	Y	Uptake of chemicals via root systems	Maintenance/enhancement of native wetland vegetation	• Species diversity index • Survival of seedlings
Surface water (vernal pools)	Y	Aquatic invertebrates	N	Ingestion, respiration, and direct contact with chemicals in surface water	Maintenance of a balanced, indigenous aquatic invertebrate community	• Species diversity index

Source: EPA 1999, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Documents*, EPA 540-R-98-031, Washington, DC, July.

Table D.3. COC Concentrations Expected to Provide Adequate Protection of Ecological Receptors

Habitat Type/Name	Exposure Medium	COC	Protective Level[a]	Units	Basis[b]	Assessment Endpoint
Small freshwater stream/West Branch Maple Creek	Sediment	Arsenic	6	mg/kg	Site-specific LOAEL	Benthic invertebrate community species diversity and abundance
		Lead	15	mg/kg	Significant difference in benthic diversity index between the site and the reference site	
		Total PCBs	0.03–0.05	mg/kg	LOAEL and NOAEL	
	Surface water	Aluminum	123	µg/L	NOAEL	Maintenance of an abundant and productive game fish population
		Arsenic	208	µg/L	Mean of values between LOAEL and NOAEL	
		Total PCBs	0.1	µg/L	Bioaccumulation factor modeling	

Source: EPA 1999, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Documents*, EPA 540-R-98-031, Washington, DC, July.

[a]A range of levels may be provided.

[b]Provide basis of selection: (1) mean of values between lowest observed adverse effect level (LOAEL) and no observed adverse effect level (NOAEL), (2) bioaccumulation factor model, (3) LOAEL and NOAEL, (4)significant difference in benthic diversity index between site and reference site.

COC = contaminant of concern

PCB = polychlorinated biphenyl

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APPENDIX E

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. Is this the first site visit? ☐ yes ☐ no If no, attach trip report of previous site visit(s), if available.

   Date(s) of previous site visit(s):_____.

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

6. Are aerial or other site photographs available? ☐ yes ☐ no If yes, please attach any available photo(s) to the site map at the conclusion of this section.

7. The land use on the site is:

_____% Urban

_____% Rural

_____% Residential

_____% Industrial (☐ light ☐ heavy)

_____% Agricultural

(Crops:_____)

_____% Recreational

(Describe; note if it is a park, etc.)

_____

_____

_____% Undisturbed

_____% Other

The area surrounding the site is:
_____ mile radius

_____% Urban

_____% Rural

_____% Residential

_____% Industrial (☐ light ☐ heavy)

_____% Agricultural

(Crops:_____)

_____% Recreational

(Describe; note if it is a park, etc.)

_____

_____

_____% Undisturbed

_____% Other

8. Has any movement of soil taken place at the site? ☐ yes ☐ no. If yes, please identify the most likely cause of this disturbance:

_____ Agricultural Use _____ Heavy Equipment _____ Mining

_____ Natural Events _____ Erosion _____ Other

Please describe:

9. 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, prairie potholes? *Remember, flood plains and wetlands are not always obvious; do not answer "no" without confirming information.*

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

10. What type of facility is located at the site?

    ☐ Chemical ☐ Manufacturing ☐ Mixing ☐ Waste disposal

    ☐ Other (specify)_____

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

12. Check any potential routes of off-site migration of contaminants observed at the site:

    ☐ Swales ☐ Depressions ☐ Drainage ditches

    ☐ Runoff ☐ Windblown particulates ☐ Vehicular traffic

    ☐ Other (specify)_____

13. If known, what is the approximate depth to the water table?_____

14. 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

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

16. Is there a waterbody anywhere on or in the vicinity of the site? If yes, also complete Section III: Aquatic Habitat Checklist -- Non-Flowing Systems and/or Section IV: Aquatic Habitat Checklist -- Flowing Systems.

☐ yes (approx. distance_____) ☐ no

17. Is there evidence of flooding? ☐ yes ☐ no *Wetlands and flood plains are not always obvious; do not answer "no" without confirming information.* If yes, complete Section V: Wetland Habitat Checklist.

18. If a field guide was used to aid any of the identifications, please provide a reference. Also, estimate the time spent identifying fauna. [Use a blank sheet if additional space is needed for text.]

19. Are any threatened and/or endangered species (plant or animal) known to inhabit the area of the site? ☐ yes ☐ no *If yes, you are required to verify this information with the U.S. Fish and Wildlife Service.* If species' identities are known, please list them next.

20. Record weather conditions at the time this checklist was prepared:

DATE:_____

_____ Temperature (°C/°F) _____ Normal daily high temperature

_____ Wind (direction/speed) _____ Precipitation (rain, snow)

_____ Cloud cover

IA. SUMMARY OF OBSERVATIONS AND SITE SETTING

Completed by_____ Affiliation_____

Additional Preparers_____

Site Manager_____

Date_____

II. TERRESTRIAL HABITAT CHECKLIST

IIA. WOODED

1. Are there any wooded areas at the site? ☐ yes ☐ no If no, go to Section IIB: Shrub/Scrub.

2. 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. Please identify what information was used to determine the wooded area of the site.

3. What is the dominant type of vegetation in the wooded area? (Circle one: Evergreen/Deciduous/ Mixed) Provide a photograph, if available.

   Dominant plant, if known:_____

4. What is the predominant size of the trees at the site? Use diameter at breast height.

   ☐ 0-6 in. ☐ 6-12 in. ☐ > 12 in.

5. Specify type of understory present, if known. Provide a photograph, if available.

IIB. SHRUB/SCRUB

1. Is shrub/scrub vegetation present at the site? ☐ yes ☐ no If no, go to Section IIC: Open Field.

2. What percentage of the site is covered by scrub/shrub vegetation? (_____% _____ acres). Indicate the areas of shrub/scrub on the site map. Please identify what information was used to determine this area.

3. What is the dominant type of scrub/shrub vegetation, if known? Provide a photograph, if available.

4. What is the approximate average height of the scrub/shrub vegetation?

   ☐ 0-2 ft. ☐ 2-5 ft. ☐ > 5 ft.

5. Based on site observations, how dense is the scrub/shrub vegetation?

   ☐ Dense ☐ Patchy ☐ Sparse

IIC. OPEN FIELD

1. Are there open (bare, barren) field areas present at the site? ☐ yes ☐ no If yes, please indicate the type below:

   ☐ Prairie/plains ☐ Savannah ☐ Old field ☐ Other (specify)_____

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

3. What is/are the dominant plant(s)? Provide a photograph, if available.

4. What is the approximate average height of the dominant plant?_____

5. Describe the vegetation cover: ☐ Dense ☐ Sparse ☐ Patchy

IID. MISCELLANEOUS

1. Are other types of terrestrial habitats present at the site, other than woods, scrub/shrub, and open field? ☐ yes ☐ no If yes, identify and describe them below.

2. Describe the terrestrial miscellaneous habitat(s) and identify these area(s) on the site map.

3. What observations, if any, were made at the site regarding the presence and/or absence of insects, fish, birds, mammals, etc.?

4. Review the questions in Section I to determine if any additional habitat checklists should be completed for this site.

III. AQUATIC HABITAT CHECKLIST -- NON-FLOWING SYSTEMS

Note: Aquatic systems are often associated with wetland habitats. Please refer to Section V, Wetland Habitat Checklist.

1. What type of open-water, non-flowing system is present at the site?

   ☐ Natural (pond, lake)
   ☐ Artificially created (lagoon, reservoir, canal, impoundment)

2. If known, what is the name(s) of the waterbody(ies) on or adjacent to the site?

   _____

3. If a waterbody is present, what are its known uses (e.g.: recreation, navigation, etc.)?

4. What is the approximate size of the waterbody(ies)? _____ acre(s).

5. Is any aquatic vegetation present? ☐ yes ☐ no If yes, please identify the type of vegetation present if known.

   ☐ Emergent ☐ Submergent ☐ Floating

6. If known, what is the depth of the water? _____

7. What is the general composition of the substrate? Check all that apply.

   ☐ Bedrock ☐ Sand (coarse) ☐ Muck (fine/black)
   ☐ Boulder (>10 in.) ☐ Silt (fine) ☐ Debris
   ☐ Cobble (2.5-10 in.) ☐ Marl (shells) ☐ Detritus
   ☐ Gravel (0.1-2.5 in.) ☐ Clay (slick) ☐ Concrete
   ☐ Other (specify)_____

8. What is the source of water in the waterbody?

   ☐ River/Stream/Creek ☐ Groundwater ☐ Other (specify)_____
   ☐ Industrial discharge ☐ Surface runoff

9. Is there a discharge from the site to the waterbody? ☐ yes ☐ no If yes, please describe this discharge and its path.

10. Is there a discharge from the waterbody? ☐ yes ☐ no If yes, and the information is available, identify from the list below the environment into which the waterbody discharges.

☐ River/Stream/Creek	☐ onsite	☐ offsite	Distance_____
☐ Groundwater	☐ onsite	☐ offsite	
☐ Wetland	☐ onsite	☐ offsite	Distance_____
☐ Impoundment	☐ onsite	☐ offsite	

11. Identify any field measurements and observations of water quality that were made. For those parameters for which data were collected provide the measurement and the units of measure below:

_____ Area

_____ Depth (average)

_____ Temperature (depth of the water at which the reading was taken) _____

_____ pH

_____ Dissolved oxygen

_____ Salinity

_____ Turbidity (clear, slightly turbid, turbid, opaque) (Secchi disk depth _____)

_____ Other (specify)

12. Describe observed color and area of coloration.

13. Mark the open-water, non-flowing system on the site map attached to this checklist.

14. What observations, if any, were made at the waterbody regarding the presence and/or absence of benthic macroinvertebrates, fish, birds, mammals, etc.?

IV. AQUATIC HABITAT CHECKLIST -- FLOWING SYSTEMS

Note: Aquatic systems are often associated with wetland habitats. Please refer to Section V, Wetland Habitat Checklist.

1. What type(s) of flowing water system(s) is (are) present at the site?

☐ River	☐ Stream	☐ Creek
☐ Dry wash	☐ Arroyo	☐ Brook
☐ Artificially created (ditch, etc.)	☐ Intermittent Stream	☐ Channeling
	☐ Other (specify)_____	

2. If known, what is the name of the waterbody?_____

3. For natural systems, are there any indicators of physical alteration (e.g., channeling, debris, etc.)?
☐ yes ☐ no If yes, please describe indicators that were observed.

4. What is the general composition of the substrate? Check all that apply.

☐ Bedrock	☐ Sand (coarse)	☐ Muck (fine/black)
☐ Boulder (>10 in.)	☐ Silt (fine)	☐ Debris
☐ Cobble (2.5-10 in.)	☐ Marl (shells)	☐ Detritus
☐ Gravel (0.1-2.5 in.)	☐ Clay (slick)	☐ Concrete
☐ Other (specify)_____		

5. What is the condition of the bank (e.g., height, slope, extent of vegetative cover)?

6. Is the system influenced by tides? ☐ yes ☐ no What information was used to make this determination?

7. Is the flow intermittent? ☐ yes ☐ no If yes, please note the information that was used in making this determination.

8. Is there a discharge from the site to the waterbody? ☐ yes ☐ no If yes, please describe the discharge and its path.

9. Is there a discharge from the waterbody? ☐ yes ☐ no If yes, and the information is available, please identify what the waterbody discharges to and whether the discharge is on site or off site.

10. Identify any field measurements and observations of water quality that were made. For those parameters for which data were collected, provide the measurement and the units of measure in the appropriate space below:

_____ Width (ft.)

_____ Depth (ft.)

_____ Velocity (specify units):_____

_____ Temperature (depth of the water at which the reading was taken_____)

_____ pH

_____ Dissolved oxygen

_____ Salinity

_____ Turbidity (clear, slightly turbid, turbid, opaque)
(Secchi disk depth _____)

_____ Other (specify)_____

11. Describe observed color and area of coloration.

12. Is any aquatic vegetation present? ☐ yes ☐ no If yes, please identify the type of vegetation present, if known.

    ☐ Emergent ☐ Submergent ☐ Floating

13. Mark the flowing water system on the attached site map.

14. What observations were made at the waterbody regarding the presence and/or absence of benthic macroinvertebrates, fish, birds, mammals, etc.?

V. WETLAND HABITAT CHECKLIST

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

   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.

2. Based on the location of the site (e.g., along a waterbody, in a floodplain) and site conditions (e.g., standing water; dark, wet soils; mud cracks; debris line; water marks), are wetland habitats suspected?
   ☐ yes ☐ no If yes, proceed with the remainder of the wetland habitat identification checklist.

3. What type(s) of vegetation are present in the wetland?

   ☐ Submergent ☐ Emergent
   ☐ Scrub/Shrub ☐ Wooded

   ☐ Other (specify)_____

4. Provide a general description of the vegetation present in and around the wetland (height, color, etc.). Provide a photograph of the known or suspected wetlands, if available.

5. Is standing water present? ☐ yes ☐ no If yes, is this water: ☐ Fresh ☐ Brackish
   What is the approximate area of the water (sq. ft.)?_____
   Please complete questions 4, 11, 12 in Checklist III - Aquatic Habitat -- Non-Flowing Systems.

6. Is there evidence of flooding at the site? What observations were noted?

   ☐ Buttressing ☐ Water marks ☐ Mud cracks

   ☐ Debris line ☐ Other (describe below)

7. If known, what is the source of the water in the wetland?

☐ Stream/River/Creek/Lake/Pond ☐ Groundwater

☐ Flooding ☐ Surface Runoff

8. Is there a discharge from the site to a known or suspected wetland? ☐ yes ☐ no If yes, please describe.

9. Is there a discharge from the wetland? ☐ yes ☐ no. If yes, to what waterbody is discharge released?

☐ Surface Stream/River ☐ Groundwater ☐ Lake/Pond ☐ Marine

10. If a soil sample was collected, describe the appearance of the soil in the wetland area. Circle or write in the best response.

Color (blue/gray, brown, black, mottled) _____

Water content (dry, wet, saturated/unsaturated) _____

11. Mark the observed wetland area(s) on the attached site map.