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Reference

Guidance for Assessing Ecological Risks Posed by Chemicals: Screening-Level Ecological Risk Assessment

New Mexico Environment Department
Hazardous and Radioactive Materials Bureau

FINAL

March 2000

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List of Acronyms

AWQC - ambient water quality criteria
BAF - bioaccumulation factor
BCF - bioconcentration factor
BISON-M - biota information system of New Mexico
BMF - biomagnification factor
BW - body weight
BV - background value
CCC -criterion continuous concentration
CESQ - cumulative ecological screening quotient
CMS - corrective measures study
COPEC - contaminants of potential ecological concern
DDT - dichloro-diphenyl-trichloro-ethane
DL - detection limit
DQO - data quality objective
DW - dry weight
EC_{50} - median effective concentration
EDQL - ecological data quality level
EEL - estimated exposure level
EPM - exposure pathway model
ESQ - ecological screening quotient
ET - ecotoxicity threshold
FCM - food chain multiplier
GLWQI - Great Lakes water quality initiative
HRMB - Hazardous and Radioactive Materials Bureau
LC_{50} - lethal concentration to 50% of the test population
LD_{50} - lethal dose to 50% of the test population
LOAEL - lowest observed adverse effect level
LOEC - lowest observed effect concentration
LOEL - lowest observed effect level
LULC - land use and land classification
NMED - New Mexico Environment Department
NMGF - Mew Mexico Game and Fish
NM WQCC - New Mexico Water Quality Control Commission
NOAA ER-L - National Oceanic and Atmospheric Administration effects range-low
NOAEL - no observed adverse effects level
NRWQC - national recommended water quality criteria
PCB - polychlorinated biphenyl
PCE - perchloroethylene
PSCEM - preliminary site conceptual model
QA/QC - quality assurance/quality control
QL - quantitation limit

List of Acronyms (cont.)

RAGS - risk assessment guidance for Superfund
RCRA - Resource Conservation and Recovery Act
RFI - RCRA facility investigation
RTECs - Registry of Toxic Effects of Chemical Substances
SCV - secondary chronic value
SQB - sediment quality benchmark
SQC - sediment quality criterion
SQG - sediment quality guideline
SQL - sample quantitation limit
SQuiRTs - screening quick reference table
TDP - technical decision point
TRV - toxicity reference value
UCL - upper confidence limit
UF - uncertainty factor
US BLM - United States Bureau of Land Management
US EPA - United States Environmental Protection Agency
USFS - United States Forest Service
USGS - United States Geologic Survey
USFWS - United States Fish and Wildlife Service
UTL - upper tolerance limit
WW - wet weight

Introduction

Many environmental regulations include consideration of consequences to ecosystems as part of their decision-making process. For example, the Resource Conservation and Recovery Act (RCRA) requires that the end result of any corrective action be protective of human health and the environment. Therefore, an ecological risk assessment is part of any RCRA corrective action investigation and can be used in other environmental regulatory programs as well. Consequently, a guidance document is needed to provide a tool to thoroughly assess the threat posed to the environment from chemical contaminant exposures.

Ecological risk assessment is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors" (US EPA 1998b). A screening level ecological risk assessment is a simplified risk assessment that can be conducted with limited site-specific data by defining assumptions for parameters that lack site-specific data (US EPA, 1997a). To ensure that sites that may pose an ecological risk are properly identified, the US EPA recommends that values used for screening should be consistently biased in the direction of overestimating risk. Without this bias, a screening evaluation could not provide a defensible conclusion for an absence of ecological risk.

The screening evaluation method described in this document uses food chain exposure models to develop screening levels. These levels are based on the media concentration for plants and invertebrates and on the dose ingested for other receptors. Default values for the factors used in the exposure equations are available in the appendices to this guidance and in US EPA's *Wildlife Exposure Factors Handbook* (US EPA, 1993g) for many contaminants and ecological receptors. When site-specific information is available, site-specific values can be substituted for these default values and conservative assumptions to yield less conservative, more accurate evaluations.

The Hazardous and Radioactive Materials Bureau (HRMB) of the New Mexico Environment Department (NMED) has produced this screening level ecological risk assessment guidance for chemicals to promote consistency, efficiency, and scientific rigor in risk assessments reviewed or conducted by HRMB and other NMED bureaus. The development of a detailed guidance for assessing ecological risks will also fill an information gap because there is little direction in this area. Ultimately, this guidance document will assist both the regulated communities and regulators by providing consistent direction.

The HRMB ecological risk assessment process consists of two distinct levels:

- Level I Screening-Level Ecological Risk Assessment
- Level II Site-Specific Ecological Risk Assessment

This document presents the approach for the Level I Screening-Level Ecological Risk Assessment (referred to as the ecoscreen). The ecoscreen identifies sites which clearly do not present risks to ecological receptors so that resources for site-specific investigations can be targeted to sites with higher potential risk. A site-specific risk assessment would include considerable additional field work such as biota tissue sampling. A site-specific ecological risk assessment may also address population level effects instead of effects just on individuals. The ecoscreen consists of two phases:

- Scoping Assessment
- Screening Assessment

The ecoscreen incorporates a number of Technical Decision Points (TDPs). Based on the information developed and presented within a given segment of the assessment, these TDPs determine one of three recommendations:

- No further ecological investigation at the site, or
- Continue the risk assessment process, and/or
- Undertake a removal or remedial action

The first or third recommendation can be made either because the residual contamination at the site does not pose excessive risk to ecological receptors, or because the available information indicates that further investigation will not affect the management decisions regarding the site. The recommendation to continue the risk assessment process indicates the need for additional information and data collection from scientific literature and/or through additional investigation and sampling of environmental media at the site.

Objective and Purpose

This guidance adopts standard screening-level ecological risk assessment (the ecoscreen) methods excerpted from US EPA (1997a, 1999a, 1999b) and other EPA guidance documents. The purpose of issuing this guidance is to provide a tool for conducting consistent ecological screenings by RCRA hazardous waste permitted facilities and corrective action/remediation projects under Hazardous and Solid Waste Amendments (HSWA).

This guidance presents a detailed method for completing these assessments. The ecoscreen

addresses current and potential future risks to ecological receptors and their habitats residing within the site itself, areas adjacent to the site, and in the locality of the site. The guidance also provides direction for the use of EPA guidance documents. This guidance is advisory only and not intended to present the only acceptable approach for completion of an ecological risk assessment. Some of the potential benefits of conducting the ecoscreen are:

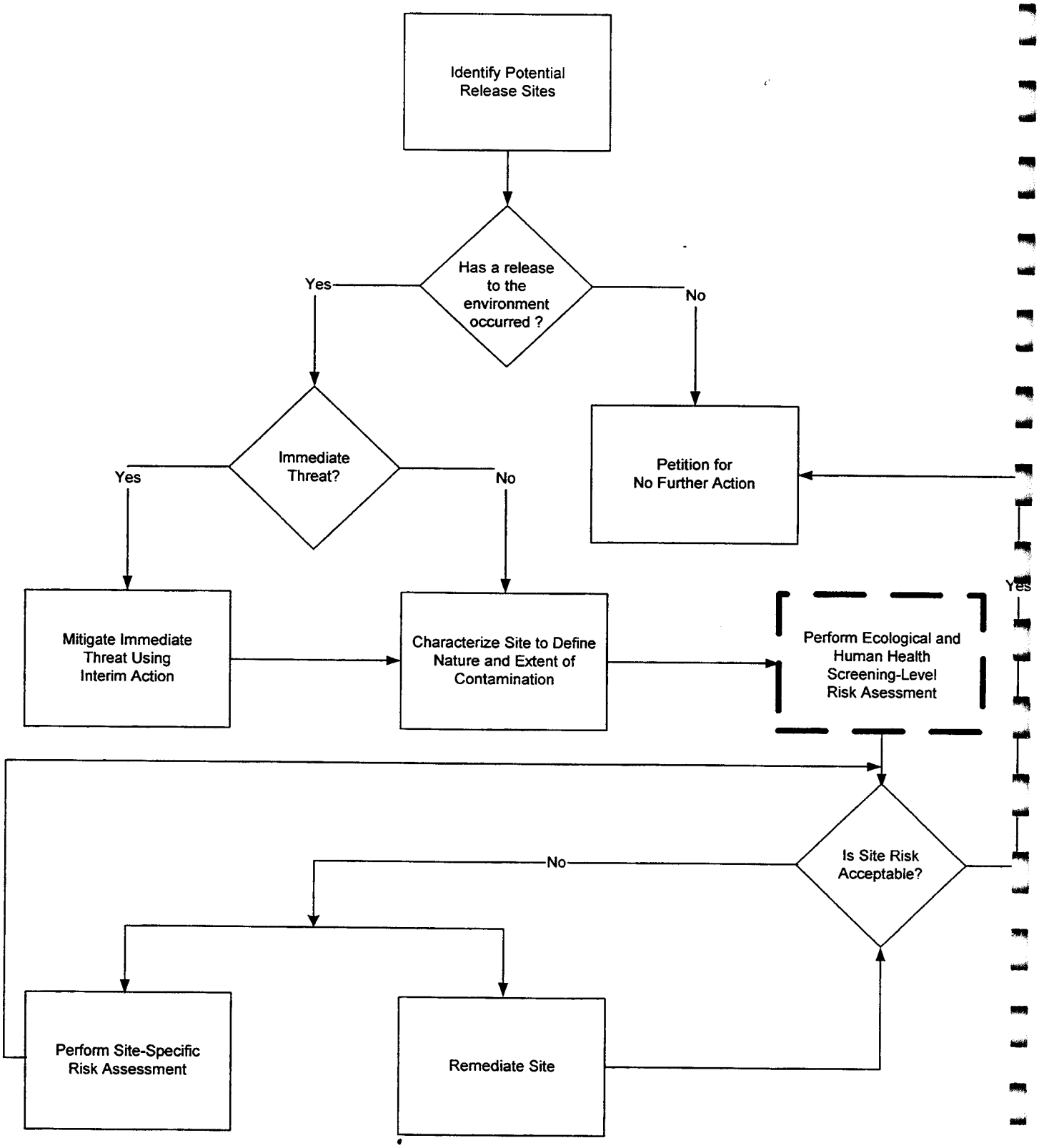
- Determining the need for interim action
- Screening sites to determine the need for
- further evaluation
- Prioritizing multiple sites
- Focusing future site-specific risk assessment efforts

The role of the ecoscreen in overall site characterization is shown in the flowchart in Figure 1. Figure 2 outlines the individual steps within the ecoscreen and how the ecoscreen can be incorporated into the RCRA Facility Investigation (RFI) process. The ecoscreen can also be appropriate for other portions of the RCRA investigation of a site. The ecoscreen can be completed subsequent to an interim measure or presumptive remedy to see if the measure or remedy may be suitable for final remediation. An ecoscreen can also be done as part of a Corrective Measures Study (CMS) to determine if the proposed alternatives considered under the CMS meet the required standard of protecting the environment.

Prerequisites

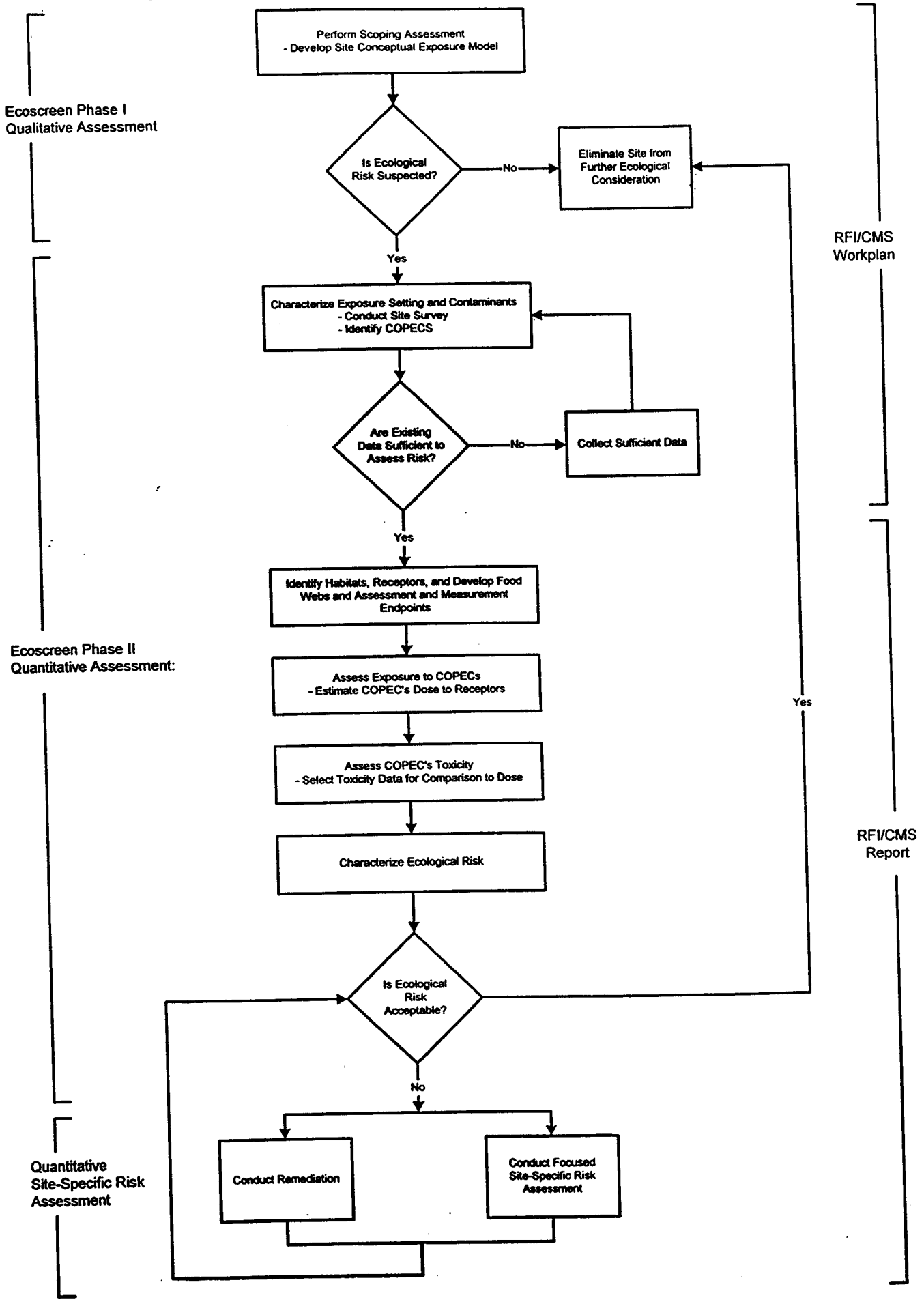
Site characterization must be sufficient to define the nature and extent of contamination in order to assess the impact on ecological receptors. To conduct a risk assessment the type, quantity, and distribution of contaminants must be identified along with migration pathways that could potentially allow receptors to be exposed to the contaminants. Characterization of contaminant migration potential should include migration within the site and beyond the site boundary. Because site and contaminant characteristics strongly influence the number and type of samples required, some of the documents listed in Appendix A should be consulted for guidance on sampling and site characterization. However, for **all media**, more than a single sample should be taken to determine the environmental concentrations to which receptors are being exposed.

Figure 1. Risk-based Corrective Action Decision Strategy



The ecological screening-level risk assessment is often performed during site characterization activities.

Figure 2. Ecological Screening-Level Risk Assessment



Phase I: Scoping Assessment

1.0 Scope and Intent

Scoping is a conservative, qualitative determination of whether there is any reason to believe that ecological receptors and/or complete exposure pathways may exist at or in the locality of the site where a release of hazardous waste/constituents has occurred. Scoping is intended to identify sites that are obviously devoid of ecological habitats (e.g., buildings, paved parking lots) and/or where exposure pathways are obviously incomplete (e.g., contaminants without the potential for subsurface transport to or direct access by receptors), so that they can be removed from the quantitative screening. Completion of a scoping assessment relies heavily on the professional judgment of the investigator to qualitatively evaluate the potential threat to biota[1] posed by site-related contaminants.

The scoping assessment uses a habitat approach as the basis for identifying the potentially complete exposure pathways between the areas of contamination and specific species or habitats which occupy, or potentially could occupy, the site. A preliminary site conceptual exposure model (PSCEM) providing a list of the potentially exposed receptors and potentially complete exposure pathways in the scoping report is used to determine whether further assessment (i.e., Phase II: Screening Assessment) and/or interim measures[2] are required or whether the site poses minimal threat to ecological receptors at or near the site. Based on information presented in the scoping assessment HRMB will determine whether quantitative screening assessment or interim measures may be required for the site.

1.1 Compile and Assess Basic Site Information

The basic information on the physical and biological aspects of the site should be obtained. Most of this information will have already been obtained as part of the initial investigation or during the RFI process. This site information includes, but is not limited to, documentation of the following:

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[1] The term "biota" refers to non-domesticated terrestrial and aquatic plants and animals, however, it may include domesticated species, such as livestock. If livestock grazing and/or watering occurs at or in the locality of the site the potential risks to these livestock and people consuming the livestock and/or their products must be evaluated under a human health site-specific risk assessment. Note, however, that one can evaluate risk to a herbivore mammal to make inferences about the potential risk to livestock.

[2] Interim measures are the actions identified and implemented to control or abate threats to the environment from releases and/or to prevent or minimize the further migration of contaminants while long-term remedies are pursued.

- Surface area and physiographic setting of the site;
- Current and historical uses of the site and nearby properties;
- Current and reasonably likely future land and/or water use(s);
- Sensitive environments[3] at, adjacent to, or in the locality of the site;
- Known or suspected presence of threatened, endangered, candidate, proposed, species of concern and/or sensitive species or their habitats in the locality of the site[4]
- Accurate site and regional maps showing buildings, roads, pavements, on- and off-site land uses, sampling locations, wetlands, surface water bodies, sensitive environments, etc.;
- Types of hazardous substances reportedly released at the site;
- Magnitude, rate, and extent of migration of any hazardous substances reportedly released at the site.

1.2 Site Visit

This is an extremely important aspect of the scoping phase. A site visit should be conducted to directly assess ecological features and conditions, and verify that the expected ecological features actually still exists at the site and verify the current land use. This is also an excellent opportunity to record dominant plant and animal species at the site.

Site visits should be conducted at times of the year when ecological features are most apparent, i.e., spring, summer, early fall. Visits during one season (e.g., the winter time) might not provide evidence of the presence or absence of receptors and potential exposure pathways. The following areas should be visited:

- the site itself,
- areas adjacent to the site, and

---

[3]Sensitive environments or habitats are defined as federally- or state-designated areas that require protection or special consideration; Table 1 lists several types of sensitive environments.

[4]This information should be documented by response letters from the New Mexico Department of Game and Fish (NMGF), tribal environmental agencies, the U.S. Fish and Wildlife Service (USFWS), the U.S. Forest Service (USFS), the New Mexico Forestry Division (NMFD) of the Energy, Minerals and Natural Resources Department, or the U.S. Bureau of Land Management (USBLM).

Table 1. SENSITIVE ENVIRONMENTS FOUND IN NEW MEXICO

National Parks and National Monuments

Designated or Administratively Proposed Federal Wilderness Areas

National Preserves

National or State Wildlife Refuges

Federal land designated for protection of natural ecosystems

State land designated for wildlife or game management

State designated Natural Areas

All areas that provide or could potentially provide habitat for state and federally listed threatened or endangered species, those species that are currently petitioned for listing, and species designated by other agencies as sensitive or species of concern.

All areas that provide or could potentially provide habitat for state protected species as defined in the Wildlife Code, Chapter 17 of the New Mexico Statutes

All areas that provide or could potentially provide habitat for migratory birds as protected by the Migratory Bird Treaty Act (16 U.S.C. §§ 703 - 712)

All areas that provide or could potentially provide habitat for bald eagles and golden eagles as protected by the Bald and Golden Eagle Protection Act (16 U.S.C. §§ 668 - 668d.)

All areas that provide or could potentially provide habitat for song birds as protected by the state of New Mexico statute (New Mexico Statute, 1978, Chapter 17, Game and Fish, 17-2-13.)

All areas that provide or could potentially provide habitat for hawks, vultures and owls as protected by the state of New Mexico statute (New Mexico Statute, 1978, Chapter 17, Game and Fish, 17-2-14.)

All areas that provide or could potentially provide habitat for horned toads and bullfrogs as protected by the state of New Mexico statute (New Mexico Statute ,1978, Chapter 17, Game and Fish, 17-2-15 and 16 resp.)

All perennial waters (e.g., rivers, lakes, playas, wetlands, sloughs, ponds, etc).

All ephemeral drainages that provide significant wildlife habitat or that could potentially transport contaminants off site to areas that provide wildlife habitat (this will probably include all ephemeral drainages).

All riparian habitats.

All perennial and ephemeral wetlands (not limited to jurisdictional wetlands).

All areas that are potentially important breeding, staging, and overwintering habitats as well as other habitats important for the survival of animals during critical periods of their life cycle.

- areas in the locality[5] of the site.

Photos taken during the site visit can be extremely valuable additions to the risk assessment report, particularly for documenting the nature, quality, and distribution of vegetation, other ecological features, and potential exposure pathways. The site visit can also be used to verify surface water flow patterns, which may be difficult to determine from other sources and may change with time.

The following activities should be performed during the site visit:

- search for signs (e.g., visual, olfactory, etc.) of a chemical release,
- note the site topography and search for any signs of surface water runoff/run-on, other drainage patterns, and potential migration pathways of chemicals within the site or offsite,
- note plant and animal species within, adjacent to, and in the locality of the site,
- assign habitat type and note possibility of presence of threatened and endangered species
- search for any signs (seeps, springs, cut banks, etc.) of groundwater discharge to the surface,
- note any natural or anthropogenic site disturbance.

Ecological scoping checklists presented in Appendix A of this document and in the appendices of *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment* (US EPA, 1997a) can be adopted for collecting this information.

1.3 Identify Preliminary Contaminants of Potential Ecological Concern

Either site-specific historical information or the results of chemical analyses of suspected source media can be used to develop the preliminary list of contaminants of potential ecological concern (COPECs). For scoping, the site-specific history of hazardous substance uses and releases is typically the source of potential contaminant information. Potential contaminants for ecological risk assessment are developed separately from potential contaminants for human health because

[5]Locality of the site refers here to any area where an ecological receptor is likely to contact site-related chemicals. The locality of the site considers the likelihood of contamination migrating over time and places the site in the context of its general surrounding. Therefore, locality is typically larger than the site and the areas adjacent to the site.

contaminants present at concentrations which are not generally considered a threat to human health may cause a threat to individual species or biological communities. The list should generally include all chemicals known or suspected of being released at the site based on information about prior activities and operations.

Although the focus of the screening-level ecological risk assessment is on hazardous substances alone, the assessment should also consider other stressors, such as mechanical disturbances or extreme climatic conditions, that might potentially add to the severity of adverse effects from contamination. The results of this evaluation should be summarized, preferably in a chart, to simplify the tracking of contaminants through the various levels of the risk assessment.

1.4 Develop a Preliminary Conceptual Site Exposure Model

This involves constructing a conceptual model of the receptors expected to be present at the site and using information about the life history of those potential receptors to determine if complete pathways exist for exposure of these receptors to contamination at the site (e.g., between contaminated surface water, fish, and an eagle). Complete exposure pathways are those having all the following attributes:

- a source and mechanism for hazardous waste/constituent release to the environment,
- an environmental transport medium for the hazardous waste/constituent,
- a point of receptor contact (i.e., exposure point) with the contaminated media or through the food web, and
- an exposure route to the receptor.

One should start by considering all possible exposure pathways for each type of receptor (e.g., local invertebrate population), then eliminating those receptor-pathway interactions that do not actually occur or are not expected to occur at the site. Evidence should be presented demonstrating why a particular pathway was eliminated. For example, terrestrial mammals have the potential to be exposed to environmental contaminants through inhalation of airborne contaminants, ingestion of soil, ingestion of water, ingestion of contaminated food, and dermal exposure to soil or water. If the contaminated site and areas in its locality completely lack any surface water, the pathways for ingestion of water and dermal exposure to water would be eliminated. The pathways for soil ingestion and dermal exposure to soil may not exist in areas that are completely paved now and will remain completely paved in the future (provided there is

no access for burrowing animals[6]). In order to remove a site from further consideration based on a lack of receptors, it is necessary to demonstrate that the contamination is inaccessible to wildlife (for example, buried below the ecologically relevant depth of five feet[7]) and that this inaccessibility will be maintained in the future. The absence of contaminant transport to surface water (via surface runoff, erosion or groundwater)should also be demonstrated . This also requires some assurance that adequate records will be maintained on the contamination at the site in order to help prevent possible future exposures.

Once all the potential exposure pathways have been identified, the probable complete exposure pathways at the site should be constructed in a figure similar to the example in Figure 3.

This scoping phase of the ecoscreen presents one method for separating those sites for which an ecological screening risk assessment may not be required. It also serves as the initial information gathering phase even for sites clearly in need of a more detailed assessment of potential risk.

1.5 Scoping Assessment Report

The information presented in Sections 1.1 through 1.4 may be submitted in a brief scoping assessment report. This report should summarize the site information and evaluation of receptors and pathways to support the decision made in the first Technical Decision Point in the following section.

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[6]Burrowing animal means a ground-dwelling animal that uses a hole/burrow or tunnel in the ground for nesting, habitation, and refuge. Examples of burrowing animals include burrowing owl and small animals such as badger, prairie dog, gopher, vole, fox, ants, beetles, etc.

[7]Ecologically relevant depth means the depth below ground surface (bgs) that can reasonably be accessed by wildlife (e.g., burrowing animals) or root system of plant species inhabiting the site. Although trees and shrubs root commonly up to about 460 cm (15 feet), with possible exception of one-seed juniper (*Juniperus monosperma*) which rooting depth may extend to 6,096 cm (200 feet) bgs (Foxx et al., 1984), the ecologically relevant depth is within the upper five feet.

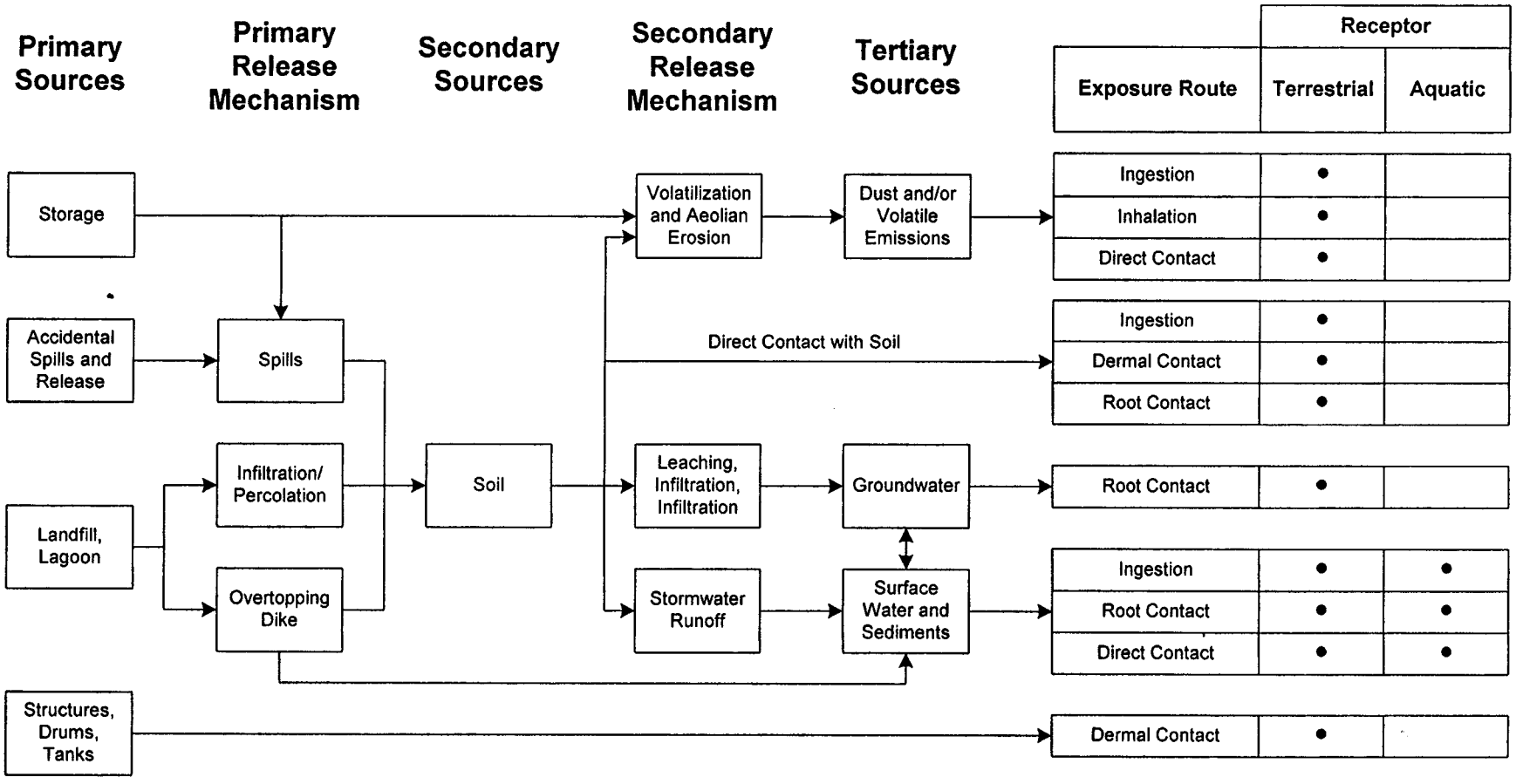

Figure 3. Example Ecological Conceptual Exposure Model for a Hypothetical Site

✦First Technical Decision Point: Is Ecological Risk Suspected?

The information presented in the scoping report can be used to eliminate the site from further consideration for ecological screening level or site-specific risk assessment if a complete exposure pathway does not exist and will not exist in the future at the site. Therefore, the scoping report needs to carefully document the reasoning behind this decision.

The decision to remove sites from consideration for a screening level risk assessment should be made with the concurrence of the regulatory agency to assure that later re-analysis of sites will not be necessary. For those sites where valid pathways for potential exposure exist or may exist in the future, a Phase II screening assessment is required.

Phase II: Level I Screening Ecological Risk Assessment

2.0 Problem Formulation

This step of the Phase II ecoscreen establishes potential links between contaminants of potential ecological concern (COPECs) and responses in site-specific receptors by means of a revised conceptual site exposure model. It also represents the first quantitative examination of potential risks from contaminants at a site. Each step of the problem formulation should assess whether the available information is adequate for making these quantitative determinations. This allows the problem formulation step to both define the problem and determine if adequate data exist to answer it.

2.1 Conduct Site Surveys

Site surveys gather site-specific data necessary for identifying relevant and complete contaminant-pathway-receptor relationships. The survey should identify the habitat types at and near the site, both aquatic (e.g., perennial streams and associated wetlands, ponds, ephemeral streams, etc.) and terrestrial (e.g., grassland, pinon-juniper woodland, ponderosa pine forest, mixed conifer forest, etc.), as well as species of plants and animals associated with those habitats. Efforts should be made to survey the site at several times of day and over a period of time sufficient to observe biota that may use the site at different time of day and/or during different seasons so that most species will be identified, or to locate such information in the literature. Once receptor species have been selected based on the survey, information on the life history of species needed to define exposure pathways should also be gathered at this point from the literature, including sources such as the *Wildlife Exposure Factors Handbook* (US EPA, 1993g).

2.2 Characterize Exposure Setting and Contaminants

This narrative description of ecological conditions at and near the site should include all the information listed under Section 1.1 as well as the more detailed information gathered during the site survey described under Section 2.1. It also includes identification and characterization of the habitats at the sites. Furthermore, this section includes evaluation of all site sampling data and the final determination of contaminants of potential ecological concern (COPECs).

Prior to beginning the data evaluation process, site sampling investigation must be sufficient to

delineate the nature and extent of contamination as described in the Prerequisites Section. All potentially contaminated media should be sampled as part of site characterization, and any media for which a potentially complete pathway to receptors exists should be included as part of the ecoscreen. The appropriate method of sample collection for the purposes of site characterization, unless prior approval has been obtained by HRMB, is to obtain discrete samples at depth intervals that are relevant to ecological receptors exposure and contaminant transport pathways of concern (i.e., sampling depth should be chosen purposely within that depth interval). For example, assessment of surface exposure will be more adequate if soil samples are collected from the shallowest depth that can be practically obtained. Usually the top 2 centimeters (cm) are of primary concern for the ingestion of soil pathway. Subsurface soil samples are important, however, if soil disturbance or plant root uptake or exposure of terrestrial invertebrates burrowing animals are likely. Therefore, concentrations of soil contaminants in the top 20 cm are appropriate for evaluating exposures to terrestrial invertebrates. It should be noted that all facility-wide and/or site-specific background levels require approval by the Hazardous and Radioactive Materials Bureau prior to use (see the HRMB Position Paper: *Application of Inorganic Background Concentrations in the Risk Assessment Process*).

Ground water and surface water samples obtained for site characterization for inorganic constituents must be unfiltered. However, for the purposes of determining contaminant environmental transport[8] and evaluation of potential risks to aquatic communities from surface water or groundwater discharging to surface water, analyses of dissolved concentrations are also required (see also Section 2.5.2). General water chemistry parameters such as pH and hardness may be important for sites where inorganic contaminants are an issue.

The general approach for evaluating sampling needs, developing a sampling and analysis plan, and conducting field sampling should follow the *Guidance for the Data Quality Objectives Process* (US EPA, 1994a), the *RCRA Corrective Action Plan* (US EPA, 1994b), the Guidance for Data Useability in Risk Assessment (Part A) (US EPA, 1992a, the *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A)* (US EPA, 1989b), the *RCRA Sampling Procedures Handbook* issued by Region 6 EPA (US EPA, 1995c), *Guidance for Data Quality Assessment: Practical Methods for Data Analysis* (US EPA, 1996c), *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance* (US EPA, 1989d), *Sediment Sampling Quality Assurance User's Guide* (US EPA, 1984), *Soil Sampling Quality Assurance Guide* (US EPA, 1989e), and *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987) and should be submitted for approval to HRMB.

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[8]Filtered water samples provide valuable information for evaluating chemical transport within an aquifer or surface water body.

2.2.1 Evaluate Data and Select Contaminants of Potential Ecological Concern

A list of the preliminary contaminants of potential ecological concern (COPECs) determined during the scoping phase is further evaluated in this section based on the results of sampling done at the sites. This list may be lengthy for sites with complex sources. The objective of this section is to describe a selection process by which preliminary COPECs can be evaluated for elimination or retention as contaminants of potential ecological concern (COPECs). This process is shown in Figure 4.

This section describes specific steps that should be followed to refine a list of site-related COPECs. These specific steps are shown in Figure 1 and discussed below.

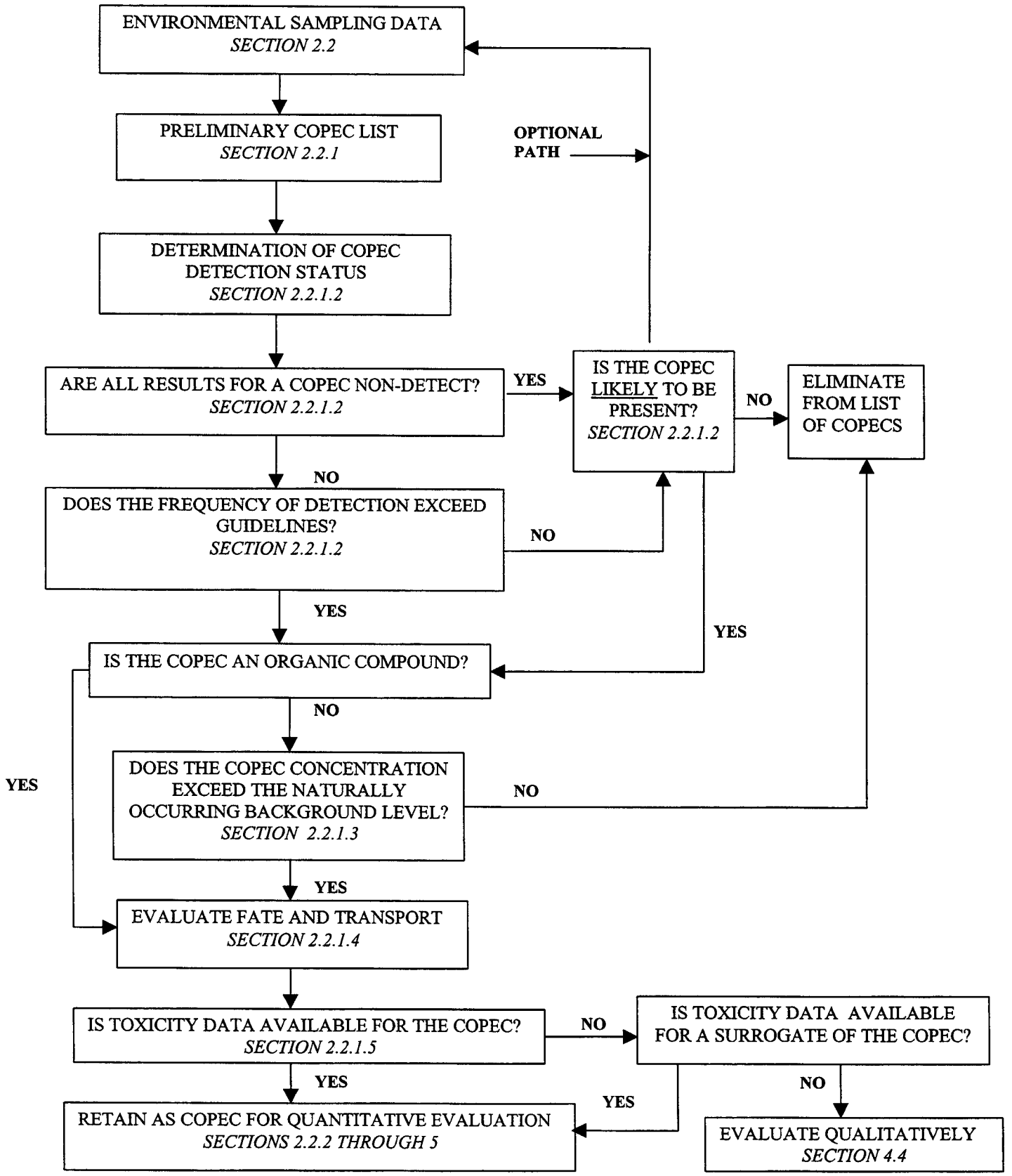
1. Gather all data available from the site investigation(s) for all preliminary COPECs and media (Section 2.2.1.1),
2. Evaluate a preliminary COPEC detection status (Section 2.2.1.2)
3. Compare preliminary COPEC concentrations with inorganic background values (Section 2.2.1.3)
4. Evaluate environmental fate and transport properties (Section 2.2.1.4)
5. Develop a COPEC list of chemicals that are likely to be site-related for use in the ecoscreen (Section 2.2.1.4).

2.2.1.1. Combine Available Data from Site Investigation(s)

Once the sampling investigation has been completed using recommended literature sources (see Section 2.2), gather data from all sampling events even if different analytical methods were used. All media identified in the scoping phase as leading to potentially completed exposure pathways should be sampled. All data should be sorted by environmental medium of concern and sampling event. It should be ensured that needs of the ecoscreen have been incorporated into the DQOs and chemical sampling program to determine the nature, extent, and degree of site contamination. Bioavailability of contaminants should not be factored in for a screening level ecological risk assessment; however, it may be discussed qualitatively among uncertainties of the ecoscreen in Section 4.4 and be addressed quantitatively in a site-specific risk assessment. A written discussion of site information used in compiling the list of preliminary COPECs should be provided in the ecoscreen report.

If the methods used to analyze samples from different sampling events (i.e., time periods) are

FIGURE 4. COPEC IDENTIFICATION PROCESS



similar in terms of the types of analyses conducted and the QA/QC procedures followed, the data may be combined for the purpose of the ecoscreen.

Any data sets eliminated from the ecoscreen should be included in the report and justification for such elimination must be fully described in the ecoscreen report.

2.2.1.2. Evaluate Detection Status

The evaluation of preliminary COPECs detection status includes the following steps:

- Evaluation of the analytical methods used
- Evaluation of the quality of data with respect to:
  - sample quantitation limits, qualifiers and codes
  - blanks
- Evaluation of the frequency of detection

Evaluate Analytical Methods

This step of data evaluation determines which analytical method results are appropriate for use in quantitative ecoscreen. Although analytical results that are not specific for a given compound (e.g., total organic carbon, pH, Eh, etc.) are generally inappropriate for quantitative ecoscreen, they are useful when evaluating sources of contamination or potential fate and transport of contaminants, including their bioavailability . Therefore, these types of data may be included in the summary of COPECs for the quantitative ecoscreen. Also, the results of analytical methods associated with unknown or no QA/QC procedures should be eliminated from further quantitative use. These types of data, however, may be useful for qualitative discussion of uncertainties in Section 4.4.

The outcome of this step is a set of site data that has been developed according to a standard set of sensitive, chemical-specific methods (e.g., SW-846 Methods [US EPA, 1998a]) with QA/QC procedures that are well documented and traceable. It is critical that all uncertainties associated with the data be determined (see steps discussed below) to ensure that only data that are appropriate and reliable for use in the quantitative ecoscreen will be carried through this process.

Evaluate Quantitation Limits

This step involves evaluation of quantitation limits (QLs) and detection limits (DLs) for all of the chemicals investigated at the site. It is important that the detection limits be low enough to detect concentrations of ecological significance[9]. Although QLs needed for the ecoscreen should be specified in the DQOs for the sampling and analysis plan (see US EPA, 1994a), for some chemicals, data may be obtained from historical sampling events using high QLs.

This evaluation may result in the re-analysis of some samples, the "proxy" (or estimated) concentrations (e.g., at DL or ½ DL), or the elimination of certain chemicals from further consideration, because they are believed not to be present at the site. However, at the minimum, the following possibilities should be examined prior to eliminating chemicals because they are not detected or conducting any other manipulation of the data:

- if the sample quantitation limit (SQL)[10] of a chemical is greater than corresponding environmental standards (e.g., WQCC *New Mexico Standards for Interstate and Intrastate Streams* and *State of New Mexico Ground and Surface Water Quality Protection Regulations*) or criteria (e.g., *Ambient Water Quality Criteria* [AWQC]) or reference values such as the *EPA Region V Ecological Data Quality Levels* [EDQLs] (US EPA, 1996a), then the chemical may be present at levels greater that these reference concentrations which may cause potential risk being overlooked; and
- if a given SQL is considerably higher than positively detected values in other samples in a data set, then it could bias the data set.

One appropriate option for a site ecoscreen is to assume that the chemical having **SQL greater than reference concentrations** is present in the sample at the SQL and carry the chemical through the ecoscreen, essentially conducting the assessment on the SQL. Re-analysis of the sample or collection of additional data is a second (preferred) option discouraging elimination of chemicals that may be present below their QL but above a level of potential concern for the ecoscreen.

If SQLs for a given chemical are unusually high in some samples (e.g., due to matrix interferences) considerably exceeding the positive results reported for the same chemical in other

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[9]Facilities may use the EPA Region V Ecological Data Quality Levels (US EPA, 1996a) for identifying analytical methods with detection limits low enough to detect chemical concentrations of ecological significance.

[10]The sample quantitation limit is defined as the detection limit that accounts for sample characteristics, sample preparation, and analytical adjustments such as dilution (US EPA, 1992a).

samples, the samples should be either re-analyzed (preferred option) or excluded from the quantitative evaluation if it causes the calculated exposure concentration to exceed the maximum detected concentration for a given data set.

Evaluate Qualified and Coded Data

Various qualifiers and codes attached to analytical results by the laboratory personnel performing samples analysis or the data validation personnel usually indicate QA/QC problems and questions concerning compound identity, concentration, or both.
All qualifiers and codes must be addressed before the compound can be used in quantitative ecoscreen.

At a minimum, current EPA guidance documents concerning qualifiers (e.g., guidelines for inorganic compounds and organic compounds [US EPA, 1994c, d]) should be consulted prior to evaluating qualified data. Ensure that definitions of data qualifiers used in the data set for the site are reported and are current.

Evaluate Blanks

Blanks are analytical quality control samples analyzed in the same manner as site samples. Therefore, blank samples provide a measure of contamination that has been introduced into a sample either (1) in the field while the samples were collected or transported to the laboratory or (2) in the laboratory during sample preparation and analysis. US EPA (US EPA, 1989b) defines four types of blank samples: trip blank, field blank, laboratory calibration blank, laboratory reagent or method blank, and water used for blanks.

To prevent the inclusion of non-site related chemicals in the risk assessment, the concentrations of chemicals detected in blanks must be compared with concentrations of the same chemicals detected in site samples associated with the blanks. If the association between blanks and site data cannot be made, blank data should be compared to the results from the entire sampling data set. The result of the comparison of site sample chemical concentration with blank chemical concentration depends on whether the chemical detected in blanks is a common laboratory contaminant or a contaminant not commonly used in laboratories.

If **compounds considered common laboratory contaminants** (i.e., acetone, 2-butanone [methyl ethyl ketone], methylene chloride, toluene, and the phthalate esters) are detected in any

of the blanks, the site sample results should be considered as positive results only if the concentration of the compounds in the site sample exceeds ten times the maximum concentration detected in the applicable blanks. If the concentration of a common laboratory contaminant is less than ten times the blank concentration, then the compound is treated as a non-detect in that sample. If all site samples contain concentrations of a common laboratory contaminant that are less than ten times the concentration of a contaminant measured in the blank, then, the compound can be completely eliminated as a COPEC.

If the blank contains detectable concentrations of one or more organic or inorganic **compounds that are not considered common laboratory contaminants** then the site sampling results should be considered as positive results only if the concentration of the compound in the site samples exceeds five times the maximum compound concentration detected in the applicable blanks. If the concentration of a compound in site samples is less than five times the blank concentration then the compound is considered non-detect. If all samples contain concentrations of a compound that are less than five times the concentration of this compound measured in the blank, then, the compound can be completely eliminated as a COPEC.

Note, however, that in order to consider blank contamination in the COPEC selection process, the following must be ensured:

- good data quality and rigorously implemented QA/QC plan and good industry sampling and analysis procedures;
- the effect of eliminated compounds on the overall risk estimates must be clearly described in the uncertainty analysis section of the ecoscreen report.

Evaluate Detection Frequency

Because carrying a large number of compounds through a quantitative ecoscreen may be complex and it may require considerable amount of time and resources, the procedure described below may be used if applicable to reduce the number of COPECs in each medium. However, prior to implementing this procedure (1) the rationale for the procedure must be clearly documented in the ecoscreen report and (2) historical site information must be carefully examined.

Chemicals likely to be present at the site[11] should not be eliminated from the quantitative ecoscreen, even if the results of the procedure described in this section indicates that such an elimination is possible.

Chemicals that are not detected in any samples in one medium but that are detected in other media. Generally, these chemicals should not be eliminated as COPECs, unless information exists to indicate that those chemicals are unlikely to be present at the site[8]. For example, if chemicals with similar fate and transport and characteristics are detected frequently in soil at a site, and some of these chemicals are detected frequently in surface water while the others are not detected, then the undetected chemicals are likely present in the surface water and therefore, need to be included in the ecoscreen as surface water COPECs.

The outcome of this step is a data set that only contains chemicals for which positive data (i.e., analytical results for which measurable concentrations are reported) are available in at least one sample from each medium. The assumption is that all positive data to which no uncertainties are attached concerning either the assigned identity of the chemical or the reported concentration (i.e., data are not "uncertain" or "qualitative") are appropriate for use in the quantitative ecoscreen.

Chemicals that are infrequently detected. These chemicals may be artifacts in the data set due to sampling, analytical, and other problems, and therefore, might not be related to site operations or disposal practices. The chemical should be considered as a candidate for elimination from the quantitative ecoscreen if:

- it is detected infrequently in one environmental medium, and
- it is not detected in any other media, and
- there is not reason to believe that the compound may be present in the site environmental media based on site sampling adequacy, historical data, and any other relevant information such as known degradation products.

Any detection frequency limit being used (e.g., five percent) should be approved by the HRMB prior to its use in this screen. As an example: if a frequency of detection limit of five percent is used, then at least 20 samples of a medium is needed (i.e., one detect in 20 samples equals a five percent frequency of detection). However, decisions about frequency of detection and sample

[11] The determination that a chemical is or is not likely present at the site should be made based on (1) site historical information and process knowledge <u>and</u> (2) evaluation of sampling adequacy at the site <u>and</u> (3) any other relevant information such as known degradation products or potential for bioaccumulation.

size will also consider other factors such as size of the contaminated area. **Compounds likely to be present at the site should not be eliminated.**

The reported concentrations and sampling locations of chemicals should be examined for **hot spots** (i.e., small or localized but highly contaminated areas), which may be important for short-term exposures of ecological receptors and which, therefore, should not be eliminated from the ecoscreen. All sampled media should be examined for detection of a given compound because some media may be sources of contamination for other media. For example, a compound that is infrequently detected in soil (a potential ground water contamination source) should not be eliminated as a site contaminant if the same compound is frequently detected in ground water.

Furthermore, infrequently detected compounds with concentrations that exceed corresponding environmental standards or criteria should not be eliminated as COPECs. **The elimination of any compounds from the ecoscreen along with justification for such elimination must be fully described in the ecoscreen report.**

2.2.1.3 Screen Against Inorganic Background Concentrations[12]

A comparison of site sample concentrations with background concentrations (e.g., using the geometric mean concentrations of the two data sets) is useful for identifying the non-site-related inorganic chemicals that are found at or near the site. EPA has issued guidance for ground water detection monitoring programs being conducted under RCRA. This guidance entitled "*Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities*" (US EPA, 1989d) and the *Draft Addendum to Interim Final Guidance* (US EPA, 1992b) provide a conceptual framework for determining and applying an appropriate statistical method for comparison of background and contaminated ground water data. These statistical methods and those presented in EPA's *Statistical Methods for Evaluating the Attainment of Cleanup Standards (Volumes 1 and 3)* (US EPA, 1989a; 1994e), *Guidance for Data Quality Assessment* (US EPA, 1996c) and in *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987) could be applied to soil background comparisons.

The objective of the statistical analysis for the ecological risk assessment is to determine if site inorganic chemical concentrations differ significantly from inorganic background concentrations

[12] Inorganic background concentrations are defined as naturally-occurring concentrations of inorganic constituents in an environmental medium (sediment, soil, air and water) not affected by Facility operations (HRMB SOP II. A.2: *Site-Specific Background*).

or values. The choice of the appropriate statistical test should be based on the distribution of the data, the percent of non-detects in background and/or site data, the presence of multiple detection limits, etc. Any statistical methods being used for comparison of site samples with background values should be identified and their use justified in the ecoscreen report.

Often, a single value to represent the inorganic background concentrations (BV[13]) is determined based on the mean or median of the collected samples (e.g., the 95% upper confidence limits [UCLs] for the mean) or the maximum concentration (e.g., the upper tolerance limits [UTLs]) or pre-determined regional inorganic background levels obtained from the literature. When the site sample concentrations fall above the BVs the preliminary COPECs are retained as COPECs. Note, however, that the 95% UCL of the site samples **should not** be compared with the UTL of the background samples (US EPA, 1989d; 1992b). This is not valid statistical comparison because the UTL represents a maximum value while the UCL is a mean. Therefore, if the UTL has been selected as a BV, each soil sample (not the mean) should be compared to the UTL. If any site soil sample exceeds the UTL, the preliminary COPEC must be retained as COPEC because this exceedance is indicative of site-related contamination.

As discussed in the HRMB Position Paper "*Application of Inorganic Background Values in the Risk Assessment Process*", if inorganic chemicals are present at the site at naturally occurring levels (i.e., in concentrations at or below facility-specific or site-specific [if applicable] or regional background), they may be eliminated from the quantitative screen. It is important that comparisons of a site and background metal concentrations consider both soluble and insoluble form of metals, if relevant. For example, background concentration should be determined for chromium (III) and (VI) separately for comparison with the site concentrations of respective chromium species. Facilities should submit values representative of background concentrations to the HRMB for approval prior to their use in ecoscreen. If background risk is of concern (e.g., in some cases background concentrations may present an excessive risk to ecological receptors), it should be estimated separately from site-related risk and included in the report so that it can be considered with other site information.

At some sites, a concern may exist for "hot spots" or situations where a small proportion of the site is contaminated above inorganic background, yet application of distributional tests show no difference between site and background levels of randomly sampled data. For example, there may have been too few samples collected at the site, so that perhaps only one or two measurements are elevated above background. One method for handling this situation is to

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[13]BV or background value means an inorganic chemical concentration representative of background concentrations that has been approved by the Hazardous and Radioactive Materials Bureau.

compare each site measurement to a "hot measurement" concentration value (US EPA, 1994e). This "hot measurement" value can be an EDQL, a standard, or some function of the background data (e.g., upper tolerance limit). The hot measurement value should be selected to identify excessive ecological risk beyond that of average site-wide exposures. If one or more site measurements equal or exceed the hot measurement value, the compound should be retained as COPEC and proceed to the environmental fate and transport evaluation.

The evaluation process below should continue for all organic preliminary COPECs and those inorganic preliminary COPECs that exceed inorganic background concentrations/values (see Figure 4). Both a justification for eliminating chemicals based on an inorganic background comparison and an overview of the type of comparison conducted should be included in the ecoscreen report.

2.2.1.4 Evaluate Contaminant Fate and Transport

Evaluation of the environmental fate of chemicals can substantially affect the selection of contaminants of potential ecological concern, determination of important exposure pathways to ecological receptors, and the feasibility and potential impacts of remediation strategies. At this point, the list of preliminary COPECs should be reviewed to evaluate any physico-chemical properties which may alter the way in which the impact of these preliminary COPECs is viewed in the risk assessment process. This is particularly true for any contaminants highly persistent and bioaccumulating in ecological receptors and food chains such as polychlorinated dibenzo-dioxins, PCBs, DDT and its breakdown products, organochlorine pesticides, chlorinated dibenzofurans, and metals capable of biomethylation (e.g., mercury). These compounds require consideration of more than their direct toxicity.

Persistence, Mobility, and Bioaccumulation

Physico-chemical parameters describing environmental persistence or mobility processes, include water solubility, log K_{ow} and K_{oc}, and environmental half-life. A contaminant's water solubility[14] influences its fate and transport in all environmental media and is especially relevant to ecological receptors exposure through aquatic pathways. Compounds soluble in water or pore water of soil/sediment are more available for chemical and biological transformations and are

[14]Water solubility is an upper limit on a chemical's dissolved (i.e., aqueous) concentration in water at a given temperature. Aqueous concentrations exceeding solubility may indicate sorption onto sediment, the presence of solubilizing chemicals such as organic solvents, or the presence of a non-aqueous phase liquid.

subject to the complex forces affecting the movement of water. Less soluble metal cations, such as aluminum, may enter solution at lower pH as a result of leaching from soils and become available for uptake by plants and aquatic animals.

The logarithm octanol/water partition coefficient (log K_{ow}) is the ratio of the chemical's concentration in octanol (representing lipid or "fat") to the concentration in water. K_{ow} provides a measure of the extent of chemical partitioning between water and octanol at equilibrium and, thus, describes a chemical affinity for the lipid portion of an organism's tissues. A high log K_{ow}, typically greater than 3, indicates higher concentrations in the octanol rather than in the water. K_{oc} is an equilibrium constant that measures the partitioning between organic carbon in the sediment and water (i.e., it measures a chemical's ability to attach or adsorb to particulate matter). K_{oc} is useful for describing mobility potential because it correlates better with adsorption to soil and sediment. A chemical's mobility is generally proportional to its water solubility and inversely proportional to K_{ow} and K_{oc}. Chemicals with log $K_{ow} < 2.7$ and $K_{oc} < 1000$ are considered to be highly mobile, while chemicals with log $K_{ow} \geq 4$ and $K_{oc} > 10{,}000$ generally have low mobility and therefore, high persistence potential (Connolly and Pedersen, 1988; Ney, 1998).

In general, organic chemicals with log K_{ow} values equal to or greater than 4.0 and inorganic chemicals with a whole-body bioconcentration factor (BCF)[15] equal to or greater than 100 have a high bioaccumulation potential (Connolly and Pedersen, 1988). These criteria were developed for aquatic environments and they have much less relevance to terrestrial systems; for terrestrial species, BCFs of as little as 0.03 can be biologically significant if the chemical residue is toxic (US EPA, 1989c). It is also important to remember, that the bioaccumulation potential of a chemical is only one factor implicated in the dose estimates for higher trophic level terrestrial organisms (e.g., a herbivore consuming large amounts of plant material contaminated with a metal having a soil-to-plant BCF of less than 1 (one) could still receive a toxic dose of this metal).

Persistence is measured by the number of days required to reduce a chemical's concentration by one-half through biotic and abiotic degradation/transformation processes. The greater the media-specific half-life[16], the more persistent a chemical is likely to be in the medium. Chemicals are considered highly persistent in water if their half-lives in water are greater than 90 days, and not

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[15]The BCF measures the concentration of a chemical in the organism relative to that of the immediate environment (soil, water, and sediments).

[16]A chemical's half-life is defined as an estimate of the time required for half of the original contaminant to be transformed by both chemical and biological processes.

persistent in water with half-lives lower than 30 days.

It is recommended that the criteria of bioaccumulation, persistence or mobility **not** be used for eliminating potential contaminants as COPECs.

Environmental Transformation

Known chemical or biological transformation products of preliminary COPECs or those that can be reliably predicted must be included in the process of COPECs' selection. The transformation or breakdown products of some compounds are often more toxic than the parent compound and, therefore, may present substantial ecological risk. For example, perchloroethylene (PCE) breaks down to vinyl chloride, which is even more toxic than its parent compound. Therefore, for COPECs that are likely to undergo transformation under the conditions found at the site, the anticipated breakdown products should be determined and added to the list of COPECs to be evaluated in this ecoscreen.

2.2.1.5. Develop a List of COPECs

Following the evaluation of site sampling data as specified in previous sections, all remaining preliminary COPECs (including their transformation products) are considered COPECs for the ecoscreen. The specific steps in the process for selection of COPECs are outlined in the flow diagram in Figure 4. However, toxicity information (i.e., toxicity reference values or TRVs) to be used in the quantitative ecoscreen may not be available for all COPECs. Nevertheless, a constituent should not be eliminated from the list of COPECs **only** because toxicity information is lacking; instead, limited or missing toxicity data must be addressed using best professional judgement, surrogate[17] toxicity data from a similar chemical, and should be discussed as an uncertainty.

Figure 1 also shows how COPECs should be evaluated based on the availability of toxicity data. Those COPECs lacking toxicological data in the literature will be evaluated qualitatively in the ecoscreen by using surrogate toxicity data from a similar compound, if available, or discussed as an uncertainty in the uncertainty analysis section of the ecoscreen report. Remaining COPECs will proceed to the quantitative ecoscreen.

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[17]Facilities should obtain HRMB approval for selecting surrogate compounds and using their toxicity data prior to performing ecoscreen.

Recommended Information for the Ecoscreen Report

The results of the COPEC selection process should be presented in a tabular format showing the initial list of preliminary COPECs, the final list of COPECs and the reason for each preliminary COPEC eliminated from further consideration. Any ecological screening levels used to retain or remove a COPEC should also be included in this table.

✦Second Technical Decision Point: Are Existing Data Sufficient to Assess Risk?

At this point, based on professional judgement and the revised conceptual site exposure model, the facility should determine if the sampling, conceptual model, and delineation of pathways is sufficient to support the ecoscreen. Any gaps in the sampling data or site information should be addressed prior to continuing with the quantitative screening process.

2.2.2. Identify Habitats and Their Boundaries

All habitats at and within the locality of the facility/site should be identified as a recognized habitat type based on vegetation, wildlife, and physical properties (see Section 1.1). A number of sources exist both for correlating habitat type with a given location and for information regarding plant and animal species commonly associated with a habitat type. These sources are described in the section for each habitat type. It is very important that information from these literature and agency sources be compared with the information gathered from the site visit to verify that the predicted habitat actually matches the one found at the site. Once a habitat type has been designated, the appropriate food web can be developed and assessment endpoints and receptor species chosen. Boundaries of habitats selected for evaluation should clearly be delineated and mapped. Include the following information:

- Facility boundaries
- Location(s) of release source(s)
- Habitat types and boundaries
- Water bodies and their associated watersheds
- Special ecological areas

2.2.2.1. Terrestrial Habitats

In New Mexico, there are several fairly well-defined terrestrial habitats that occur naturally. They are the forest (for example, mixed conifer, ponderosa pine, and pinyon-juniper), tallgrass prairie, shortgrass prairie, agricultural land, scrub/shrub, and desert. Particular types of vegetation characterize each of these habitats and can be used to identify them. A selection of some of the guides to determining habitat type can be found in Appendix A.

Habitat types may also be determined by reviewing land use and land classification maps (LULC maps) which are available in hard copy or electronically[18]. GIS mapping can also be used to define habitats. Classifications made using these maps should be verified with a combination of topographic maps available from the United States Geologic Survey (USGS) and other sources, aerial photographs (also available from USGS), and information gathered during site visits. A number of sites under consideration are in areas that have been disturbed by man sufficiently that they no longer match any of the naturally occurring habitats typical of the southwest. Particularly at heavily used areas at facilities, the two most common of these areas are usually described as "weed fields" and "lawn grass". Vegetation at "weed fields" should be examined to determine whether the weeds consist primarily of species native to the southwest or of introduced species such as Kochia . Fields of native weeds are best evaluated using the short grass prairie habitat. Fields consisting primarily of introduced agricultural weeds should be evaluated using the specific plants present at the site, and animal species likely to be present at the area or associated with neighboring habitats and thus potentially entering the area. Areas consisting primarily of lawn grass should be evaluated as a modified form of the shortgrass prairie food web. Site survey information should be used to determine which species of the feeding guilds in trophic levels one through three are present and also to determine if species in trophic level four of this web are actually utilizing the grass area. It is worth noting that much of the wildlife using lawn grass areas is crepuscular in nature, and site surveys of these areas are best done at dawn and dusk.

2.2.2.2. Aquatic Habitats

There are several types of aquatic habitats in New Mexico: lentic (lakes, ponds, and some wetlands), lotic (streams and rivers) and ephemeral (arroyos, some wetlands, puddles/pools, and playa lakes). These types are characterized by different wildlife, different sediment accumulation

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[18]Available on the World Wide Web from US GS at http://mapping.usgs.gov/index.html or from EPA at ftp://ftp.epa.gov/pub.

rates, and widely differing water chemistry (particularly salinity); the various types may respond differently to the impacts of contaminants. The habitat types referred to here mean the scientific habitats segregated based on wildlife and food web differences, not the "designated use" types developed under regulatory structures. Information pertaining to taxonomy, status, distribution, habitat, environmental association, feeding habits, management practices and references for aquatic and terrestrial ecosystems in New Mexico is available from the Biota Information System of New Mexico (BISON-M), maintained by the New Mexico Game and Fish Conservation Services Division in its BISON database[19].

For aquatic communities it is particularly important to address the potential for offsite transport of contamination to downstream habitats and receptors. While methods for addressing this issue in perennial water ecosystems such as streams are fairly well-established, off-site transport of contamination is also an important consideration for ephemeral waters such as arroyos and intermittent streams. One relatively simple screening level method for evaluating the potential impact of this contamination on downstream habitats is to assume that the levels of contamination found in the ephemeral waters will be transported to the nearest perennial waterway and to evaluate the potential impact to that aquatic community. This evaluation of potential impacts on downstream habitats supplements the risk assessment for any resident or seasonal community in the arroyo itself.

2.2.2.3 Special Ecological Areas

A special ecological area is a habitat that could require protection or special consideration on a site-specific basis because unique and/or rare ecological receptors and natural resources are present, or because of legislatively-conferred protection status (for example, national monument status or wild and scenic river designation). A list of types of areas that qualify as special ecological areas is shown in Table 2. All special ecological areas in or adjacent to the assessment area should be identified and evaluated for potential exposure. Representative species should be chosen for each of these areas and evaluated through the same risk assessment procedures used for other areas. Although the same procedures are used for evaluation of special areas as for other areas, identification of these areas is important for risk management decisions because the protection of these areas is crucial.

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[19] Available on the World Wide Web:http://www.fw.vt.edu/fishex/states/nm.htm. Technical contact at the NM Dept. of Game & Fish for this database is John Klingel (505-827-9904).

Recommended Information for the Ecoscreen Report

- number, type and size of habitats present in assessment area
- sources of information used to determine habitats
- plant and animal species typical of those habitats

2.2.3 Identify Ecological Receptors

For each of the habitats present at the assessment site, a group of ecological receptors should be identified which will eventually be used to develop the food webs for the risk assessment screening process. A number of information sources are available to determine the plant and animal species associated with a particular type of ecosystem. These include government organizations such as the US Fish and Wildlife Service (a source for wetland inventory maps), the U.S. Forest Service, the U.S. Bureau of Land Management, the New Mexico Natural Heritage Program[20], and tribal governments. Information pertaining to taxonomy, status, distribution, habitat, environmental association, feeding habits, management practices and references for all vertebrates and selected invertebrates in New Mexico is available from the Biota Information System of New Mexico (BISON-M), maintained by the New Mexico Game and Fish Conservation Services Division in its BISON database. There are also numerous regional field guides which can be used for development of habitat-specific food webs; a selection of some of the guides available are listed in Appendix A. Local chapters of private and professional organizations including the National Audubon Society, the Sierra Club, the National Geographic Society, and universities can also provide information on species found in New Mexico. These sources should be used to compile master lists of wildlife and plant species potentially present at the site.

Lists of species should include those typical of the area in addition to those seen during the site surveys. Therefore, the master lists should include species that, while not physically observed in the assessment area, occur in habitats that exist at or near the site and therefore could possibly be present at the site. In addition to these species, migratory species that pass through the assessment area should be included, particularly if the migratory species will remain in the area long enough to be exposed to contaminants at the site. All threatened and endangered species known or expected to frequent the assessment area should be included in the list of receptors.

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[20]University of New Mexico, 2500 Yale Blvd SE, Suite 100, Albuquerque, NM 87131

2.3 Develop a Habitat-Specific Food Web

The list of species and information obtained during characterization of the exposure setting will be used to develop a habitat-specific food web. A site-specific food web can be developed or the information on the plant and animal species present at the site can be used to assign the site to a food web developed in the literature for the habitat type at the site. In the ecoscreening process the food webs serve primarily to assist in the choice of assessment endpoints and selection of measurement receptors for each habitat under consideration. Food webs will include all the species from each habitat selected for evaluation. Representative species or measurement receptors from the food web will then be designated to evaluate assessment endpoints. A separate food web is needed for each habitat type found in the assessment area, even if the COPECs are the same.

Examples of food webs for all the common habitats occurring in New Mexico are reproduced in Appendix B. The example webs reproduced in the appendix are designed for the western region of the US, but should be modified when necessary to reflect the species composition of the actual assessment site under consideration. The species included should be limited to those reasonably known or expected to exist at the site. For example, the forest food web includes the pika as a herbivorous mammal, but this species occurs in New Mexico only at high altitudes, so it should not be included in webs for most sites.

2.3.1 Organize Food Web Structure by Trophic Level

The food webs should be organized by trophic levels, which reflect the role of a species' diet on its place in the ecosystem. These trophic level designations are designed to separate the species into herbivores, omnivores, and carnivores to coincide with the equations used to determine the potential dose of the COPEC ingested by members of each group. This is particularly important when bioaccumulating compounds are among the constituents of concern. **Trophic level 1** consists of all species which are primary producers, usually green plants. **Trophic level 2** consists of species that are primary consumers. These species are herbivores (which consume the plants from trophic level 1) and detritivores (which consume dead and decaying organic matter from sediment and soil). **Trophic level 3** contains omnivores (species which consume both plant and animal matter) and intermediate carnivores such as shrews. **Trophic level 4** or higher levels contain only carnivores. Once the expected species in the habitat are organized this way, they can more easily be divided into feeding guilds from which representative receptors can be chosen.

2.3.2 Group Receptors into Class-specific Feeding Guilds and Communities

A class-specific feeding guild is a group of species within a particular trophic level that share similar feeding strategies and dietary habits. Examples of class-specific feeding guilds are herbivorous mammal, omnivorous reptile, carnivorous mammal, and invertivorous bird. Class-specific guild designation is important because a representative species from each guild is used to assess the risk to all species in the guild. Organisms in the upper trophic levels are organized into these class-specific feeding guilds, but plants and invertebrates are grouped into communities distinguished by the media which they inhabit. Examples of these communities include terrestrial plants and sediment fauna. The reason for grouping higher trophic level organism into class-specific guilds and lower trophic level organisms into communities is because risk to upper trophic level organisms will be based on dose ingested, while risk to lower trophic level organisms will be based on the media concentration of COPECs.

2.3.3 Define Dietary Relationships Between Class-specific Guilds and Communities

Arrows on the example food webs (Appendix B) define the dietary relationships between class-specific guilds and communities. These relationships are determined by evaluating the dietary composition of the receptors for each class-specific guild or community. US EPA recommends that only those interactions that contribute more than 5 (five) percent of the total diet should be considered for development of a food web (US EPA, 1999a). This recommendation is based on the assumption that the food web can be simplified without underestimating potential exposure.

2.3.4 Identify Complete Exposure Pathways

Ecological receptors may be exposed to contaminated media by uptake through the food web. Additionally, receptors can be exposed to contaminated media directly through ingestion of vegetation, water, or soil/sediment, or through physical contact or inhalation.

In Section 1.4 potential pathways for migration of contaminants from a source to an ecological receptor were qualitatively defined. Once ecological receptors and dietary relationships for the site have been specifically identified the initial set of potentially complete exposure pathways may require modification. This step of evaluation requires an understanding of the physico-chemical properties and environmental fate and transport characteristics of the COPECs (see Section 2.2.1).

For example, the initial analysis may have included pathways of primary exposure to burrowing mammals; if the selection of habitat and receptors shows that these mammals are not likely to be present at the site, then this pathway need no longer be considered complete. Another example of an incomplete exposure pathway is a site with inaccessible buried contamination and no potential for off-site transport. At this point it may be possible to demonstrate that some pathways, though complete, do not contribute substantially to the potential exposure. The determination that a pathway does not contribute significantly to exposure should include supporting documentation from studies or guidance documents.

Recommended Information for the Ecoscreen Report

- All food webs developed for habitats occurring in the assessment area including
    - media for which web is constructed
    - division into trophic levels
    - class-specific guild designations for each trophic level
    - major dietary interactions
    - source citation
    - rationale for selection

2.4 Identify and Select Assessment Endpoints

Ecological risk assessment involves so many species that it is not practical to directly evaluate risks to all of the individual species in the ecosystem at a site. Assessment endpoints are particular components or attributes of the ecosystem which are critical to maintenance of the ecosystem structure and function. Assessment endpoints focus the risk screening on components of the ecosystem that may be impacted by contaminants at the site. These assessment endpoints establish a clear connection between regulatory goals for a site, endpoint species, and the objectives of the ecological risk assessment to protect the assessment endpoint. The endpoints should be chosen based on their ability to reflect functions critical to the ecosystem (ecological relevance), their susceptibility to stress by the contaminants, and their relevance to risk management goals.

For a given site, ecological relevance will be determined using professional judgement and based on site-specific information and preliminary surveys. Sensitivity to particular contaminants is related to both the mode of action of the contaminant and the life history characteristics of the species in question. Relevance to management goals can include protection of economically

valuable species or of aesthetic and recreation values, in addition to those assessment endpoints used for protection of the overall ecosystem.

Assessment endpoints can encompass a single species or a group of species with common characteristics, such as a class-specific feeding guild. Assessment endpoints specific to each guild and community within each trophic level of the food webs should be identified. Examples of assessment endpoints for guilds include seed disperser, major food source for predator, decomposer/detritivore, pollinator, or (for predators) regulator of prey species. While aesthetic or societal value can be used to add a species for consideration as representative of an assessment endpoint, lack of societal value should never be used to remove a species that is ecologically important from consideration. Examples of assessment endpoints for communities include diversity (species richness), community composition, productivity, major food source for consumer species, or habitat for wildlife. Assessment endpoints determine which species will be chosen as measurement receptors in the next section.

2.5 Identify and Select Measurement Endpoints

Evaluation of the biological effects (effects on survival, reproduction, or growth) of contaminants on the assessment endpoint requires identification of a measurement receptor species suitable for making inferences about potential changes in the assessment endpoint. The assessment endpoint and measurement receptor can actually be the same if the assessment endpoint defined above refers to a single species within the ecosystem. Measurement receptors are defined as the species used to represent a functional group of organisms at the site for evaluation of assessment endpoints; all class/guilds and communities present should be represented. Measurement receptors should be chosen based primarily on their function in the ecosystem/food web and should represent each community (e.g., soil invertebrate, phytoplankton) and class-specific guild (e.g., mammal herbivore, bird insectivore) presented in the site-specific food web which has been selected as an assessment endpoint at a site. The table in Appendix C lists measurement receptors for the food webs described in this document, and also lists some of the critical ecological attributes that allow those receptors to represent the assessment endpoints for those ecosystems. Additional considerations in selecting measurement receptors should include the species sensitivity to the toxicity of the particular contaminant found at the site, its potential for a high level of exposure to the contaminants at the site, the availability of natural history information on the species, social and economic importance of the species, and its relevance to risk management goals at the site. This section covers the two types of measurement receptors for communities and guilds; these should be developed to represent the assessment endpoint.

2.5.1 Identify Measurement Receptors for Communities

For communities (i.e., soil, surface water, sediment), the community or assemblage of communities in the media are selected as the measurement receptors. COPEC concentrations in the media for the community will be compared to toxicity benchmarks developed for that community as further described in Sections 3.1 and 3.2.

Representative measurement receptors should be selected for communities in all media which may be impacted by contamination. For the different media, representative receptors include:

- soil media: soil invertebrate community and terrestrial plant community
- surface water media: phytoplankton community, aquatic invertebrate community
- sediment media: benthic invertebrate community

2.5.2 Identify Measurement Receptors for Guilds

These measurement receptors should be individual species relevant to those expected to occur at the site. Measurement receptors should be chosen to represent each class-specific guild (e.g., mammal herbivore, bird insectivore) presented in the site-specific food web which has been selected as an assessment endpoint at a site. For a species to serve as a measurement receptor, there must be sufficient natural history information available on its diet and body weight. The *Wildlife Exposure Factors Handbook* published by US EPA (1993g) is a good source of this information for many species. The measurement receptor selected for each class-specific guild will be used to model the COPEC dose ingested and the whole body COPEC concentration in prey eaten by predators at the next trophic level as explained in Section 3.1. More than one measurement receptor can be selected for each assessment point, but one of the measurement receptors selected for a guild should be the species with the highest ingestion rate per unit body weight of the species in that guild. This assures that risk to a class-specific guild is not underestimated. Examples of information gathered on potential measurement receptors are in Appendix D.

2.6 Determine COPEC Environmental Concentrations at Point of Potential Exposure

Site environmental media sampling (soil, sediment, surface water, and ground water) and chemical analyses of environmental samples generally produce a range of concentrations; some analysis of the sampling results is needed to determine the concentration of COPECs to which ecological receptors are potentially exposed. For all receptors, it is important to use

concentrations from samples that are biologically relevant to the receptor species. For example, exposure to burrowing rodents should be estimated using soil sampling results from the depths at which they are expected to burrow, not an average of all soil samples taken.

Whether the 95% UCL or the maximum value of a COPEC concentration is being used to determine the environmental exposure, measured COPEC concentrations together with the SQLs of nondetected COPECs (see Section 2.2.1.2) should be used when determining the concentrations most representative of potential exposure of ecological receptors to COPECs at the site. If there is a reason to believe that the COPEC is present in a sample at a concentration well below the SQL, then one-half of the SQL can be used as a "proxy" concentration. The SQL value itself can be used, if there is reason to believe the true concentration is closer to SQL than to one-half the SQL. The non-detected results should not be simply omitted from the ecoscreen, nor should zero values be substituted in place of the SQL.

For soil and sediment samples, the COPEC concentration typically used to represent the environmental concentration for the ecoscreen is the maximum measured COPEC concentration. However, if the COPCs are distributed uniformly at the site and the sample size is large enough, a statistically derived value such as the 95 percent upper confidence limit (UCL) of the arithmetic mean can be used (except when the 95% UCL exceeds the maximum concentration) to represent the environmental concentration at the point of ecological receptors exposure. In this case, the US EPA guidance document *Supplemental Guidance to RAGS: Calculating the Concentrations Term*" (US EPA, 1992c) should be consulted to estimate the 95 percent UCL. Averaging and statistical treatment of data is correct only for samples that were collected with an appropriate random or systematic sampling design. If "hot spots" (i.e., small but highly contaminated areas) are present at the site, it is recommended that exposure to "hot spots" be evaluated separately because they may require separate consideration for risk management .

Water samples are less heterogeneous than soil or sediment samples, and it should be easier to come up with a statistically supportable average COPEC concentration even with smaller sample sizes. Data from unfiltered water samples should be used to estimate exposure point concentration for terrestrial measurement receptors. Toxicity values and most biotransfer factors for aquatic receptors are developed using the dissolved concentration of COPECs in water, so concentrations in filtered samples correspond better to toxicity values for the aquatic receptors.

2.7 Refine Conceptual Site Exposure Model

In Section 1.4 a preliminary conceptual site exposure model was developed showing anticipated complete pathways to receptors based on site-specific information and generally, qualitative analysis of site historical data and information. Now, the list of COPECs, the food web developed for site, and the measures of effect can be summarized into a box and arrow diagram Exposure Pathway Model (EPM). This diagram should show the relationship between exposure pathways and measurement receptors, and should be added to the risk assessment report in addition to the information on the full food web.

Recommended Information for the Ecoscreen Report

- Assessment endpoints selected for guilds and communities (and rationale)
- Measures of effect selected for guilds and communities (and rationale)
- Revised conceptual site model

3.0 Exposure and Effects Analysis

3.1 Exposure Assessment

Exposure of ecological receptors to COPECs released from facility contaminant sources is evaluated through consideration of exposure pathways. All exposure pathways identified as potentially complete should be evaluated in the exposure assessment. The summation of this potential exposure for all pathways to a measurement receptor quantifies the exposure of that measurement receptor to a COPEC. Exposure assessments are conducted separately for each community and each measurement receptor.

3.1.1. Assess exposure to community measurement receptors

Invertebrate species in each media (water, sediment, soil) are designated as community measurement receptors. Since the primary exposure route for these types of measurement receptors is through contact with the surrounding media, the assumption for a screening level assessment is that the exposure for the receptor is equivalent to the COPEC concentration in the media. For aquatic communities, the dissolved concentration of the COPEC is used, therefore

filtered water samples should be used to generate the exposure estimate.

3.1.2. Assess Exposure to Class-specific Guild Measurement Receptors

For this type of measurement receptor, the exposure is assessed by quantitatively estimating the daily dose ingested of contaminated food items and abiotic media using the equation below. This requires also knowing the concentration that may be present in the plant or animal food item. Therefore, the COPEC concentration is also calculated for those measurement receptors which will serve as food items for other measurement receptors.

$$DD = \sum IR_F \times C_F \times P_F \times F_F + \sum IR_M \times C_M \times P_M$$

where: DD = daily dose of COPEC ingested (mg COPEC/kg BW-day)
IR_F = measurement receptor daily ingestion rate (kg/kg BW-day)
C_F = COPEC concentration in the food item (mg COPEC/kg)
P_F = proportion of the food item that is contaminated (unitless)
F_F = fraction of diet consisting of food item (unitless)
IR_M = measurement receptor media ingestion rate (kg/kg BW-day [soil or sediment] or L/kg BW-day [water])
C_M = COPEC concentration in media (mg/kg [for soil or sediment] or mg/L [for water])
P_M = proportion of ingested media that is contaminated (unitless)

The equation used to estimate this daily dose ingested also contains the terms IR_F and IR_M, which represent species-specific ingestion rates for food items and media (soil, sediment, or water), respectively. Values for weight-specific food and media ingestion rates (IR_F and IR_M) and average body weights for measurement receptors from the example food webs are given in Appendix D and can be found in the *Wildlife Exposures Factor Handbook* (EPA, 1993g). For the screening assessment, one would assume that all food and media ingested came from the contaminated site, so P_F and P_M would be equal to one. Therefore, dose ingested by a receptor can be calculated using the default values for these parameters and a value for the concentration of the contaminant in media at the site.

For a screening level assessment, it is recommended that for receptors ingesting both plant and animal food items (omnivores), the equation be solved for both "equal" and "exclusive" diets. This approach allows the most complete evaluation of exposure potential for a measurement receptor and determination of exposure pathways associated with the highest potential risk for

the receptor. This information can be used to focus further site investigations and support risk management decisions for a site. Under the "equal diet" scenario, each food type is assumed to make up an equal fraction of the diet. For an omnivore the term $F_F = ½$ for ingestion of plant material and $F_F = ½$ for ingestion of animal food. Under the "exclusive diet" scenario, $F_F = 1.0$ for plant material and for animal food, and the equation is solved individually for each food type. If specific dietary composition information for the receptor is available, the daily dose of COPEC ingested by a measurement receptor should be determined by summing the contributions from each type of food item that constitutes more than 5% of the total diet and from ingestion of each type of abiotic media. In this case, F_F would be set equal to 1/x, where x equals the number of food items being evaluated using the equations. **For use in this and the subsequent equations, food and water ingestion rates must be given on a wet weight basis, while soil and sediment ingestion rates must be given on a dry weight basis.**

The daily dose calculation should use media COPEC concentrations measured on site within the habitat being evaluated. The term P_F indirectly accounts for the size of the home range of the measurement receptor by accounting for the fraction of the food item in a diet which is uncontaminated. In the same way, P_M accounts for the size of the home range indirectly by accounting for ingestion of uncontaminated media.

However, for a screening level assessment, 100% the ingested food items and ingested media are assumed to be from the contaminated area (i.e., P_F and P_M are each assigned a value of 1.0). Other assumptions recommended for screening level risk assessments include the assumption that the total of COPEC concentrations in food items and media are bioavailable, and that each individual species in a class-specific feeding guild is equally exposed, and that body weights and food ingestion rates used represent the lower body weight and higher food and abiotic medium ingestion rate of those available in the literature.

For contaminants that remain COPECs after this initial run, site-specific factors can be substituted for the default values. For example, the ratio of the size of the contaminated area divided by the size of the known home range for a receptor can be used to estimate a value for P (this would represent an area use factor). Site-specific values substituted for default values in the equations must be based on information about the receptor known from the site or derived from reliable literature sources

3.1.2.1 Estimate COPEC concentration in invertebrates, phytoplankton, and rooted aquatic plants.

The preferred approach for determining the COPEC concentration for these receptor groups is to multiply a measured media-to-receptor bioconcentration factor (BCF)[21] by the concentration of the COPEC in the media which the organism inhabits. This same method is applied in Section 3.1.2.2 to estimate uptake of COPECs from soil by terrestrial plants.

For aquatic invertebrates representing communities in water, COPEC concentration in the organism is equivalent to the COPEC concentration in the water multiplied by the water to invertebrate bioconcentration factor ($BCF_{W\text{-}WI}$). For benthic invertebrate receptors representing sediment communities, the COPEC concentration in the organism is equivalent to the concentration of the COPEC in the sediment multiplied by the sediment to benthic invertebrate bioconcentration factor ($BCF_{BS\text{-}BI}$). The COPEC concentration in the soil based receptor is equivalent to the concentration of the COPEC in the soil multiplied by the soil to invertebrate bioconcentration factor ($BCF_{S\text{-}INV}$).

Empirical BCF values from the literature or site-specific studies should preferentially be used, if available and appropriate. Information on whether BCFs have been derived based on a wet- or dry tissue-weight basis should be provided. Recommended BCF values should be based on wet tissue weight and dry media weight (except for water). Therefore, if empirical BCF values are reported in the literature as dry tissue weight over dry soil weight, they should be converted to wet weight over dry weight using known conversion factors for that species or the following default conversion factors:

- for soil-to-soil invertebrate or bed sediment-to-benthic-invertebrate or water-to-aquatic invertebrate BCFs, by dividing the concentration in dry invertebrate by a factor of 5.99 (assuming an invertebrate's total weight is 83.3 percent [by mass] moisture) (Pietz, Peterson, Prater, and Zenz, 1984);
- for water-to-algae BCFs, by dividing the concentration in dry algae tissue weight by a factor of 2.92 (assuming an algae's total weight is 65.7 percent [by mass] moisture) (Isensee, Kearney, Woolson, Jones, and Williams, 1973).

If empirical BCF values are unavailable, BCFs for organic compounds can be calculated using regression equations and the log K_{ow}, as shown below. Other proven and validated models for

[21]The bioconcentration factor is the ratio, at steady state, of the COPEC concentration in a food item to its concentration in a medium.

estimating BCFs may be chosen from the available literature, if those models are more appropriate for the COPEC and organism being considered.

For soil-to-plant and sediment-to-plant BCFs (Southworth *et. al.*,1978)

$$\log BCF = 1.588 - 0.578 \log K_{ow}$$

For soil-to-soil-invertebrate, water-to-algae, sediment-to-benthic-invertebrates, and water-to-aquatic-invertebrate BCFs (Southworth *et. al.*,1978),

$$\log BCF = 0.819 \log K_{ow} - 1.146$$

For water-to-fish BCFs (Travis and Arms, 1988),

$$\log BCF = 0.76 * \log K_{ow} - 0.23$$

For inorganic compounds for which laboratory or empirical data are unavailable, values for BCFs can be calculated from the arithmetic mean of values for BCFs of other inorganic compounds.

Appendix E presents BCFs for a number of compounds which are commonly COPECs for the following media-to-receptor combinations:

- soil to soil invertebrate
- soil to plant/sediment to rooted plant
- water to aquatic invertebrate
- water to algae
- water to fish
- sediment to benthic invertebrate
-

The derivation for each of these BCFs is explained in the text portion of Appendix E.

3.1.2.1.1 Derivation of BCFs Using Equilibrium Partitioning

It is also possible to derive BCFs for soil invertebrates (Connell and Markwell, 1990) and benthic invertebrates (US EPA, 1993h) using the equilibrium partitioning approach. Equilibrium

partitioning assumes that the concentration in those organisms is in equilibrium with the concentration in the environment. This approach requires knowledge of the organic carbon fraction data for soil and sediment. The approach is only applicable for hydrophobic nonionic organic compounds for which an empirical water bioconcentration factor is known. The equilibrium partitioning approach is based on the equation below:

$$C_I = C_{IW} * BCF_{WI}$$

where: C_I = COPEC concentration in the soil or benthic invertebrate (mg/kg)
C_{IW} = COPEC concentration in soil or sediment interstitial water (mg/L)
BCF_{WI} = Bioconcentration factor for media to invertebrate (L/kg)

The concentration in interstitial water can be calculated using:

$$C_{IW} = C_M /(f_{oc} * K_{oc})$$

C_{IW} = COPEC concentration in soil or sediment interstitial water (mg/L)
f_{oc} = fraction of organic carbon in soil or sediment (unitless)
K_{oc} = organic carbon partitioning coefficient (L/kg)
C_M = COPEC concentration in soil/sediment (mg/kg)

3.1.2.2 Estimate COPEC concentration in terrestrial plants

Uptake of COPECs by terrestrial plants may occur through root uptake of contaminants in soil and groundwater (Pr). COPEC concentration due to this uptake is described by the equation below which can be used to convert soil concentrations of COPECs into expected concentrations in the aboveground portion of the plant due to root uptake. This equation incorporates a BCF obtained using the methods in Section 3.1.2.1.

$$Pr = C_s * BCF_r * 0.12$$

Pr = plant concentration due to root uptake (mg COPEC/ kg WW)
BCF_r = soil-to-plant biotransfer factor (unitless)
C_s = COPEC concentration in soil (mg COPEC/kg DW soil)
0.12 = Dry weight to wet weight conversion factor (unitless)

This equation is based on Travis and Arms (1988), modified with a dry weight to wet weight conversion factor of 0.12 from Taiz *et al* (1991). Values for BCF_r are reproduced in Appendix E

of this document. Literature values for BCF_r may also be used; sources should be checked to make certain the factors are for root uptake to the aboveground portion of the plant. At some sites vapor transfer from air to the plant or direct deposition of contaminants onto the plant may contribute to the COPEC concentration within the plant. An examination of both the site characteristics and the contaminant properties is needed to determine if these two pathways will contribute to the COPEC concentration in the plant material for a given site.

3.1.2.3. Estimate COPEC concentration in fish

The COPEC concentration in a fish species includes both a BCF to account for uptake from the water media and a trophic level specific food chain multiplier (FCM). The FCM must be appropriate for the trophic level of the fish species. The equation for the COPEC concentration is:

$$C_F = BCF * FCM * C_{dw}$$

C_F = COPEC concentration in fish (mg/kg)
BCF = bioconcentration factor for water-to-fish (L/kg)
FCM = food chain multiplier for trophic level of fish (unitless)
C_{dw} = dissolved COPEC concentration in water (mg/L)

Since most BCFs for fish are developed using the dissolved concentration of the COPEC in water, dissolved concentrations are used in the above equation. This means that water samples used to determine the COPEC concentration for this equation should be filtered water samples. The FCM derivation is discussed below; recommended values for food chain multipliers are given in Appendix F.

3.1.2.3.1 Derivation of Food Chain Multipliers (FCMs)

Food Chain Multipliers (FCMs) are used to model COPEC concentrations in fish that are ingested as food items by a measurement receptor. These FCMs account for biomagnification through the food chain, and include the conservative assumption that compounds are not metabolized. Determining the FCM from the table in Appendix F relies on knowing both the K_{ow} of the COPEC and the trophic level of the consumer of the fish as determined during the food web development. The trophic level specific FCMs in the table were derived using the

bioaccumulation factor (BAF[22]) reported on a lipid-normalized basis using the freely dissolved concentration of a chemical in the water (L/kg) reported in Gobas (1993). The BAFs were based on chemical uptake, rate of compound depuration, metabolism, and dilution (due to growth) in fishes.

$$FCM = BAF/(K_{ow})$$

BAF = bioaccumulation factor (L/kg)
K_{ow} = compound specific octanol-water partition coefficient (L/kg)

Since the K_{ow} of a compound approximates its bioconcentration factor (BCF) reported on a lipid-normalized basis using the freely dissolved concentration of the chemical in water, the above equation can also be written as:

$$FCM = BAF/BCF$$

FCM = Food chain multiplier for the trophic level of the prey ingested by a measurement receptor (unitless)
BAF = Bioaccumulation factor for a measurement receptor (unitless)
BCF = Media-to-plant/invertebrate bioconcentration factor (unitless)

For inorganic chemicals, the FCM is assumed to be one. The FCMs always relate back to the first trophic level (not necessarily the trophic level directly consumed), so a ratio of FCMs is used (in the form of FCM_{x+1}/FCM_x , with x representing the trophic level of the prey item and x + 1 the trophic level of the predator) to estimate COPEC concentrations in the following sections. This ratio of FCMs is equivalent to the biomagnification factor (BMF) which may be more familiar.

3.1.2.4. Estimate COPEC concentration in mammals, birds, amphibians, and reptiles (terrestrial vertebrates)

Equations for generating COPEC concentrations for land vertebrates are specific to each feeding guild (i.e., herbivore, omnivore, and carnivore) and include terms for plants, animals, and media ingested. Each equation includes a term for a ratio of FCMs to account for biomagnification. The equations for mammals and birds in each of the three feeding guilds are presented in the

[22]Bioaccumulation is the result of combined uptake from both food and abiotic media, and must be measured at steady-state, when the rate of uptake is balanced by the rate of excretion.

following subsections. Values for FCMs and BCFs for these equations for the measurement receptors in the example food webs appear in Appendix F of this document.

3.1.2.4.1 Derivation of Food Chain Multipliers (FCMs) for Terrestrial Mammals and Birds

The FCMs provided in Appendix F were developed to model COPEC concentrations in fish as part of EPA's Great Lakes study. To date, most bioaccumulation studies have been done on fish. Although applying FCMs derived from aquatic food web data to terrestrial receptors, regardless of whether their food is aquatic or not, may introduce an uncertainty, these FCMs can be used in this relatively simple screening model. Because this uncertainty may overestimate potential exposures, its impact on the risk estimates should be discussed in the uncertainty analysis section of the ecoscreen report. The equations developed by EPA to estimate the COPEC concentrations in prey items include terms to account for biomagnification through the use of an FCM. Since the FCMs always relate back to the first trophic level (not necessarily the trophic level directly consumed), a ratio of FCMs is used (in the form of FCM_{x+1}/FCM_x , with x representing the trophic level of the prey and x + 1 representing the trophic level of the predator) in the equations. This ratio of FCMs is equivalent to the biomagnification factor (BMF) which may be more familiar. In order to develop FCMs specifically for mammals or birds, one would need the BAFs for those species and the BCFs for their prey.

3.1.2.4.2. COPEC Concentration in Terrestrial Mammals or Birds

The specific BCF terms for wildlife measurement receptors incorporated in the subsequent COPEC concentration equations can be found in Appendix F of this document or obtained from the literature.

For herbivorous mammals or birds,

$$C_{HM} = (C_{TP} * BCF_{TP\text{-}HM} * P_{TP} * F_{TP}) + (C_S * BCF_{S\text{-}HM} * P_S) + (C_{wctot} * BCF_{W\text{-}HM} * P_W)$$

C_{HM} = COPEC concentration in herbivorous mammals or birds (mg/kg WW tissue)
C_{TP} = COPEC concentration in terrestrial plants (mg/kg WW)
$BCF_{TP\text{-}HM}$ = terrestrial plant-to-herbivorous mammal or bird bioconcentration factor (unitless)
P_{TP} = ratio of contaminated to total terrestrial plant in diet (unitless)
F_{TP} = fraction of diet comprised of terrestrial plants (unitless)

C_S = COPEC concentration in soil (mg/kg DW)
$BCF_{S\text{-}HM}$ = soil-to-herbivorous mammal or bird bioconcentration factor (unitless)
P_S = ratio of contaminated to total ingested soil
C_{wctot} = total COPEC concentration in water column (mg/L)
$BCF_{W\text{-}HM}$ = water-to-herbivorous mammal or bird bioconcentration factor (L/kg)
P_W = ratio of contaminated to total ingested water

For omnivorous mammals or birds, the following equation should be adapted to include only the terms for items in the omnivore's diet. For example, if an omnivorous bird species does not consume herbivorous birds as part of its diet, the term $(C_{HB} * (FCM_{TL3}/FCM_{TL2}) * P_{HB} * F_{HB})$ should be left out of the equation.

$$C_{OM} = (C_{INV} * (FCM_{TL3}/FCM_{TL2}) * P_{INV} * F_{INV}) + (C_{TP} * BCF_{TP\text{-}OM} * P_{TP} * F_{TP}) + (C_{HM} * (FCM_{TL3}/FCM_{TL2}) * P_{HM} * F_{HM}) + (C_{HB} * (FCM_{TL3}/FCM_{TL2}) * P_{HB} * F_{HB}) + (C_S * BCF_{S\text{-}OM} * P_S) + (C_{wctot} * BCF_{W\text{-}OM} * P_W)$$

C_{OM} = COPEC concentration in omnivorous mammal or bird (mg/kg WW tissue)
C_{INV} = COPEC concentration in invertebrates (mg/kg WW tissue)
(FCM_{TL3}/FCM_{TL2}) = food chain multiplier for trophic level 3 predator consuming trophic level 2 prey (unitless)
P_{INV} = ratio of contaminated to total invertebrates in diet (unitless)
F_{INV} = fraction of diet composed of invertebrates (unitless)
C_{TP} = COPEC Concentration in terrestrial plants ingested by the mammal (mg/kg WW)
$BCF_{TP\text{-}OM}$ = terrestrial plant to omnivorous mammal or bird bioconcentration factor (unitless)
P_{TP} = ratio of contaminated to total plants in diet (unitless)
F_{TP} = fraction of diet composed of plants (unitless)
C_{HB} = COPEC concentration in herbivorous birds ingested by the mammal or bird (mg/kg WW tissue)
P_{HB} = ratio of contaminated to total herbivorous birds in diet (unitless)
F_{HB} = fraction of diet composed of herbivorous birds (unitless)
C_{HM} = COPEC concentration in herbivorous mammals ingested by the mammal or bird (mg/kg WW tissue)
P_{HM} = ratio of contaminated to total herbivorous mammals in diet (unitless)
F_{HM} = fraction of diet composed of herbivorous mammals (unitless)
C_S = COPEC concentration in soil (mg/kg DW)
$BCF_{S\text{-}OM}$ = soil to omnivorous mammal or bird bioconcentration factor (unitless)
P_S = ratio of contaminated to total soil ingested (unitless)

C_{wctot} = total COPEC concentration in water column (mg/L)
$BCF_{W\text{-}OM}$ = water to omnivorous mammal or bird bioconcentration factor (unitless)
P_W = ratio of contaminated to total water ingested (unitless)

For carnivorous mammals or birds in both terrestrial and freshwater ecosystems, prey items can come from several trophic levels. Therefore, the equation is expressed as the summation of contributions of terms for all prey items. The COPEC concentration in carnivorous mammals and birds is needed only for food webs in which these species serve as prey items for other carnivores (this occurs in the model food webs for the playa lake and the Chihuahuan Desert):

$$C_{CM} = \sum(C_X * (FCM_{TL4}/FCM_{TLX}) * P_X * F_X) + (C_S * BCF_{S\text{-}CM} * P_S) + (C_{wctot} * BCF_{W\text{-}CM} * P_W)$$

C_{CM} = COPEC concentration in omnivorous mammal or bird (mg/kg WW tissue)
C_X = COPEC concentration in prey item X (mg/kg WW tissue)
(FCM_{TL4}/FCM_{TLX}) = food chain multiplier for trophic level 4 predator consuming trophic level X prey (unitless)
P_X = ratio of contaminated to total prey item X in diet (unitless)
F_X = fraction of diet composed of prey item X (unitless)
C_S = COPEC concentration in soil (mg/kg DW)
$BCF_{S\text{-}CM}$ = soil to carnivorous mammal or bird bioconcentration factor (unitless)
P_S = ratio of contaminated to total soil ingested (unitless)
C_{wctot} = total COPEC concentration in water column (mg/L)
$BCF_{W\text{-}CM}$ = water to carnivorous mammal or bird bioconcentration factor (unitless)
P_W = ratio of contaminated to total water ingested (unitless)

3.1.2.4.3. COPEC Concentration in Reptiles and Amphibians

Equations for mammal and bird can also be used to model the COPEC concentrations in amphibians and reptiles, assuming that appropriate biotransfer and toxicity factors can be located in the literature. However, the availability of biotransfer and toxicity data for reptiles and amphibians is currently very limited. Ingestion rates specific to reptile and amphibian species would have to be developed, since these species may eat much less frequently than mammals or birds.

3.1.2.5 Estimate COPEC Concentration in Freshwater Mammals and Birds

For herbivorous riparian/wetland mammals or birds,

$$C_{HM} = (C_{AV} * BCF_{AV\text{-}HM} * P_{AV} * F_{AV}) + (C_{AL} * BCF_{AL\text{-}HM} * P_{AL} * F_{AL}) + (C_{SED} * BCF_{BS\text{-}HM} * P_{BS}) + (C_{wctot} * BCF_{W\text{-}HM} * P_{W})$$

C_{HM} = COPEC concentration in herbivorous riparian/wetland mammals or birds (mg/kg WW tissue)
C_{AV} = COPEC concentration in aquatic vegetation (mg/kg WW)
$BCF_{AV\text{-}HM}$ = aquatic vegetation-to-herbivorous mammal or bird bioconcentration factor (unitless)
P_{AV} = ratio of contaminated to total aquatic vegetation in diet (unitless)
F_{AV} = fraction of diet comprised of aquatic vegetation (unitless)
C_{AL} = COPEC concentration in algae (mg/kg WW)
$BCF_{AL\text{-}HM}$ = algae-to-herbivorous mammal or bird bioconcentration factor (unitless)
P_{AL} = ratio of contaminated to total algae in diet (unitless)
F_{AL} = fraction of diet comprised of algae (unitless)
C_{SED} = COPEC concentration in sediment (mg/kg DW)
$BCF_{BS\text{-}HM}$ = sediment-to- aquatic herbivorous mammal or bird bioconcentration factor (unitless)
P_{BS} = ratio of contaminated to total ingested bed sediment (unitless)
C_{wctot} = total COPEC concentration in water column (mg/L)
$BCF_{W\text{-}HM}$ = water-to-aquatic herbivorous mammal or bird bioconcentration factor (unitless)
P_{W} = ratio of contaminated to total ingested water (unitless)

For omnivorous mammals or birds, the following equation should be adapted to include only the terms for items in the omnivore's diet. For example, if an omnivorous bird species does not consume herbivorous birds as part of its diet, the term $(C_{HB} * (FCM_{TL3}/FCM_{TL2}) * P_{HB} * F_{HB})$ should be left out of the equation.

$$C_{OM} = (C_{BI} * (FCM_{TL3}/FCM_{TL2}) * P_{BI} * F_{BI}) + (C_{WI} * (FCM_{TL3}/FCM_{TL2}) * P_{WI} * F_{WI}) + (C_{HM} * (FCM_{TL3}/FCM_{TL2}) * P_{HM} * F_{HM}) + (C_{HB} * (FCM_{TL3}/FCM_{TL2}) * P_{HB} * F_{HB}) + (C_{AL} * BCF_{AL\text{-}OM} * P_{AL} * F_{AL}) + (C_{AV} * BCF_{AV\text{-}OM} * P_{AV} * F_{AV}) + (C_{SED} * BCF_{BS\text{-}OM} * P_{BS}) + (C_{wctot} * BCF_{W\text{-}OM} * P_{W})$$

C_{OM} = COPEC concentration in aquatic omnivorous mammal or bird (mg/kg WW tissue)

C_{BI} = COPEC concentration in benthic invertebrates (mg/kg WW tissue)
FCM_{TL3}/FCM_{TL2} = food chain multiplier for trophic level 3 predator consuming trophic level 2 prey (unitless)
P_{BI} = ratio of contaminated to total benthic invertebrates in diet (unitless)
F_{BI} = fraction of diet composed of benthic invertebrates (unitless)
C_{WI} = COPEC concentration in water invertebrates (mg/kg WW tissue)
P_{WI} = ratio of contaminated to total water invertebrates in diet (unitless)
F_{WI} = fraction of diet composed of water invertebrates (unitless)
C_{HM} = COPEC concentration in herbivorous mammals ingested by the mammal or bird (mg/kg WW tissue)
P_{HM} = ratio of contaminated to total herbivorous mammals in diet (unitless)
F_{HM} = fraction of diet composed of herbivorous mammals (unitless)
C_{HB} = COPEC concentration in herbivorous birds ingested by the mammal or bird (mg/kg WW tissue)
P_{HB} = ratio of contaminated to total herbivorous birds in diet (unitless)
F_{HB} = fraction of diet composed of herbivorous birds (unitless)
C_{AL} = COPEC Concentration in algae ingested by the mammal or bird (mg/kg WW)
$BCF_{AL\text{-}OM}$ = algae to omnivorous mammal or bird bioconcentration factor (unitless)
P_{AL} = ratio of contaminated to total algae in diet (unitless)
F_{AL} = fraction of diet composed of algae (unitless)
C_{AV} = COPEC Concentration in aquatic vegetation ingested by the mammal or bird (mg/kg WW)
$BCF_{AV\text{-}OM}$ = aquatic vegetation to omnivorous mammal or bird bioconcentration factor (unitless)
P_{AV} = ratio of contaminated to total aquatic vegetation in diet (unitless)
F_{AV} = fraction of diet composed of aquatic vegetation (unitless)
C_{SED} = COPEC concentration in bed sediment (mg/kg DW)
$BCF_{BS\text{-}OM}$ = bed sediment to omnivorous mammal or bird bioconcentration factor (unitless)
P_{BS} = ratio of contaminated to total soil ingested (unitless)
C_{wctot} = total COPEC concentration in water column (mg/L water)
$BCF_{W\text{-}OM}$ = water to omnivorous mammal or bird bioconcentration factor (unitless)
P_W = ratio of contaminated to total water ingested (unitless)

3.1.2.6. Estimate COPEC Dose Ingested by Mammals, Birds, Amphibians, and Reptiles (Terrestrial Vertebrates)

The set of equations in the following subsections calculate the dose ingested for different feeding

guilds. These dose ingested equations estimate the exposure of members of the guild to the COPEC; these values are then compared to Toxicity Reference Values (TRVs) as described in Section 3.2.

3.1.2.6.1. COPEC Dose Ingested by Terrestrial Mammals and Birds

For herbivorous terrestrial mammals and birds,

$$D_{HM} = (C_{TP} * IR_{HM} * P_{TP} * F_{TP}) + (C_S * IR_{S\text{-}HM} * P_S) + (C_{WCTOT} * IR_{W\text{-}HM} * P_W)$$

D_{HM} = daily dose of COPEC ingested by herbivorous bird or mammal (mg COPEC/kg BW-day)
C_{TP} = COPEC concentration in terrestrial plants (mg/kg WW)
IR_{HM} = food ingestion rate of herbivorous mammal or bird in (kg WW/ kg BW-day)
P_{TP} = ratio of contaminated to total terrestrial plant in diet (unitless)
F_{TP} = fraction of diet comprised of terrestrial plants (unitless)
C_S = COPEC concentration in soil (mg/kg DW)
$IR_{S\text{-}HM}$ = soil ingestion rate of omnivorous mammal or bird (kg DW/kg BW-day)
P_S = ratio of contaminated to total ingested soil (unitless)
C_{WCTOT} = total COPEC concentration in water column (mg/L)
$IR_{W\text{-}HM}$ = water ingestion rate of herbivorous mammal or bird (L/kg BW-day)
P_W = ratio of contaminated to total ingested water (unitless)

For omnivorous terrestrial mammals or birds, the following equation should be adapted to include only the terms for items in the omnivore's diet. For example, if an omnivorous bird species does not consume herbivorous birds as part of its diet, the term ($C_{HB} * IR_{OM} * P_{HB} * F_{HB}$) should be left out of the equation.

$$D_{HM} = (C_{HM} * IR_{OM} * P_{HM} * F_{HM}) + (C_{HB} * IR_{OM} * P_{HB} * F_{HB}) + (C_{INV} * IR_{OM} * P_{INV} * F_{INV}) + (C_{TP} * IR_{OM} * P_{TP} * F_{TP}) + (C_S * IR_{S\text{-}OM} * P_S) + (C_{WCTOT} * IR_{W\text{-}OM} * P_W)$$

D_{OM} = daily dose of COPEC ingested by omnivorous bird or mammal (mg COPEC/kg BW-day)

C_{HM} = COPEC concentration in herbivorous mammals or birds (mg/kg WW tissue)
IR_{OM} = food ingestion rate of omnivorous mammal or bird (kg WW/ kg BW-day)
P_{HM} = ratio of contaminated to total herbivorous mammal in diet (unitless)
F_{HM} = fraction of diet comprised of herbivorous mammals (unitless)
C_{HB} = COPEC concentration in herbivorous birds (mg/kg WW tissue)
P_{HB} = ratio of contaminated to total herbivorous birds in diet (unitless)
F_{HB} = fraction of diet comprised of herbivorous birds (unitless)
C_{INV} = COPEC concentration in invertebrates (mg/kg WW tissue)
P_{INV} = ratio of contaminated to total invertebrates in diet (unitless)
F_{INV} = fraction of diet comprised of invertebrates (unitless)
C_{TP} = COPEC concentration in terrestrial plants (mg/kg WW)
P_{TP} = ratio of contaminated to total terrestrial plant in diet (unitless)
F_{TP} = fraction of diet comprised of terrestrial plants (unitless)
C_S = COPEC concentration in soil (mg/kg DW)
$IR_{S\text{-}OM}$ = soil ingestion rate of omnivorous mammal or bird (kg DW/kg BW-day)
P_S = ratio of contaminated to total ingested soil (unitless)
C_{WCTOT} = total COPEC concentration in water column (mg/L water)
$IR_{W\text{-}OM}$ = water ingestion rate of omnivorous mammal or bird (L/kg BW-day)
P_W = ratio of contaminated to total ingested water (unitless)

For terrestrial carnivorous mammals and birds,

$$D_{CM} = (C_{HB} * IR_{CM} * P_{HB} * F_{HB}) + (C_{OB} * IR_{CM} * P_{OB} * F_{OB}) + (C_{OM} * IR_{CM} * P_{OM} * F_{OM}) + (C_{HM} * IR_{CM} * P_{HM} * F_{HM}) + (C_S * IR_{S\text{-}CM} * P_S) + (C_{WCTOT} * IR_{W\text{-}CM} * P_W)$$

D_{CM} = daily dose of COPEC ingested by carnivorous bird or mammal (mg COPEC/kg BW-day)
C_{HB} = COPEC concentration in herbivorous (mg/kg WW tissue)
IR_{CM} = food ingestion rate of carnivorous mammal or bird (kg WW/ kg BW-day)
P_{HB} = ratio of contaminated to total herbivorous birds in diet (unitless)
F_{HB} = fraction of diet comprised of herbivorous birds (unitless)
C_{OB} = COPEC concentration in omnivorous birds (mg/kg WW tissue)
P_{OB} = ratio of contaminated to total omnivorous birds in diet (unitless)
F_{OB} = fraction of diet comprised of omnivorous birds (unitless)
C_{OM} = COPEC concentration in omnivorous mammals (mg/kg WW tissue)
P_{OM} = ratio of contaminated to total omnivorous mammals in diet (unitless)
F_{OM} = fraction of diet comprised of omnivorous mammals (unitless)

C_{HM} = COPEC concentration in herbivorous mammals (mg/kg WW)
P_{HM} = ratio of contaminated to total herbivorous mammals in diet (unitless)
F_{HM} = fraction of diet comprised of herbivorous mammals (unitless)
C_S = COPEC concentration in soil (mg COPEC/kg DW)
$IR_{S\text{-}CM}$ = soil ingestion rate of carnivorous mammal or bird (kg DW/kg BW-day)
P_S = ratio of contaminated to total ingested soil (unitless)
C_{WCTOT} = total COPEC concentration in water column (mg/L water)
$IR_{W\text{-}CM}$ = water ingestion rate of carnivorous mammal or bird (L/kg BW-day)
P_W = ratio of contaminated to total ingested water (unitless)

3.1.2.6.2. COPEC Dose Ingested by Reptiles and Amphibians

Equations for mammal and bird can also be used to model the COPEC concentrations in amphibians and reptiles, assuming that appropriate ingestion rate and dietary composition information can be located in the literature. However, the availability of these data for reptiles and amphibians is currently very limited. Ingestion rates specific to reptile and amphibian species would have to be developed, since these species may eat much less frequently than mammals or birds.

3.1.2.7. Estimate COPEC Dose Ingested by Freshwater Mammals and Birds

For herbivorous riparian/wetland mammals and birds,

$$D_{HM} = (C_{AV} * IR_{HM} * P_{AV} * F_{AV}) + (C_{AL} * IR_{HM} * P_{AL} * F_{AL}) + (C_{SED} * IR_{S\text{-}HM} * P_S) + (C_{WCTOT} * IR_{W\text{-}HM} * P_W)$$

D_{HM} = daily dose of COPEC ingested by herbivorous bird or mammal (mg COPEC/kg BW-day)
C_{AV} = COPEC concentration in aquatic vegetation (mg/kg WW)
IR_{HM} = food ingestion rate of aquatic herbivorous mammal or bird (kg WW/ kg BW-day)
P_{AV} = ratio of contaminated to total aquatic vegetation in diet (unitless)
F_{AV} = fraction of diet comprised of aquatic vegetation (unitless)
C_{AL} = COPEC concentration in algae (mg/kg WW)
P_{AL} = ratio of contaminated to total terrestrial plant in diet (unitless)
F_{AL} = fraction of diet comprised of algae (unitless)

C_{SED} = COPEC concentration in bed sediment (mg/kg DW)
$IR_{S\text{-}HM}$ = soil ingestion rate of aquatic herbivorous mammal or bird (kg DW/kg BW-day)
P_S = ratio of contaminated to total ingested bed sediment (unitless)
C_{WCTOT} = total COPEC concentration in water column (mg/L water)
$IR_{W\text{-}HM}$ = water ingestion rate of aquatic herbivorous mammal or bird (L/kg BW-day)
P_W = ratio of contaminated to total ingested water (unitless)

For omnivorous mammals or birds, the following equation should be adapted to include only the terms for items in the omnivore's diet. For example, if an omnivorous bird species does not consume herbivorous birds as part of its diet, the term ($C_{HB} * IR_{OM} * P_{HB} * F_{HB}$) should be left out of the equation.

$$D_{OM} = (C_{HM} * IR_{OM} * P_{HM} * F_{HM}) + (C_{HB} * IR_{OM} * P_{HB} * F_{HB}) + (C_{BI} * IR_{OM} * P_{BI} * F_{BI}) + (C_{WI} * IR_{OM} * P_{WI} * F_{WI}) + (C_{AV} * IR_{OM} * P_{AV} * F_{AV}) + (C_{AL} * IR_{OM} * P_{AL} * F_{AL}) + (C_{SED} * IR_{S\text{-}OM} * P_S) + (C_{WCTOT} * IR_{W\text{-}OM} * P_W)$$

D_{OM} = daily dose of COPEC ingested by omnivorous bird or mammal (mg COPEC/kg BW-day)
C_{HM} = COPEC concentration in herbivorous mammals (mg/kg WW)
IR_{OM} = food ingestion rate of omnivorous mammal or bird (kg WW/ kg BW-day)
P_{HM} = ratio of contaminated to total herbivorous mammal in diet (unitless)
F_{HM} = fraction of diet comprised of herbivorous mammals (unitless)
C_{HB} = COPEC concentration in herbivorous birds (mg/kg WW)
P_{HB} = ratio of contaminated to total herbivorous birds in diet (unitless)
F_{HB} = fraction of diet comprised of herbivorous birds (unitless)
C_{BI} = COPEC concentration in benthic invertebrates (mg/kg WW)
P_{BI} = ratio of contaminated to total benthic invertebrates in diet (unitless)
F_{BI} = fraction of diet comprised of benthic invertebrates (unitless)
C_{WI} = COPEC concentration in water invertebrates (mg/kg WW)
P_{WI} = ratio of contaminated to total water invertebrates in diet (unitless)
F_{WI} = fraction of diet comprised of water invertebrates (unitless)
C_{AV} = COPEC concentration in aquatic vegetation (mg/kg WW)
P_{AV} = ratio of contaminated to total aquatic vegetation in diet (unitless)
F_{AV} = fraction of diet comprised of aquatic vegetation (unitless)

C_{AL} = COPEC concentration in algae (mg/kg WW)
P_{AL} = ratio of contaminated to total algae in diet (unitless)
F_{AL} = fraction of diet comprised of algae (unitless)
C_{SED} = COPEC concentration in bed sediment (mg/kg DW)
$IR_{S\text{-}OM}$ = soil ingestion rate of aquatic omnivorous mammal or bird (kg DW/kg BW-day)
P_S = ratio of contaminated to total ingested bed sediment (unitless)
C_{WCTOT} = total COPEC concentration in water column (mg/L water)
$IR_{W\text{-}OM}$ = water ingestion rate of aquatic herbivorous mammal or bird (L/kg BW-day)
P_W = ratio of contaminated to total ingested water (unitless)

For carnivorous riparian/wetland mammals and birds,

$$D_{CM} = (C_{HB} * IR_{CM} * P_{HB} * F_{HB}) + (C_{OF} * IR_{CM} * P_{OF} * F_{OF}) + (C_{CF} * IR_{CM} * P_{CF} * F_{CF}) + (C_{OB} * IR_{CM} * P_{OB} * F_{OB}) + (C_{OM} * IR_{CM} * P_{OM} * F_{OM}) + (C_{HM} * IR_{CM} * P_{HM} * F_{HM}) + (C_{SED} * IR_{S\text{-}CM} * P_S) + (C_{WCTOT} * IR_{W\text{-}CM} * P_W)$$

D_{CM} = daily dose of COPEC ingested by carnivorous bird or mammal (mg COPEC/kg BW-day)
C_{HB} = COPEC concentration in herbivorous birds (mg/kg WW tissue)
IR_{CM} = food ingestion rate of carnivorous mammal or bird (kg WW/ kg BW-day)
P_{HB} = ratio of contaminated to total herbivorous birds in diet (unitless)
F_{HB} = fraction of diet comprised of herbivorous birds (unitless)
C_{OF} = COPEC concentration in omnivorous fishes (mg/kg WW tissue)
P_{OF} = ratio of contaminated to total omnivorous fish in diet (unitless)
F_{OF} = fraction of diet comprised of omnivorous fish (unitless)
C_{CF} = COPEC concentration in carnivorous fish (mg/kg WW tissue)
P_{CF} = ratio of contaminated to total carnivorous fish in diet (unitless)
F_{CF} = fraction of diet comprised of carnivorous fish (unitless)
C_{OB} = COPEC concentration in omnivorous birds (mg/kg WW tissue)
P_{OB} = ratio of contaminated to total omnivorous birds in diet (unitless)
F_{OB} = fraction of diet comprised of omnivorous birds (unitless)
C_{OM} = COPEC concentration in omnivorous mammals (mg/kg WW tissue)
P_{OM} = ratio of contaminated to total omnivorous mammals in diet (unitless)
F_{OM} = fraction of diet comprised of omnivorous mammals (unitless)
C_{HM} = COPEC concentration in herbivorous mammals (mg/kg WW tissue)

P_{HM} = ratio of contaminated to total herbivorous mammals in diet (unitless)
F_{HM} = fraction of diet comprised of herbivorous mammals (unitless)
C_{SED} = COPEC concentration in bed sediment (mg/kg DW)
$IR_{S\text{-}CM}$ = soil ingestion rate of aquatic carnivorous mammal or bird (kg DW/kg BW-day)
P_S = ratio of contaminated to total ingested bed sediment (unitless)
C_{WCTOT} = total COPEC concentration in water column (mg/L water)
$IR_{W\text{-}CM}$ = water ingestion rate of aquatic carnivorous mammal or bird (L/kg BW-day)
P_W = ratio of contaminated to total ingested water (unitless)

3.2 Toxicity Assessment

Toxicity of a COPEC is assessed by identifying toxicity reference values (TRVs) specific to a COPEC and to the measurement receptor being evaluated. The TRV is the dose for a measurement receptor that is likely to be without appreciable risk of deleterious effects from chronic exposure. TRVs are therefore developed based on a no-observed-adverse-effect level (NOAEL) for a particular COPEC, except for aquatic and sediment receptors (see Section 3.2.1). NOAELs are derived experimentally or by applying uncertainty factors to available toxicity data. Since a screening level ecological risk assessment should protect against chronic effects, the chronic NOAEL should be used as the toxicity value endpoint to determine the TRV.

For lower trophic level communities, these TRVs are presented as media levels (in mg/kg [soil or sediment] or mg/L [water]), since we have assumed that the level of COPEC in these organisms will be proportional to the concentration found in the media.

TRVs for upper trophic level class-specific guilds are expressed in terms of dose ingested (in mg/kg BW/day). The ingested dose can be calculated using the methods explained in section 3.1 from the media concentrations to which both the measurement receptor and its prey items are exposed.

TRVs for COPECs can be determined from toxicity values derived from a number of sources. Values for TRVs specific to the measurement receptors presented in the food webs in this guidance document are presented in Appendix G. In order of decreasing general preference, these sources are:

- toxicity values used by regulatory agencies (standards, criteria, guidance, benchmarks)

These values are typically developed for surface water and sediment such as state or national ambient water quality criteria (AWQC) for surface water and NOAA Effects Range-Low (ER-L) criteria for sediment.

- toxicity values published in the scientific literature
- toxicity values generated for sediment using equilibrium partitioning
- toxicity values from surrogate compounds

3.2.1 Toxicity Values for Community Measurement Receptors

Surface Water

The preferred toxicity reference values (TRVs) for surface water measurement receptors are the current New Mexico chronic numeric water quality standards for fisheries and wildlife habitat (NM WQCC, Appendix I or current revision) or the chronic National Recommended Water Quality Criteria (NRWQC) for the protection of freshwater aquatic life (US EPA, 1999c), whichever is more stringent. The chronic NRWQC or the criterion continuous concentration (CCC) is defined as an estimate of the highest concentration of a chemical in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. These criteria are intended to be protective of the vast majority of the aquatic communities in the United States. The NRWQC for several metals are functions of water hardness. The criteria that are hardness-dependent were calculated using a hardness of 100 mg/L as $CaCO_3$. Therefore, for sites with different water hardness, site-specific criteria should be calculated from the formulas for hardness correction included in footnotes to individual chemicals. If the site-specific water hardness is greater than 400 mg/L as $CaCO_3$, a factor of 400 mg/L should be used. If the site-specific hardness is less than 50 mg/L as $CaCO_3$, a factor of 50 mg/L should be used.

Secondary chronic values (SCVs) should be used for chemicals that do not have NRWQC. The SCVs were developed using the Tier II method described in the Great Lakes Water Quality Initiative (GLWQI) (40 CFR 122 et al.). Using Tier II method, SCVs were calculated with less than the complete minimum data (e.g., tests for species from eight families of aquatic organisms) required for the NRWQC calculation. The Tier II method used statistically derived "adjustment factors" to calculate a SCV value. The adjustment factor decreases as the number of representative families increases. The SCVs or Tier II values can be obtained from the EPA's Office of Solid Waste and Emergency Response *ECO Update* (US EPA, 1996b). The *Eco Update* includes 34 Ecotox Thresholds (ETs) developed by Suter and Mabrey (1994) using the

GLWQI Tier II method. These ETs have been reviewed by EPA and verified for accuracy.

If neither NM WQCC, NRWQC, or SCVs are available for a chemical, the EPA Region IV chronic surface water screening values can be used (US EPA Region IV, 1995a). These values were derived by taking the lowest reported effect level and dividing by 10. Values for metals assume a hardness of 50 mg/L as $CaCO_3$. A footnote on the Region IV table gives the equation for adjusting the hardness value for those values which are hardness dependent. These screening values are appropriate for pH range between 6.5 and 9.0 (US EPA Region IV, 1995a).

Sediment

TRVs from studies using freshwater sediments have the highest priority. The following literature sources should be consulted to obtain TRVs for sediment measurement receptors:

- Proposed Sediment Quality Criteria (SQC) published by EPA's Office of Water (Federal Register, January 18, 1994) for acenaphthene, dieldrin, endrin, fluoranthene, and phenanthrene (US EPA, 1993a - e). These values were derived using the equilibrium partitioning (EqP) method described in *Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by Using Equilibrium Partitioning* (US EPA, 1993f). The equation for estimating the SQC is:

  $$SQC = f_{oc} \times K_{oc} \times FCV$$

  Where:

  f_{oc} = mass fraction of organic carbon for sediment
  K_{oc} = organic carbon partition coefficient
  FCV = final chronic value from chronic Ambient Water Quality Criteria (AWQC)

  These SQC can be obtained from the EPA's Office of Solid Waste and Emergency Response *ECO Update* (US EPA, 1996b). The SQC values presented in the *ECO Update* are normalized to 1 percent organic carbon and represent the lower limit of the 95 percent confidence interval reported in the criteria documents. This results in some degree of conservatism required for screening purposes.

- Sediment Quality Benchmarks (SQBs) derived by the EPA' Office of Water and Office of Solid Waste. The SQBs are calculated using the same EqP approach as

the SQC except that Tier II surface water SCVs are substituted for the AWQC or FCV in the calculation. The SQBs are presented in the *ECO Update* (US EPA, 1996b). They are normalized to 1 percent organic carbon in sediment.

- Canadian Sediment Quality Guidelines (SQGs) (Environment Canada, 1995) can be applied as the sediment TRVs if all the above sediment values (i.e., SQC, SQBs, and ER-Ls) are unavailable. The SQGs were developed using the methodology described in a formal protocol (Canadian Council of Ministers of the Environment, 1995).

- Effects Range Low (ER-L) value should be used as the sediment TRVs if neither an SQC nor an SQB is available. ERLs are included in the "effects range approach" initially developed for the National Oceanic and Atmospheric Administration's (NOAA's) *National Status and Trends Program*, by Long and Morgan (1990). The Long and Morgan method was revised by MacDonald (1992). Subsequently the ER-L values were revised using the MacDonald method by Long et al. (1995) and as such they are presented in the *ECO Update* (US EPA, 1996b). While Long and Morgan (1990) values were based on data from freshwater, estuarine, and marine sediments, Long et al. (1995) derived values based on data from estuarine and marine sediments using modeling techniques, as well as laboratory and field studies.

  Trace metals data were taken only from studies using a strong acid digestion techniques. No-effects, possible-effects, and probable-effects were developed. The ER-L values represent the lower 10th percentile concentration associated with observation of biological effects. According to this method, concentrations below the ER-L should rarely be associated with adverse effects. The *ECO Update* (US EPA, 1996b) notes that there is relatively low correlation between the incidence of effects and the ER-L's for mercury, nickel, total PCBs, and DDT and that the ER-Ls for these four chemicals should be used cautiously.

- NOAA has developed *Screening Quick Reference Tables*, or SQuiRTs, that include multiple sediment screening values representing the entire spectrum of contaminant concentrations which have been associated with potential adverse effects. The SquiRTs tables are available from NOAA at http://response.restoration.noaa.gov/living/SQuiRT/SQuiRT.html.

3.2.2. Types of Toxicity Test Data for Guild Measurement Receptors

Toxicity values from the literature should be evaluated based on exposure duration, study endpoints, and ecological relevance for the measurement receptor. The study duration/endpoints are listed below in order of decreasing preference for use in calculating TRVs:

- chronic NOAEL
- subchronic NOAEL
- chronic LOAEL
- subchronic LOAEL
- acute median lethality point estimate (LC_{50} or LD_{50})
- single dose toxicity value

TRV development should be based on well-designed studies, even if that study appears lower in the list of preferences than a poorly designed study. The uncertainty factors (UFs) discussed in Section 3.2.2.2 can be used to extrapolate the other types of toxicity test results listed into chronic NOAELs for use as TRVs. When appropriate, these UFs have been applied to development of the default TRVs in Appendix G.

Toxicologists usually divide the exposure duration of animals to chemicals into four categories: acute, subacute, subchronic, and chronic. These exposure duration categories are defined as follows (Klaassen, 1996; US EPA, 1999): *acute exposure* is defined as one dose or multiple doses of a chemical given over a short duration spanning less than or equal to 24 hours; *subacute exposure* refers to repeated exposure to a chemical for 1 to 3 months or spanning approximately 10 % of the lifetime of an organism; and *chronic exposure* is defined as multiple exposures to a chemical occurring over more than three months or a significant fraction of the organism's lifespan. For the purposes of this document, the terms chronic, subchronic, and acute are generally by the following guidelines. For vertebrates (fish, mammals, birds), chronic tests last more than 90 days, subchronic tests last 14 to 90 days, and acute tests last less than 14 days. For other receptors, a chronic test lasts for 7 or more days, subchronic tests last 3 to 6 days, and acute tests last less than 3 days.

A summary of the toxicity studies used to obtain TRVs (if the TRVs are different from those listed in Appendix G) must be part of the Ecoscreen Report. Desirable elements that should be included in a summary to allow adequate review of toxicity studies include:

- species employed
- critical toxicity endpoint or target organ and all other endpoints evaluated

- chemical form of compound tested
- number of animals/group and their body weights
- study duration
- all doses and exposures, including dosing schedule, rates, and concentration
- vehicle of dose
- the quantitative toxicity estimate from the source used/selected
- dose conversion method, if applicable

- overall weight of evidence or uncertainty factors applied, confounding factors, and rationale
- toxicity value recommended as TRV
- source used

These elements can be summarized in a table or included in a summary appendix to the ecoscreen report. Whenever possible, any toxicity values obtained from secondary sources such as the Registry of Toxic Effects of Chemical Substances (RTECSs) should be verified by viewing the original study.

3.2.2.1. Best Professional Judgement for Evaluation of Toxicity Data

In some cases, more than one study of the appropriate toxicity endpoints and duration will be available in the literature. A number of aspects of experimental design should be considered when choosing one study over another for the purposes of TRV development.

- smaller spread between NOAEL and LOAEL doses in study leads to less uncertainty about the endpoint
- higher number of replicates (animals per dose) leads to a more sensitive test
- exposure route in test as close as possible to one occurring in nature
- more sensitive life stage of receptor used for study
- toxicant concentrations measured in test chamber instead of calculated from amount added to chamber
- use, type and performance of controls
- statistical test used to determine endpoint from test doses

3.2.2.2. Use of Uncertainty Factors for Extrapolation from Toxicity Test Values to TRVs

Often the study endpoint available from toxicological literature is not the chronic NOAEL needed for development of a TRV. A set of uncertainty factors (UFs) has been developed for

extrapolating a chronic NOAEL value from other toxicity values; these UFs are designed to be protective by preventing underestimation of the chronic NOAEL value (Chapman *et al.*, 1998).

The following UFs should be used to extrapolate toxicity test data to a chronic NOAEL. Either a chronic LOAEL (or LOEL or LOEC) or a subchronic NOAEL should be multiplied by a UF of 0.1 to extrapolate to a chronic NOAEL. An acute lethal value (LC_{50}, LD_{50}, or EC_{50}) should be multiplied by a UF of 0.01 to extrapolate to a chronic NOAEL. Other toxicity values, such as a subchronic LOAEL or a single oral dose test, should be reviewed to determine the appropriate uncertainty factor. This set of UFs was developed by EPA based on reviews of the available toxicological literature to compare the relationship between the different types of toxicity values (Dourson and Stara, 1983; Calabrese and Baldwin, 1993; US EPA, 1999a). If different UFs are used, the user should demonstrate both the rationale (or source) for the UF values and how the use of these other UFs are still be protective of the environment.

Subchronic NOAEL x 0.1 = chronic NOAEL
Chronic LOAEL(or LOEL or LOEC) x 0.1 = chronic NOAEL
(LC_{50}, LD_{50}, or EC_{50}) x 0.01 = chronic NOAEL

Recommended Information for Ecoscreen Report

In addition to the site and toxicity data mentioned below, the ecoscreen report should contain the information on risk estimation, risk characterization, and uncertainties described in Section 4.

- estimated COPEC concentration in each component of each trophic level
- quantified exposure for each measurement receptor for each pathway
- summary of toxicity values including:
  - species employed
  - critical toxicity endpoint or target organ and all other endpoints evaluated
  - chemical form of compound tested
  - number of animals/group and their body weights
  - study duration
  - all doses and exposures examined, including dosing schedule, rates, and concentration
  - vehicle of dose
  - the quantitative toxicity estimate from the source used/selected
  - dose conversion method, if applicable
  - overall weight of evidence or uncertainty factors applied, confounding factors, and rationale

  - toxicity value recommended as TRV
  - source used
- media concentrations for community TRVs
- TRVs extrapolated from toxicity data for measurement receptors

4.0 Risk Characterization

This section involves integrating the exposure assessment and toxicity assessment from the previous sections to produce an estimate of risk in the form of ecological screening quotients (ESQ) for a single chemical or cumulative ecological screening quotients (CESQ) for multiple chemicals. These ESQs and CESQs are receptor-specific, media-specific, and COPEC-specific. For those COPECs with an ESQ or CESQ exceeding the benchmark, a description of the risk to the receptor should be discussed. This portion of the Ecoscreen Report also reviews the uncertainties involved with the risk screening process.

4.1 Estimate Risk with the ESQ/CESQ Method

An ESQ is equal to the COPEC estimated exposure level (EEL) divided by the TRV developed in Section 3. For community receptors, the COPEC EEL is equal to the media concentration of the COPEC. For guild measurement receptors, the COPEC EEL is equal to the daily dose of COPEC ingested per unit body weight The EEL is calculated for each receptor and COPEC using the equations in Section 3.1.2.6. An ESQ is generated for each measurement receptor for each COPEC it is exposed to at each area of contamination. For both community and guild receptors, is defined by the equation given below. For guild measurement receptors ESQ should be evaluated for both equal and exclusive diets.

$$ESQ = EEL/TRV$$

ESQ = COPEC-specific ecological screening quotient for a receptor (unitless)

EEL = Estimated exposure level (mass COPEC/mass media [for community receptors] or mass daily dose ingested/mass BW-day [for class-specific guild receptor])

TRV = COPEC-specific toxicity reference value for a receptor (mass COPEC/mass media [for community receptors] or mass daily dose ingested/mass BW-day [for class-specific guild receptor])

If multiple COPECs are present at a site, each of the COPEC- specific ESQ values for a receptor should be summed to derive a cumulative ecological screening quotient (CESQ) for each receptor, according to the following equation:

$$CESQ_{Receptor} = \sum ESQ_{COPEC}$$

$CESQ_{Receptor}$ = Receptor-specific cumulative ecological screening quotient (unitless)

ESQ_{COPEC} = COPEC-specific ecological screening quotient for a receptor (unitless)

For guild measurement receptors, CESQs should be evaluated for both equal and exclusive diets. CESQs assume that the exposure and risk to multiple contaminants are additive (i.e., two or more contaminants may affect the same target organs or organ systems and/or act by similar mechanisms). Therefore, ESQs calculated using TRVs based on different effects (for example, survivorship vs. reproductive ability), toxicity endpoints (e.g., NOAEL, LOAEL), and/or exposure durations (e.g., acute, chronic) should not be summed to derive CESQs. In these cases, risk assessment efforts should be focused on the highest contributing COPEC or class of COPECs which can reasonably be summed across effects, toxicity endpoints, and exposure durations (US EPA, 1999a).

4.2 Describe Risk

The purpose of the description of risk is to provide information so that the risk managers can judge the likelihood and ecological significance of the risk to measurement receptors for guilds or communities. If an ESQ exceeds 1.0 for sites with one COPEC, this indicates a potential for ecological risk. For sites with multiple COPECs, a CESQ greater than 1.0 suggests a potential for ecological risk. ESQs or CESQs exceeding this benchmark indicate the need for an additional screening with site-specific factors replacing some of the default factors, a site specific risk assessment, or action to mitigate potential risks at the site.

There are a number of assumptions made during the ecoscreen regarding the fate and transport of the COPECs. These assumptions, which are listed below, should be examined and their effect on the risk estimate qualitatively evaluated.

- none of the COPEC mass is lost through degradation, volatilization, runoff, etc.
- the maximum COPEC concentration at a site is considered to be representative of the

site
- the COPEC is 100% bioavailable
- the receptor does not metabolize or depurate the COPEC (except when empirically derived BCFs are used)
- 100% of the home range for any receptor is in the assessment area
- receptors are exposed throughout their life history (including critical life stage)
- concentrations in plants and invertebrates are in equilibrium with the surrounding media

For the purposes of an ecoscreen, the effect of these assumptions should be qualitatively discussed. Most of these assumptions should not be changed during a screening level assessment, but incorporating an area use factor to account for differences between the size of the site and the size of the home range of the receptor can be done provided the home range size is substantiated with documentation. During a site-specific assessment the assumptions can be revised using data gathered about the specific site.

4.3 Evaluate Limitations and Uncertainties of the Screening Process

The ecoscreen process is based on the premise that protection of ecological receptors chosen on the basis of their role within the ecosystem will protect the ecosystem as a whole. This approach is necessary to allow quantitative determinations of risk to the ecosystem, but in some cases the receptor species may not be the most sensitive to the effects of a particular COPEC. Availability of toxicity and natural history information must also be considered.

Exposure assumptions, including those related to home range and COPEC fate in measurement receptors, can substantially affect the evaluation of risk to a given species. For an ecoscreen, exposure assumptions should be protective of the measurement receptor species, and should default to the more conservative value where uncertainties exist.

The results of sampling and COPEC selection can have a substantial effect on the overall risk assessment process. Care should be taken to ensure that the sampling and analysis are as reflective of actual site conditions as possible.

Other important sources of uncertainty that affect the uptake of a COPEC by plants and animals, and therefore the estimated daily dose of COPEC ingested by measurement receptors, include bioavailability of the contaminant, metabolism of the contaminant by the receptor, and the feeding behavior and digestive system of animals. In addition, bioaccumulation data reported in

the literature may be specific to a tissue or organ and not reflective of whole body accumulation, or the lipophilicity of a COPEC may not be the only predictor of its bioaccumulation potential. As a result, the estimated dose and risk may be over- or underestimated to an unknown degree.

The toxicological information itself may be the source of several areas of uncertainty. Bioavailability of COPECs can vary substantially with factors such as pH, temperature, alkalinity of soil, organic carbon content of soil or sediment, etc. Uncertainty also arises from use of surrogate species, such as rats and mice, to determine values for wildlife species. Extrapolating from one type of toxicity data to the chronic NOAEL is also a source of uncertainty in the assessment.

Sources of uncertainty arise also from the inherent complexities of the ecosystem. In addition, methods of predicting nonchemical stresses (e.g., drought), biotic interactions, behavior patterns, biological variability (e.g., differences in physical conditions, nutrient availability), and resiliency and recovery capacities are often unavailable and therefore, their effect on ecological risk estimates cannot be addressed quantitatively.

The effect of these factors on the ecological risk estimates should be qualitatively addressed in the ecoscreen report. Table 2 is an example of this type of qualitative uncertainty analysis. It is recommended that the uncertainty analysis in the ecoscreen report follows this format.

Recommended Information for the Ecoscreen Report

- results of ESQ/CESQ calculations for each measurement receptor and each COPEC
- evaluation of nature/magnitude of risk
- qualitative analysis of impact of uncertainties on risk assessment process

5.0 Recommended Content of the Ecoscreen Report

In addition to the information delineated below, risk assessors should include in the report any other information about the site which they feel is relevant to evaluating the ecological risk at the site. For purposes of clarity, it is recommended that this additional information be included in an appendix to the risk assessment report and merely referenced in the main body of the report.

The results of the COPECs selection process should be presented in a tabular format showing the initial list of preliminary COPECs, the final list of COPECs and the justification for each

preliminary COPEC eliminated from further consideration.

The following items should be included in the Ecoscreen Report:

- number, type and size of habitats present in assessment area
- sources of information used to determine habitats
- plant and animal species typical of those habitats
- all food webs developed for habitats occurring in the assessment area including
    - media for which web is constructed
    - division into trophic levels
    - class-specific guild designations for each trophic level
    - major dietary interactions
- assessment endpoints selected for guilds and communities (and rationale)
- measures of effect selected for guilds and communities (and rationale)
- revised conceptual site exposure model
- estimated COPEC concentration in each component of each trophic level
- quantified exposure for each measurement receptor for each pathway
- summary of toxicity values including:
    - species employed
    - critical toxicity endpoint or target organ and all other endpoints evaluated
    - chemical form of compound tested
    - number of animals/group and their body weights
    - study duration
    - all doses and exposures examined, including dosing schedule, rates, and concentration
    - vehicle of dose
    - the quantitative toxicity estimate from the source used/selected
    - dose conversion method, if applicable
    - overall weight of evidence or uncertainty factors applied, confounding factors, and rationale
    - toxicity value recommended as TRV
    - source used
- media concentrations for community TRVs
- TRVs extrapolated from toxicity data for measurement receptors
- results of ESQ/CESQ calculations for each receptor and each COPEC
- evaluation of nature/magnitude of risk from ESQs exceeding screening level
- qualitative analysis of impact of uncertainties on risk assessment process

6.0 Develop Site-Specific Soil Screening Levels

Large facilities which are screening a number of sites with similar habitats for common COPECs may want to calculate levels of COPECs in soil that should not represent an excess risk to the ecosystem as a whole. This process of developing soil screening levels for multiple sites within one type of ecosystem is described in Appendix H. However, the following restrictions or limitations should be kept in mind when estimating or applying the soil screening levels:

- they are applicable to exposure and risk from soil
- they are not appropriate if there is a potential of COPECs transport between different media (e.g., from soil to water)
- when ingestion of contaminated water is also important exposure pathway for a receptor soil screening levels may differ from those derived by using the process described in Appendix H
- the soil screening levels are only protective of the food web exposure pathways they were derived for and need to be verified on a case-by-case basis as to appropriateness.

✦Third Technical Decision Point: Is Ecological Risk Possible?

Based on the results presented in the Ecoscreen Report, do any COPECs have an ESQ exceeding 1.0 for a site with a single COPEC or a CESQ exceeding 1.0 for a site with multiple COPECs? If so, this indicates that ecological risk is possible at the site and the options described in the Fourth Technical Decision Point for remediating or further evaluating the site should be considered. Any data gaps that come to light in the process of performing the risk assessment should be addressed prior to proceeding to the fourth technical decision point.

Table 2

Example Summary of Uncertainty Analysis

Uncertainty Element	Effect on Risk Estimates		
	Potential for Overestimation	**Potential for Underestimation**	**Potential for Over- or Underestimation**
Environmental Data			
Use of maximum values as exposure point concentrations for all media	Moderate-High		
Use of current exposure concentrations to represent future site conditions (i.e., assumption of no attenuation of site chemicals)	Moderate		
Elimination of chemicals from quantitative analysis based on background levels		Low	
Insufficient data to fully characterize all media being evaluated			Low
Fate and Transport Parameters			
Assumption on the 100% bioavailability of COPECs in the environmental media and diet	Moderate		
Use of literature-based BCFs			Moderate
Exposure Assumptions			
Use of literature-based exposure parameter values	Low		
Assumption on area use factor	Low-Moderate		
Toxicity Data			
Use of literature-based sources of chemicals' effect data (i.e., not specific to the site conditions)	Low-Moderate		

✦Fourth Technical Decision Point: How Can the Problems at the Site be Addressed?

The results of the ecoscreen can be used by risk managers and the public to assist in making decisions about further action at the site in question. Three key questions should be considered at this point:

- are data adequate to allow determination of an appropriate remedy?
- would remediation be more cost effective than further investigation?
- would a site-specific risk assessment change the results of the ecoscreen for the site?

The last question is an important one which is often overlooked. Based on professional judgement and an examination of the ecoscreen report, risk managers should try to ascertain whether those COPECs that exceed the screening levels do so because of limitations in the ecoscreen model or because levels of those COPECs may truly represent excessive risk. If there are indications that the limitations of the ecoscreen model can be overcome by collecting site-specific information, then the facility has the option of doing a site-specific risk assessment. US EPA's *Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (US EPA, 1999d) aids in planning site-specific ecological risk assessments of appropriate scope and complexity.

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APPENDIX A

SPECIES/HABITAT GUIDES

REFERENCES FOR SAMPLING GUIDANCE

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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.

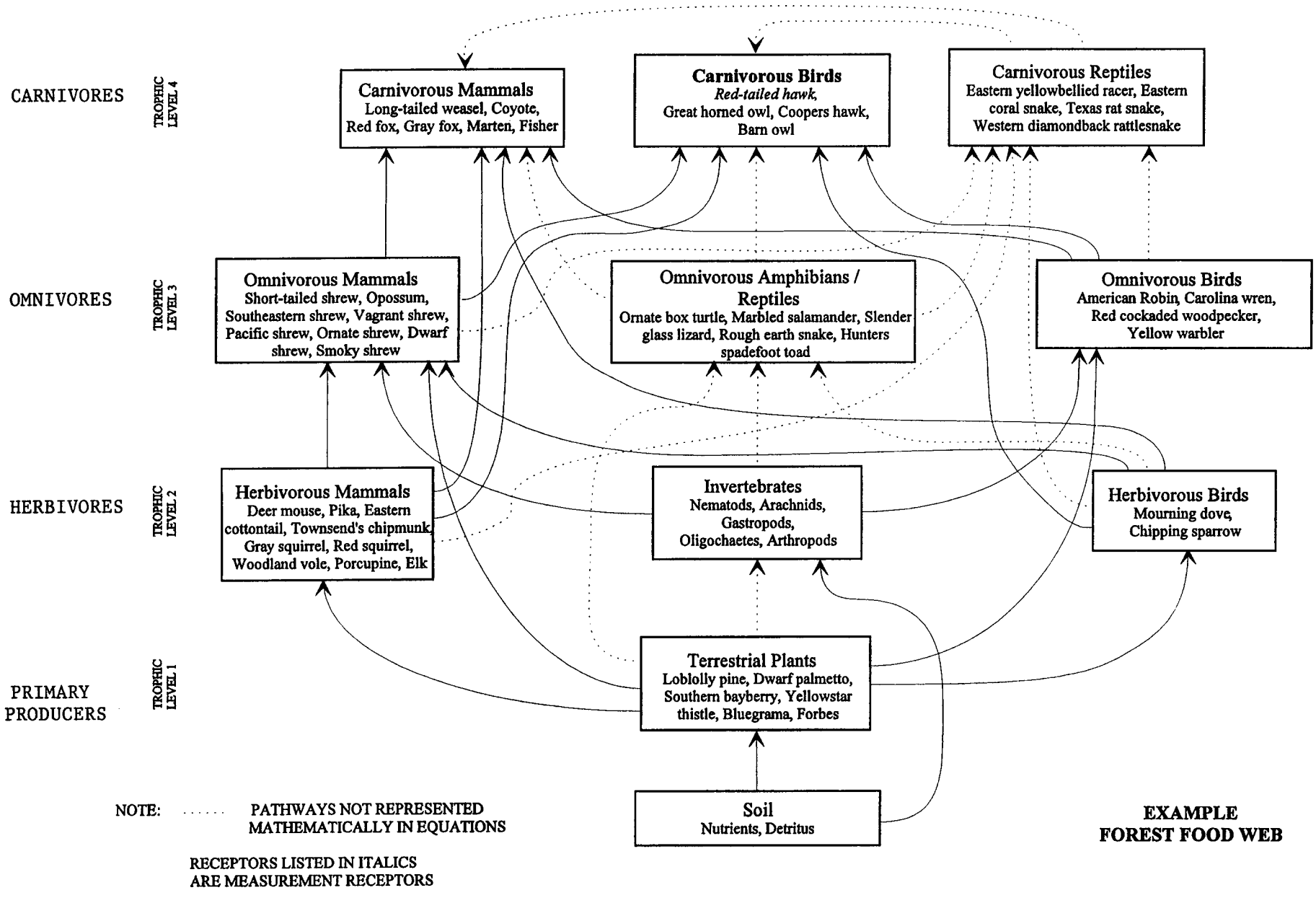
Color (blue/gray, brown, black, mottled) _____

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

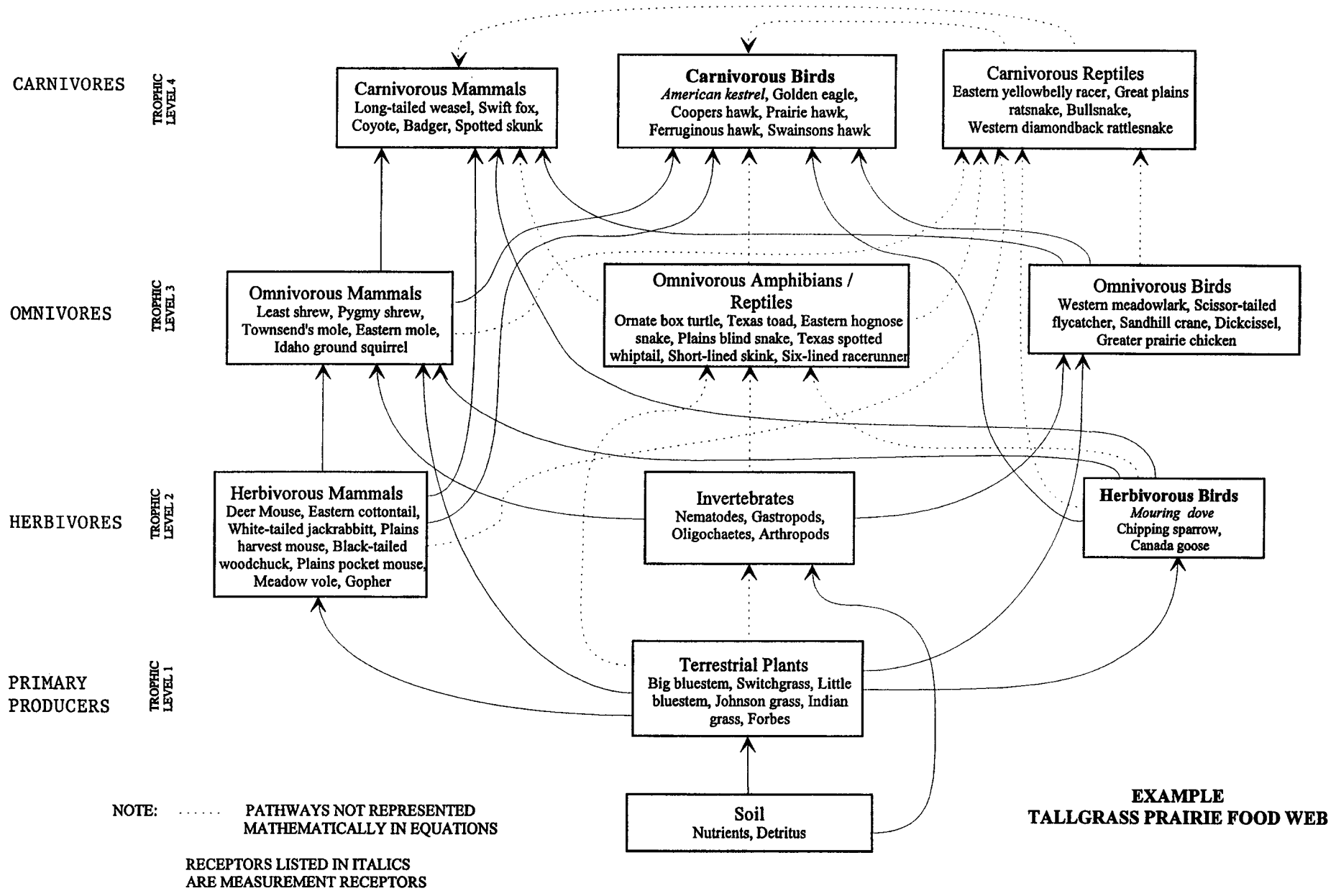
11. Mark the observed wetland area(s) on the attached site map.

APPENDIX B

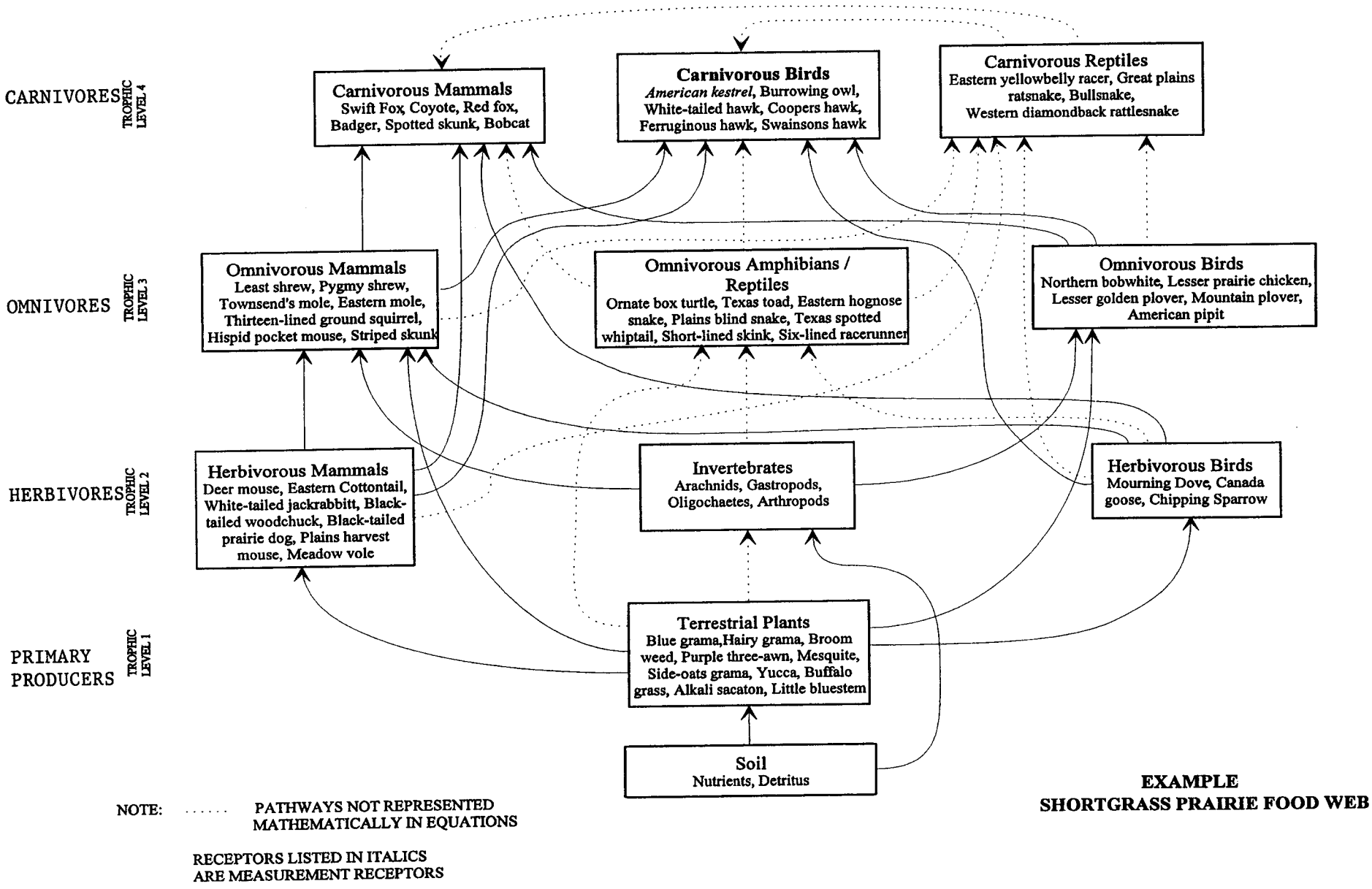
EXAMPLE FOOD WEBS
from EPA, 1999a except as otherwise noted



EXAMPLE FOREST FOOD WEB



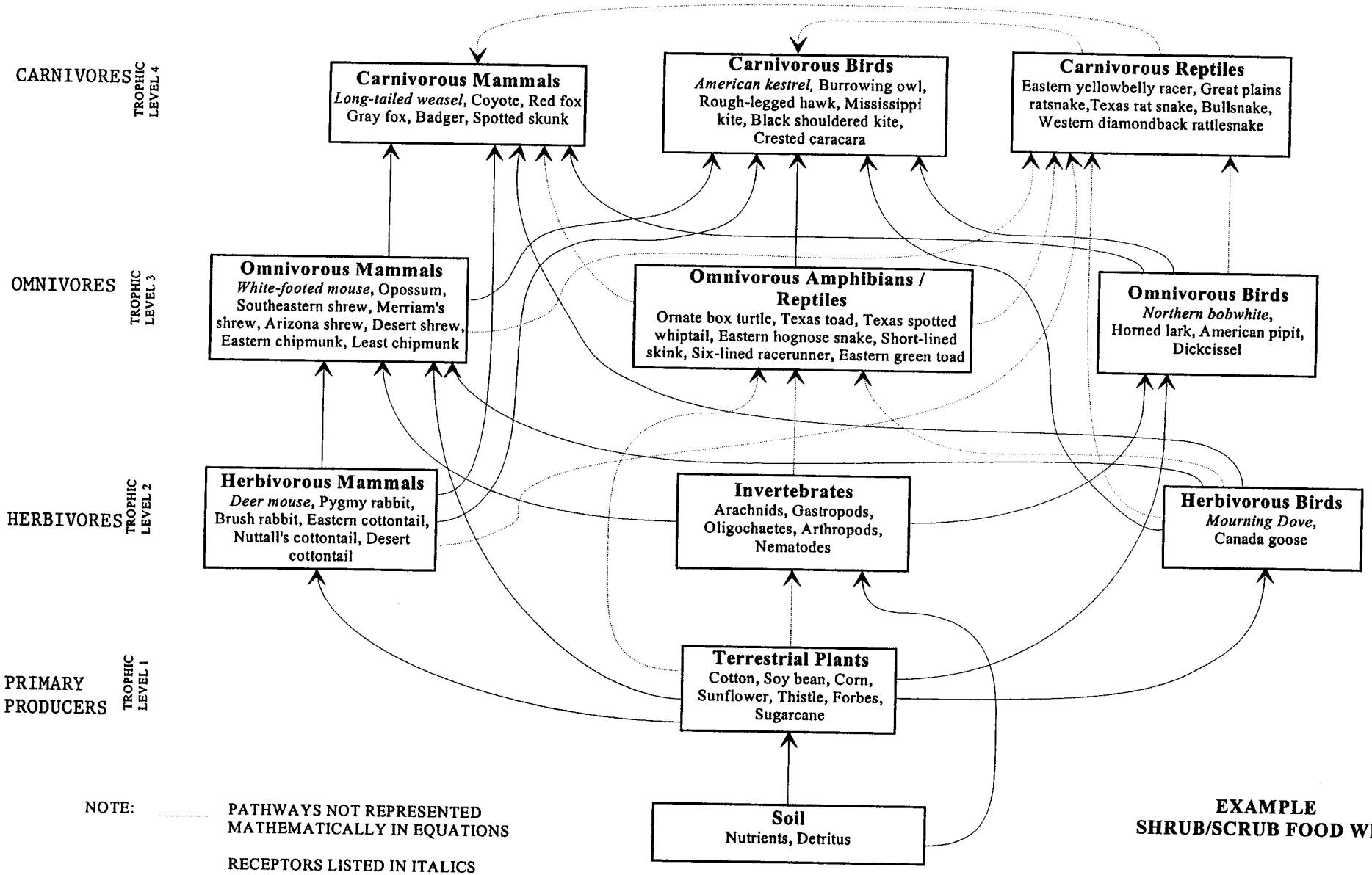
EXAMPLE TALLGRASS PRAIRIE FOOD WEB



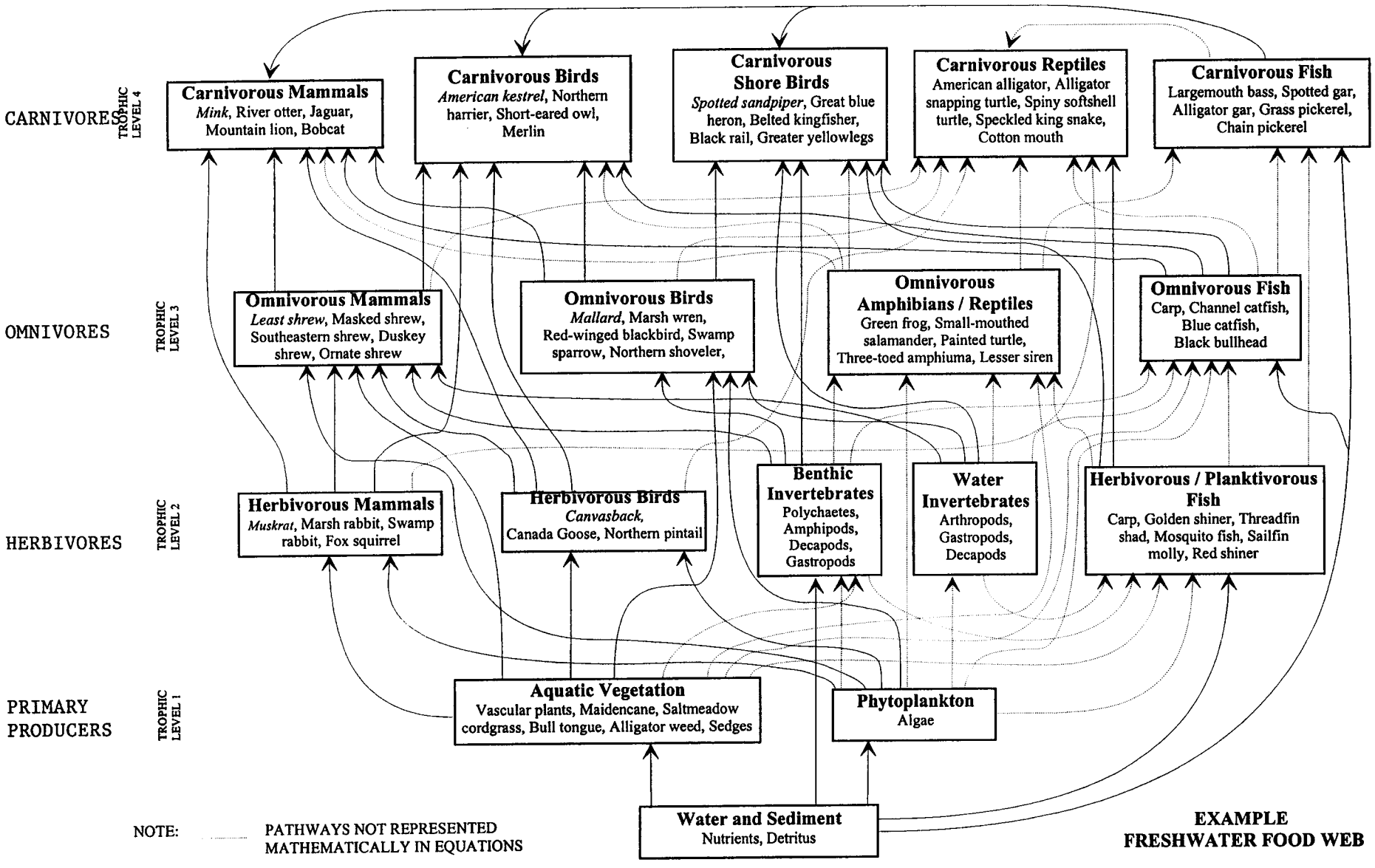
NOTE: ..... PATHWAYS NOT REPRESENTED MATHEMATICALLY IN EQUATIONS

RECEPTORS LISTED IN ITALICS ARE MEASUREMENT RECEPTORS

EXAMPLE SHORTGRASS PRAIRIE FOOD WEB



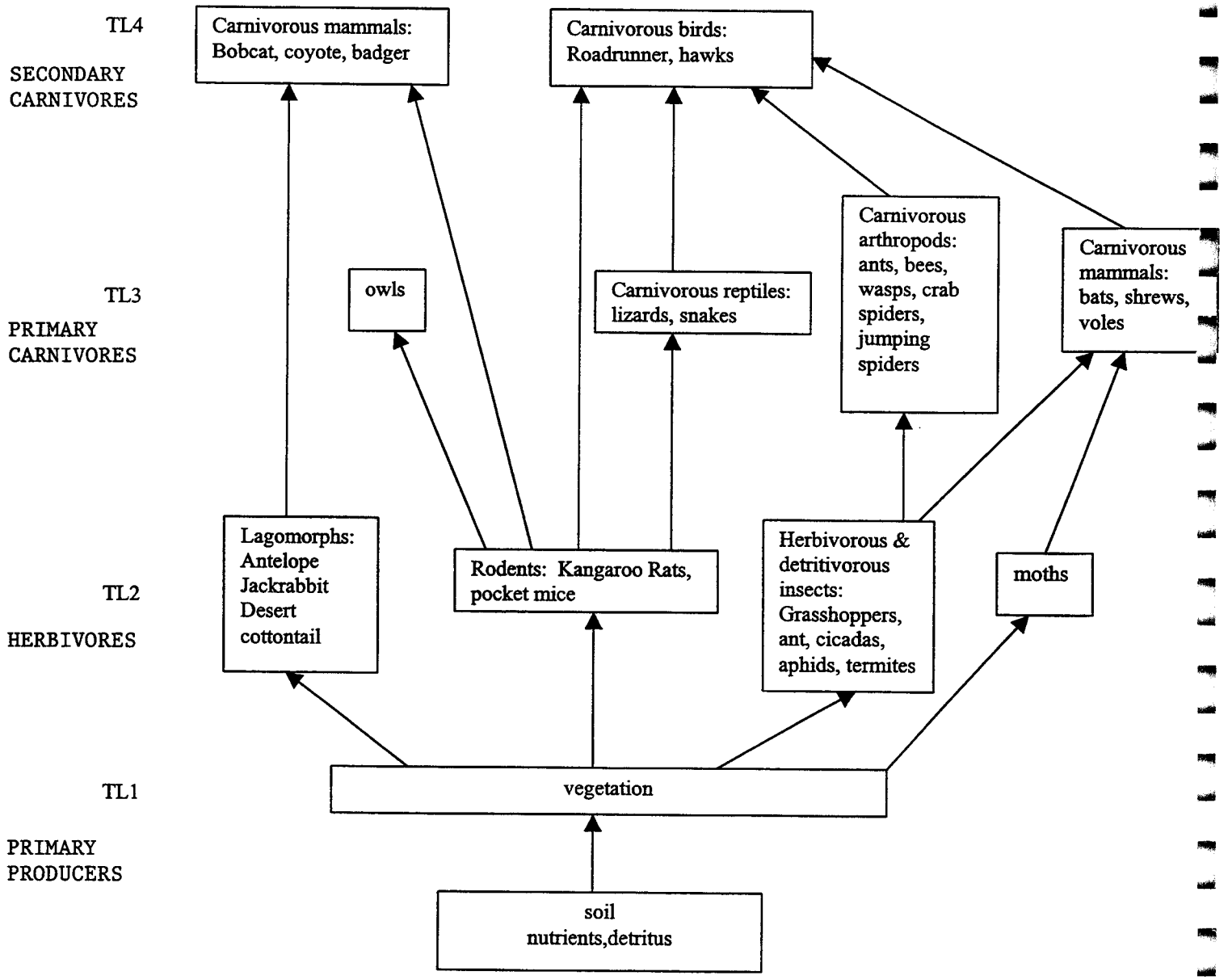
EXAMPLE SHRUB/SCRUB FOOD WEB



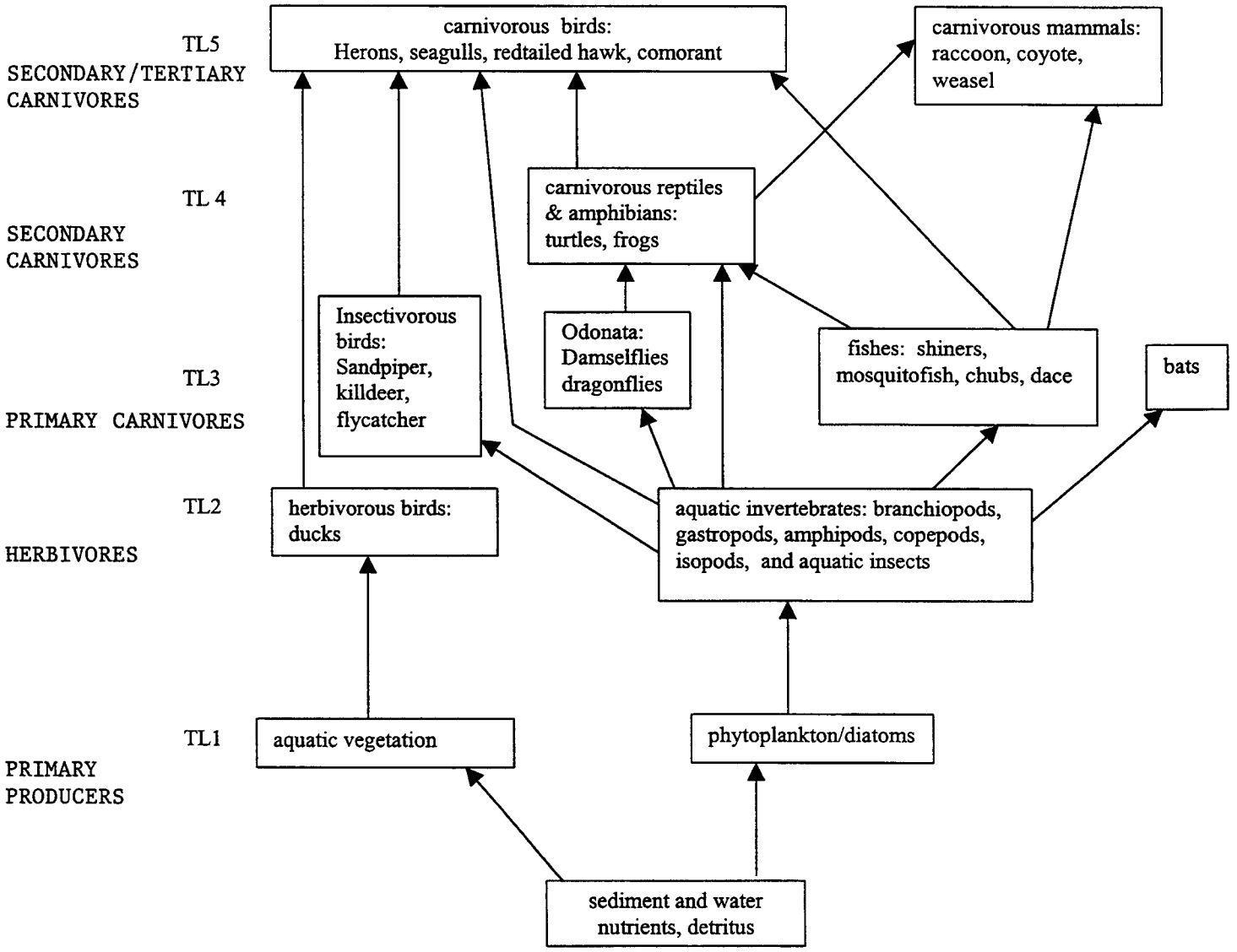
NOTE: ..... PATHWAYS NOT REPRESENTED MATHEMATICALLY IN EQUATIONS

RECEPTORS LISTED IN ITALICS ARE MEASUREMENT RECEPTORS

EXAMPLE FRESHWATER FOOD WEB



Example Chihuahan Desert Food Web. As with all example food webs in this guidance, this web should be modified to reflect the species present at the actual site under consideration. Source: adapted from arid lands food webs provided by Dr. Walter Whitford at the USDA Agricultural Service in Las Cruces, NM.



Example Playa Lake Food Web. Playa Lakes are highly variable and each site should be reviewed to see which of the above groups are actually present at the lake being screened for ecological risk. Source: adapted from Lake Water Quality Assessment Surveys, Playa Lakes, 1994. NMED Document number SWQ-96/3.

APPENDIX C

EXAMPLE ASSESSMENT ENDPOINTS
from EPA, 1999a

ASSESSMENT ENDPOINTS FOR GUILDS AND COMMUNITES IN EXAMPLE FOOD WEBS

Representative Receptors		Example Critical Ecological Attributes
Aquatic Receptors		
Aquatic Plants	Phytoplankton, Vascular plants	Primary producers convert light energy into biomass, and are the first link in aquatic food chains supporting higher trophic level aquatic consumers and wildlife. Rooted vegetation also provides habitat and bottom stability.
Water Invertebrates	Crustaceans, Rotifers, Amphipods	Aquatic invertebrates are an important food source for many higher trophic level consumers. Zooplankton regulate phytoplankton populations, and are a critical link in energy transfer to higher trophic levels in aquatic ecosystems.
Herbivorous / Planktivorous Fish	Carp, Gulf killifish, Threadfin shad, Molly, Golden Shiner, Goby, Mosquito Fish, Red Shiner	Herbivorous/Planktivorous Fish are an important prey species for higher trophic level predators in the aquatic and terrestrial ecosystems, and provide a critical link for energy transfer from primary producers to higher trophic level consumers. They generally comprise the majority of tissue biomass in aquatic ecosystems, and provide an important role to the ecosystem through regulating algae and plankton biomass.
Omnivorous Fish	Carp, Channel catfish, Gafftopsail fish, Atlantic midshipman, Feather blenny, Gulf toad fish, Bluecat, Bullhead	Omnivorous fish are an important prey item for higher trophic level predators. Through predation, they may also regulate population levels in lower trophic level fish and invertebrates.
Carnivorous Fish	Largemouth bass, Spotted gar, Bull shark, Redfish, Grass pickerel, Alligator gar, Chain pickerel, American eel, Atlantic stingray, Spotted moray eel, Fine toothed shark	Carnivorous fish provide an important function for the aquatic environment by regulating lower trophic populations through predation. They are also an important prey item for many top level mammal and bird carnivores.
Sediment Receptors		
Sediment Invertebrates	Oligochaetes, Pelecypods, Amphipods, Decapods, Polychaetes, Gastropods	Sediment invertebrates are an important food source for many higher trophic level predators. They also provide an important role as decomposers/detritivores in nutrient cycling.
Soil Receptors		
Terrestrial Plants	Vascular plants, Grasses, Forbs, Lichens	Primary producers provide a critical food source and are the first link in the terrestrial food chain for higher trophic level consumers. In addition, vegetation provides critical habitat for wildlife.
Soil Invertebrates	Nematodes, Gastropods, Oligochaetes, Arthropods	Soil invertebrates provide an important food source for many higher trophic level species. As decomposers/detritivores they play a critical role in nutrient cycling. They also aid in soil aeration and infiltration by increasing macro, and micro porosity.

Representative Receptors		Example Critical Ecological Attributes
Upper Trophic Level Avian and Mammalian Wildlife		
Herbivorous Mammals	Deer mouse, Nutria, Eastern cottontail, Prairie vole, Fox squirrel, Grey squirrel, Swamp rabbit, Eastern wood rat, White-tailed deer, Fulvous harvest mouse, Black-tailed jackrabbit, Hispid cotton rat, Hispid pocket mouse, Black-tailed prairie dog,	Herbivorous mammals are an important prey item for many higher trophic level predators. They provide an important link for energy transfer between primary producers and higher trophic level consumers. In addition, these organisms generally comprise the majority of the terrestrial tissue biomass, and are important in seed dispersal and pollination for many plant species.
Herbivorous Birds	Mourning dove, Canada goose, Chipping sparrow, Northern pintail	Herbivorous birds are an important prey item for many higher trophic level predators. They are important in seed dispersal for many plants in both terrestrial and aquatic ecosystems. Aquatic herbivorous birds may also play an important role in egg dispersion for fish and invertebrate species.
Omnivorous Mammals	Least shrew, Raccoon, Muskrat, Marsh rice rat, Wild boar, Cotton mouse, Eastern spotted skunk, Coyote, Nine-banded armadillo, Virginia opossum, Elliot's short-tailed shrew, Striped skunk, Golden mouse, Seminole bat.	Omnivorous mammals are an important prey item for higher trophic level predators, and influence lower trophic level populations through predation. They play an important role in seed dispersal for many types of terrestrial vegetation and aquatic plants.
Omnivorous Birds	American robin, Northern bobwhite, Marsh wren, Carolina wren, Swamp sparrow, Yellow warbler, Lesser prairie chicken, Roadrunner, Mallard, Least sandpiper, Red cockaded wood pecker, Roseate spoonbill, Greater prairie chicken, Scissor-tailed flycatcher, Sandhill crane, Dickcissel, Canada goose, Red-winged blackbird, Hooded merganser, Northern shovler.	Omnivorous birds are an important prey item for higher trophic level predators. They play an important role in seed dispersal and pollination for many types of terrestrial vegetation and aquatic plants. In addition, aquatic species provide egg dispersal for some fish and invertebrate species.
Omnivorous Amphibians and Reptiles	Ornate box turtle, Green frog, Texas toad, Eastern hognose snake, Plains blind snake, Small-mouthed salamander, Diamondback terrapin, Short-lined skink, Six-lined racerunner, Eastern green toad, Marbled salamander, Slender glass lizard,	Omnivorous amphibians and reptiles provide an important food source for predators. They also provide seed dispersal for many plants and regulate lower trophic level populations through predation.
Carnivorous Mammals	Grey fox, Swift fox, River otter, Bobcat, Mountain lion, Long-tailed weasel, American badger, Red fox, American mink, Red wolf	Carnivorous mammals provide an important functional role to the environment by regulating lower trophic level prey populations.
Carnivorous Birds	Red-tailed hawk, American kestrel, Marsh hawk, Great-horned owl, Barn owl, Burrowing owl, White-tailed hawk, Ferruginous hawk , Swansons hawk, Golden eagle, Mississippi kite, Prairie hawk, Merlin	Carnivorous Birds provide an important functional role to the environment by regulating lower trophic level prey populations.
Carnivorous Shore Birds	Great blue heron, Belted kingfisher, Spotted sandpiper, Black rail, Greater yellowlegs, Dunlin,	Carnivorous Shore Birds provide an important functional role to the environment by regulating lower trophic level prey populations, and influencing species composition in terrestrial and aquatic ecosystems. They also provide egg dispersal for some fish and aquatic invertebrates.
Carnivorous Reptiles	Eastern yellowbelly racer, Eastern coral snake, Texas rat snake, Western Diamondback rattlesnake, American alligator, Bullsnake, Alligator snapping turtle, Cotton mouth, Speckled king snake, Spiny softshell turtle, Gulf salt marsh snake,	Carnivorous Reptiles provide an important functional role to the environment by regulating lower trophic level prey and are an important prey item for other upper trophic level predators.

APPENDIX D

EXAMPLES OF INFORMATION GATHERED ON MEASUREMENT RECEPTORS
INGESTION RATES FOR EXAMPLE MEASUREMENT RECEPTORS
from EPA, 1999a

American Kestrel

The American kestrel (*Falco sparverius*), or sparrow hawk, was selected as the measurement receptor for the carnivorous bird guild in the example shortgrass prairie, tallgrass prairie, shrub/scrub, freshwater wetland, and brackish/intermediate marsh food webs based on the following information:

- The kestrel is important in regulating small mammal populations through predation. Predators of the kestrel include larger raptors such as red-tailed hawks, golden eagles, and great horned owls.
- The kestrel's prey include a variety of invertebrates such as worms, spiders, scorpions, beetles, and other large insects, as well as an assortment of small to medium-sized birds and mammals. Winter home ranges vary from a few hectares to hundreds of hectares, depending on the amount of available prey in the area.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

American Robin

The American robin (*Turdus migratorius*) was selected as the measurement receptor for the omnivorous bird guild in the example forest food web based on the following information:

- The robin serves an important function in seed dispersion for many fruit species, making it a valuable component of the ecosystem.
- Habitats include forests, wetlands, swamps, and habitat edge where forested areas are broken with agricultural and range land. The robin forages on snails and other soil invertebrates, seeds, and fruit.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Canvasback

The Canvasback (*Aythya valisineria*) was selected as the measurement receptor for the herbivorous bird guild in all three example aquatic food webs based on the following information:

- The Canvasback provides a valuable functional role to aquatic habitats by dispersing seeds for aquatic vegetation.
- The Canvasback is the largest member of the Pochards (bay ducks) and is common throughout North America. They breed from Alaska to Nebraska, and in intermountain marshes of Washington, Oregon, and northern California. Their diet consists of aquatic vegetation, and small invertebrates, which they obtain by digging in sediments. Although the canvasback consumes aquatic invertebrates during certain times of the

year, in winter when they are present along coastal regions, a large portion of their diet is aquatic vegetation and was therefore selected to represent the herbivorous bird guild.

- Since natural history information on the canvasback was scarce, the Lesser Scaup (*Aythya affinis*), for which natural history information is readily available, was selected as a surrogate receptor.

Deer Mouse

The deer mouse (*Peromyscus maniculatus*) was selected as the measurement receptor for the herbivorous mammal guild in the example forest, shortgrass prairie, tallgrass prairie, shrub/scrub food webs based on the following information:

- The deer mouse is preyed upon by owls, snakes, and small carnivorous mammals, making it a very important prey item. This animal also plays an important ecological role in seed and fruit dispersion for many types of vegetation. In addition, their burrowing activities influence soil composition and aeration.

- The deer mouse is almost strictly nocturnal and feeds chiefly on seeds, fruits, bark, roots, and herbage. Due to its burrowing and dietary habits, there is a high potential for direct and indirect exposure. The home range for a deer mouse is rarely over 100 meters, and it spends most of its day in an underground burrow.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Least Shrew

The least shrew (*Cryptotis parva*) was selected as the measurement receptor for the omnivorous mammal guild in the example tallgrass prairie, shortgrass prairie, and freshwater wetland food webs based on the following information:

- Because of the shrews abundance and high population density, they make up a large portion of the diet of owls, hawks, and snakes.

- Shrews feed on snails, insects, sow bugs, and other small invertebrates. The home range size is on average 0.39 hectares. Their diet of invertebrates and their burrowing behavior result in a high potential of direct and indirect exposure to contaminants.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Long-tailed Weasel

The long-tailed weasel (*Mistily Renata*) was selected as the measurement receptor for the carnivorous mammal guild in the example forest, tallgrass prairie and shrub/scrub food webs based on the following information:

- The long-tailed weasel is important in regulating small mammal populations through predation. Predators of the weasel include cats, foxes, snakes, and large raptors such as hawks and owls.

- Habitats are varied and include forested, brushy, open areas including farm lands preferably near water, where they prey on rabbits, chipmunks, shrews, mice, rats and birds.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Mallard Duck

The mallard duck (*Anas platyrhynchos*) was chosen as the measurement receptor for the omnivorous bird guild for the freshwater wetland and brackish/intermediate marsh food webs based on the following information:

- The mallard serves as a valuable component in aquatic food webs providing dispersion of seeds for aquatic vegetation, and due to their role in the nutrient cycle of wetlands. In addition, the mallard is a major prey item for carnivorous mammals, birds, and snakes.

- The mallard is present in a diverse amount of aquatic habitats throughout the United States. Although their diet is considered omnivorous, 90 percent of their diet may be plant material at some times of the year. Mallards are surface feeders that will often filter through soft mud and sediment searching for food items.

- The mallard is very important game species, representing approximately one-third of all waterfowl harvested.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Marsh Rice Rat

The marsh rice rat (*Oryzomys palustris*) was selected as the measurement receptor for the omnivorous mammal guild in the example brackish/intermediate and salt marsh food web based on the following information:

- The marsh rice rat inhabits marsh and wetland areas where it feeds on crabs, insects, fruits, snails, and aquatic plants. The rice rat plays an important role in seed dispersal and is a major food item for many predators including raptors, cats, weasels and snakes.

- The marsh rice rat has a high potential for exposure due to their aquatic diet and direct contact with media.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Marsh Wren

The marsh wren (*Cistothorus palustris*) was selected as the measurement receptor for the omnivorous bird guild in the example salt marsh food web based on the following information:

- The marsh wren consumes large numbers of aquatic insects thus regulating their populations, which make it a valuable component of the ecosystem. Main predators are snakes and turtles which prey heavily upon the eggs.
- The marsh wren is common throughout the United States, inhabiting freshwater, brackish, and saltwater marshes. Its diet consists mainly of aquatic invertebrates, although snails and spiders may be taken. In addition, its diet of aquatic invertebrates makes it susceptible to accumulation and toxicity of bioaccumulative chemicals
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Mink

The mink (*Mustela vison*) was selected as the measurement receptor for the carnivorous mammal guild in the example brackish/intermediate marsh and freshwater food webs based on the following information:

- As a high trophic level predator, the mink provides an important component to the ecosystem by influencing the population dynamics of their prey. Their main predators include fox, bobcats, and great-horned owls.
- The mink is one of the most abundant carnivorous mammals in North America, inhabiting rivers, creeks, lakes, and marshes. They are distributed throughout North America, except in extreme north Canada, Mexico, and areas of the southwestern United States. Mink are predominantly nocturnal hunters, although they are sometimes active during the day. They are opportunistic feeders and will consume whatever prey is most abundant including: small mammals, fish, birds, reptiles, amphibians, crustaceans, and insects.
- They have been shown to be sensitive to PCBs and similar chemicals, and have a high potential for exposure due to their aquatic diet and direct contact with the media.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Mourning Dove

The Mourning Dove (*Zenaida macroura*) was selected as the measurement receptor for the herbivorous bird guild in all four example terrestrial food webs based on the following information:

- The dove plays an important functional role in seed dispersion for many grasses and forbs. Doves provide an important prey item for many higher trophic level omnivores and carnivores. Predators of the mourning dove include falcons, hawks, fox, and snakes.

- The mourning dove inhabits open woodlands, forests, prairies, and croplands. It feeds mostly on seeds, which comprise 99 percent of its diet. It may ingest insignificant amounts of animal matter and green forage incidently.

- Mourning doves have a high potential for exposure through ingestion of inorganic contaminants.

- Mourning doves are an important game species, contributing significantly as a food and economic resource.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Muskrat

The muskrat (*Ondrata zibethicus*) was selected as the measurement receptor for the herbivorous mammal guild in the example freshwater wetland and brackish/intermediate marsh food webs based on the following information:

- The muskrat is important to the overall structure of the aquatic ecosystem by regulating aquatic vegetation diversity and biomass, resulting in stream bank stability and increased habitat diversity for aquatic organisms including fish. It was also chosen as the measurement receptor based on its value to the ecosystem including its large population densities and importance as a prey species (e.g., prey for hawks, mink, otters, owls, red fox, snapping turtles, alligators, and water snakes).

- The muskrat spends a large part of its time in the water, and is common in fresh, brackish, and saltwater habitats. It has relatively high food and water ingestion rates, and a diet that consists mainly of aquatic vegetation, clams, crayfish, frogs, and small fish.

- Due to the large numbers, the muskrat plays an important economic role in the fur industry, and as a food item for some cultures.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Northern Bobwhite

The northern bobwhite (*Colinus virginianus*) was selected as the measurement receptor for the omnivorous bird guild in the example shortgrass prairie and shrub/scrub food webs based on the following information:

- The bobwhite plays an important role in seed dispersion for many plant species, and is an important prey item for snakes, and other small mammals. If habitat conditions permit, their numbers will increase rapidly, providing an additional food source for many predators. They also are valuable in controlling insect populations during certain times of the year.

- The bobwhite's diet consists mainly of seeds and invertebrates, although in the winter green vegetation can dominate its diet. During breeding season, the bobwhite's home range may encompasses several hectares, including areas for foraging, cover, and a nest site. In non-breeding season, the bobwhite's home range can be as large as 16 hectares. It has a high potential for exposure through ingestion and dermal contact with soil during dust bathing.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Northern Harrier

The Northern harrier (*Circus cyaneus*), also called the Marsh hawk was selected as the measurement receptor for carnivorous bird guild in the example salt marsh food web based on the following information:

- The marsh hawk plays an important role in the ecosystem in regulating small mammal populations through predation.

- The marsh hawks diet consists of small mammals, birds, and occasionally snakes, frogs, and insects. Their habitat preferences include wetlands or marshes.

- In addition, the marsh hawk has demonstrated sensitivity to pesticides, which bioaccumulate through food chains.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Red Fox

The red fox (*Vulpes vulpes)* was selected as the measurement receptor for the carnivorous mammal guild in the example salt marsh food web based on the following information:

- Red fox have a high potential for exposure due to bioaccumulation though the food chain, and are a valuable component to ecosystem structure by regulating the abundance, reproduction, distribution, and recruitment of lower trophic level prey.

- Although omnivorous in dietary habits, the majority of the diet consists of cottontail rabbits, voles, mice, birds, and other small mammals. This animal was chosen because of its status as a top carnivore and its widespread distribution in the United States, inhabiting chaparral, wooded and brushy areas, coastal areas and rim rock country.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Red-tailed Hawk

The red-tailed hawk (*Buteo jamaicensis*) was selected as the measurement receptor in the carnivorous bird guild in the example forest food web based on the following information:

- The red-tailed hawks position as a high trophic level predator makes them a valuable component of terrestrial food webs through their regulation of populations of lower trophic level prey species.
- The red-tailed hawk is widely distributed in the United States among a diverse number of habitat types ranging from woodlands to pastures. Its diet includes small mammals (such as mice, shrews, voles, rabbits, and squirrels), birds, lizards, snakes, and large insects. It is an opportunistic feeder, preying on whatever species is most abundant. Red-tailed hawks are territorial throughout the year, and have home ranges that can be over 1,500 hectares.
- Red-tailed hawks have shown sensitivity to many chemicals which disrupt reproduction or egg development.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Salt Marsh Harvest Mouse

The salt marsh harvest mouse (*Reithrodontomys raviventris*) was selected as the measurement receptor for the herbivorous mammal guild in the example salt marsh food web based on the following information:

- The salt marsh harvest mouse plays an important functional role in aquatic habitats through seed dispersal for aquatic vegetation.
- Predators include owls, snakes, and many mammals including weasels, fox, and cats.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Short-tailed Shrew

The short-tailed shrew (*Blarina brevicauda*) was selected as the measurement receptor for the omnivorous mammal guild in the example forest food web based on the following information:

- The short-tailed shrews value as a prey species for many high level predators is very important to the health of an ecosystem. They also play an important role in soil recycling and aeration, through tunnel excavation.
- The short-tailed shrew is one of the most common mammals in the United States. It is a small insectivorous mammal that represents secondary consumers (insectivores) present in terrestrial ecosystems. Their diet of invertebrates such as earthworms and their burrowing behavior result in a high potential of direct and indirect exposure to

contaminants It has a very high metabolism rate which requires almost constant feeding. The most common habitats are wooded and wet areas in the drier parts of the range.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Spotted Sandpiper

The spotted sandpiper (*Actitis macularia*) was selected as the measurement receptor for the carnivorous shore bird guild in the example freshwater wetland, brackish/intermediate, and salt marsh food webs based on the following information:

- The spotted sandpiper inhabits a wide variety of habits usually associated with water or marsh.
- Spotted sandpipers have a high potential for exposure through ingestion of aquatic insects, worms, fish , crustaceans, mollusks, and carrion.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Swift Fox

The Swift Fox (*Vulpes velox*) was selected as the measurement receptor for the carnivorous mammal guild in the example shortgrass prairie food web based on the following information:

- The swift fox fills an important functional role by regulating the population dynamics of many prey species.
- The swift fox is mainly nocturnal and its diet consists of small mammals, insects, birds, lizards, and amphibians. It spends most of its days in a den, emerging at night to hunt. Their home range extends several kilometers.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Western Meadow Lark

The western meadow lark (*Sturnella neglecta*) was selected as the measurement receptor for the omnivorous bird guild in the example tallgrass prairie food web based on the following information:

- The western meadow lark serves an important function in seed dispersion for many forb and grass species, making it a valuable component of the ecosystem.
- Habitats include grassland, savanna, pasture, and cultivated fields. The western meadow lark forages on spiders, sowbugs, snails, and grass and forb seeds.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

White-footed Mouse

The white-footed mouse (*Peromyscus polionotus*) was selected as the measurement receptor for the omnivorous mammal guild in the example shrub/scrub food web based on the following information:

- The white-footed mouse plays an important role in seed dispersal and provide an important food source for raptors, snakes and other mammals including cats, weasels and fox.
- The white-footed mouse feeds on nuts, seeds, fruits, beetles, caterpillars, and other insects. Due to its burrowing and dietary habits, there is a high potential for direct and indirect exposure.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

INGESTION RATES FOR EXAMPLE MEASUREMENT RECEPTORS

Measurement Receptor	Example Food Web[a]	Body Weight (kg)	Reference	Food IR[e] (kg WW/ kg BW-day)	Reference	Water IR (L /kg BW-day)	Reference	Soil/Sed IR[m] (kg DW/ kg BW-day)	Reference
American Kestrel	SG, TG, SS, FW, BR	1.00E-01	U.S. EPA 1993o	4.02E-01[f]	U.S. EPA 1993o; Nagy 1987	1.25E-01[k]	U.S. EPA 1993o	1.39E-03[n]	Pascoe et al. 1996
American Robin	F	8.00E-02	U.S. EPA 1993o	4.44E-01[f]	U.S. EPA 1993o; Nagy 1987	1.37E-01[k]	U.S. EPA 1993o	1.43E-02[o]	Beyer et al. 1994
Canvas Back	FW, BR, SW	7.70E-01[b]	U.S. EPA 1993o	1.99E-01[f]	U.S. EPA 1993o; Nagy 1987	6.43E-02[k]	U.S. EPA 1993o	1.82E-03[p]	Beyer et al. 1994
Deer Mouse	TG, F, SG, SS	1.48E-02	U.S. EPA 1993o	5.99E-01[g]	U.S. EPA 1993o; Nagy 1987	1.51E-01[l]	U.S. EPA 1993o	1.44E-03[q]	Beyer et al. 1994
Least Shrew	SG, FW, TG	4.00E-03	National Audubon Society 1995	6.20E-01[h]	U.S. EPA 1993o	1.72E-01[l]	U.S. EPA 1993o	1.36E-02[o]	Beyer et al. 1994
Long Tailed Weasel	TG ,F, SS	8.50E-02	National Audubon Society 1995	3.33E-01[i]	U.S. EPA 1993o; Nagy 1987	1.27E-01[l]	U.S. EPA 1993o	2.98E-03[r]	Beyer et al. 1994
Mallard Duck	BR, FW	1.04E+00	U.S. EPA 1993o	1.79E-01[f]	U.S. EPA 1993o; Nagy 1987	5.82E-02[k]	U.S. EPA 1993o	3.18E-03	Beyer et al. 1994
Marsh Rice Rat	BR, SW	3.00E-02	National Audubon Society 1995	4.40E-01[g]	U.S. EPA 1993o; Nagy 1987	1.41E-01[l]	U.S. EPA 1993o	2.33E-03[s]	Beyer et al. 1994
Marsh Wren	SW	1.00E-02	U.S. EPA 1993o	9.26E-01[f]	U.S. EPA 1993o; Nagy 1987	2.75E-01[k]	U.S. EPA 1993o	1.96E-02[o]	Beyer et al. 1994
Mink	FW, BR	9.74E-01	U.S. EPA 1993o	2.16E-01[i]	U.S. EPA 1993o; Nagy 1987	9.93E-02[l]	U.S. EPA 1993o	1.93E-03[r]	Beyer et al. 1994

INGESTION RATES FOR EXAMPLE MEASUREMENT RECEPTORS

Measurement Receptor	Example Food Web[a]	Body Weight (kg)	Reference	Food IR[e] (kg WW/ kg BW-day)	Reference	Water IR (L /kg BW-day)	Reference	Soil/Sed IR[m] (kg DW/ kg BW-day)	Reference
Mourning Dove	F, SS, TG, SG	1.50E-01[c]	U.S. EPA 1993o	3.49E-01[f]	U.S. EPA 1993o; Nagy 1987	1.09E-01[k]	U.S. EPA 1993o	7.01E-03[o]	Beyer et al. 1994
Muskrat	BR, FW	1.09E+00	U.S. EPA 1993o	2.67E-01[j]	U.S. EPA 1993o; Nagy 1987	9.82E-02[l]	U.S. EPA 1993o	6.41E-04	Beyer et al. 1994
Northern Bobwhite	SG, SS	1.50E-01	U.S. EPA 1993o	3.49E-01[f]	U.S. EPA 1993o; Nagy 1987	1.09E-01[k]	U.S. EPA 1993o	1.20E-02[t]	Beyer et al. 1994
Northern Harrier	SW	9.60E-01	U.S. EPA 1993o	1.85E-01[f]	U.S. EPA 1993o; Nagy 1987	5.99E-02[k]	U.S. EPA 1993o	9.95E-03[n]	Beyer et al. 1994
Red Fox	SW	3.94E+00	U.S. EPA 1993o	1.68E-01[i]	U.S. EPA 1993o; Nagy 1987	8.63E-02[l]	U.S. EPA 1993o	1.51E-03	Beyer et al. 1994
Red-tailed Hawk	F	9.60E-01[d]	U.S. EPA 1993o	1.85E-01[f]	U.S. EPA 1993o; Nagy 1987	5.99E-02[k]	U.S. EPA 1993o	9.95E-03[n]	Beyer et al. 1994
Salt-marsh Harvest Mouse	SW	9.10E-03	U.S. EPA 1993o	7.41E-01[g]	U.S. EPA 1993o; Nagy 1987	1.58E-01[l]	U.S. EPA 1993o	1.78E-03[q]	Beyer et al. 1994
Short-tailed Shrew	F	1.50E-02	U.S. EPA 1993o	6.20E-01[h]	U.S. EPA 1993o	1.51E-01[l]	U.S. EPA 1993o	1.36E-02[o]	Beyer et al. 1994
Spotted Sandpiper	SW, BR, FW	4.00E-02	U.S. EPA 1993o	5.69E-01[f]	U.S. EPA 1993o; Nagy 1987	1.74E-01[k]	U.S. EPA 1993o	4.15E-02[u]	Beyer et al. 1994
Swift Fox	SG	1.40E+00	U.S. EPA 1993o	1.93E-01[i]	U.S. EPA 1993o; Nagy 1987	9.34E-02[l]	U.S. EPA 1993o	1.73E-03[r]	Beyer et al. 1994
Western Meadow Lark	TG	9.00E-02	U.S. EPA 1993o	4.21E-01[f]	U.S. EPA 1993o; Nagy 1987	1.31E-01[k]	U.S. EPA 1993o	1.39E-02[o]	Beyer et al. 1994

INGESTION RATES FOR EXAMPLE MEASUREMENT RECEPTORS

Measurement Receptor	Example Food Web[a]	Body Weight (kg)	Reference	Food IR[e] (kg WW/ kg BW-day)	Reference	Water IR (L /kg BW-day)	Reference	Soil/Sed IR[m] (kg DW/ kg BW-day)	Reference
White-footed Mouse	SS	1.00E-02	U.S. EPA 1993o	6.14E-01[g]	U.S. EPA 1993o; Nagy 1987	1.52E-01[l]	U.S. EPA 1993o	2.70E-03	Beyer et al. 1994

Notes: IR- Ingestion Rate; WW- Wet weight; DW-Dry Weight; BW- Body Weight; kg - kilogram; L - Liter

a = Food Webs: BR - Brackish/Intermediate Marsh; F - Forest; FW - Freshwater/Wetland; SG - Shortgrass Prairie; SS - Shrub/Scrub; SW - Saltwater Marsh; TG - Tallgrass Prairie.

b = The body weight reported for the mallard is used as a surrogate value for the canvas back.

c = The body weight reported for the northern bobwhite is used as a surrogate value for the morning dove.

d = The body weight reported for the red-tailed hawk is used as a surrogate value for the northern harrier.

e = Food ingestion rate (IR) values are reported in Table 5-1 as kg WW/kg BW-day. To convert IR from a dry weight (as calculated using allometric equations) to a wet weight basis, the following general equation is used:

IR kg WW/kg BW-day = (IR kg DW/BW-day)/(1 - % moisture/100)

Ingestion rate values provided in Table 5-1 are calculated based on assumed percent moisture content of food items of measurement receptors specified. For herbivores, the moisture content of ingested plant matter is assumed to be 88.0 percent (Taiz et al. 1991). For carnivores, the moisture content of ingested animal matter is assumed to be 68.0 percent (Sample et al. 1997). For omnivores, an equal fraction of plant and animal matter is assumed ingested with an overall average moisture content of 78.0 percent [(88.0 + 68.0)/2].

f = Food ingestion rates generated using the following allometric equation for all birds: IR (g/day) = 0.648 $Wt^{0.651}$ (g).

g = Food ingestion rates generated using the following allometric equation for rodents: IR (g/day) = 0.621 $Wt^{0.564}$ (g).

h = Allometric equations reported in U.S. EPA (1993o) do not represent intake rates for shrews; therefore, measured field values from the referenced sources are presented.

i = Food ingestion rates generated using the following allometric equation for all mammals: IR (g/day) = 0.235 $Wt^{0.822}$ (g).

j = Food ingestion rates generated using the following allometric equation for herbivores: IR (g/day) = 0.577 $Wt^{0.727}$ (g).

k = Water ingestion rates generated using the following allometric equation for all birds: IR (L/day) = 0.059 $Wt^{0.670}$ (kg).

l = Water ingestion rates generated using the following allometric equation for all mammals: IR (L/day) = 0.099 $Wt^{0.900}$ (kg).

m = Soil and sediment ingestion rates calculated based on percent soil in diet as reported in Beyer et al. 1994.

n = Percent soil in diet reported for the bald eagle is used as a surrogate value for the american kestrel, northern harrier, and red-tailed hawk.

o = Percent soil in diet is assumed as 10.0 percent of diet based on range presented in Beyer et al. 1994.

p	=	Percent soil in diet reported for the mallard is used as a surrogate value for the canvas back.
q	=	Percent soil in diet reported for the white-footed mouse is used as a surrogate value for the deer mouse and salt-marsh harvest mouse.
r	=	Percent soil in diet reported for the red fox is used as a surrogate value for the long-tailed weasel, mink, and swift fox.
s	=	Percent soil in diet is assumed as 2.0 percent of diet based on range presented for herbivores.
t	=	Percent soil in diet reported for the wild turkey is used as a surrogate value for the northern bobwhite.
u	=	Percent soil in diet reported for the western sandpiper is used as a surrogate value for the spotted sandpiper.

APPENDIX E

BCF VALUES FOR COMMUNITY MEASURMENT RECEPTORS
from Appendix C of EPA, 1999b

APPENDIX C

MEDIA-TO-RECEPTOR *BCF*s

Appendix C provides recommended guidance for determining values for media-to-receptor bioconcentration factors (*BCF*s) based on values reported in the scientific literature, or estimated using physical and chemical properties of the compound. Guidance on use of *BCF* values in the screening level ecological risk assessment is provided in Chapter 5.

Section C-1.0 provides the general guidance recommended to select or estimate *BCF* values. Sections C-1.1 through C-1.7 further discuss determination of *BCF*s for specific media and receptors. References cited in Sections C-1.1 through C-1.7 are located following Section C-1.7.

For the compounds commonly identified in risk assessments for combustion facilities (identified in Chapter 2), *BCF* values have been determined following the guidance in Sections C-1.1 through C-1.7. *BCF* values for these limited number of compounds are included in this appendix in Tables C-1 through C-7 to facilitate the completion of screening ecological risk assessments. However, it is expected that additional compounds may require evaluation on a site specific basis, and in such cases, *BCF* values for these additional compounds could be determined following the same guidance (Sections C-1.1 through C-1.7) used in determination of the *BCF* values reported in this appendix. For reproducibility and to facilitate comparison of new data and values as they become available, all data reviewed in the selection of the *BCF* values provided at the end of this appendix are also included in Tables C-1 through C-7. References cited in Tables C-1 through C-7 (Media-to-Receptor *BCF* Values) are located following Table C-7.

For additional discussion on some of the references and equations cited in Sections C-1.1 through C-1.7, the reader is recommended to review the Human Health Risk Assessment Protocol (HHRAP) (U.S. EPA 1998) (see Appendix A-3), and the source documents cited in the reference section of this appendix.

C-1.0 GENERAL GUIDANCE

This section summarizes the recommended general guidance for determining compound-specific *BCF* values (media-to-receptors) provided in Tables C-1 through C-7. As a preference, *BCF* values were selected from empirical field and/or laboratory data generated from reviewed studies that are published in the scientific literature. Information used from these studies included calculated *BCF* values, as well as, collocated media and organism concentration data from which *BCF* values could be calculated. If two or more *BCF* values, or two or more sets of collocated data, were available in the published scientific literature, the geometric mean of the values was used.

Field-derived *BCF* values were considered more indicative of the level of bioconcentration occurring in the natural environment than laboratory-derived values. Therefore, when available and appropriate, field-derived *BCF* values were given priority over laboratory-derived values. In some cases, confidence in the methods used to determine or report field-derived *BCF* values was less than for the laboratory-derived values. In those cases, the laboratory-derived values were used for the recommended *BCF* values.

When neither field or laboratory data were available for a specific compound, data from a potential surrogate compound were evaluated. The appropriateness of the surrogate was determined by comparing the structures of the two compounds. Where an appropriate surrogate was not identified, a regression equation based on the compound's log K_{ow} value was used to calculate the recommended *BCF* value.

With the exception of the air-to-plant biotransfer factors (*Bv*), recommended *BCF* values provided in the tables at the end of this appendix are based on wet tissue weight and dry media weight (except for water). As necessary, reported values were converted to these units using the referenced tissue or media wet weight percentages. The conversion factors, equations, and references for these conversions are discussed in Sections C-1.1 through C-1.7 where appropriate, and are presented at the end of each table (Tables C-1 through C-7).

C-1.1 SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS

Soil-to-soil invertebrate *BCF* values (see Table C-1) were developed mainly from data for earthworms. Measured experimental results were primarily in the form of ratios of compound concentrations in a earthworm and the compound concentrations in the soil in which the earthworm was exposed. As necessary, values were converted to wet tissue and dry media weight assuming a moisture content (by mass) of 83.3 percent for earthworms and 20 percent for soil (Pietz et al. 1984).

<u>*Organics*</u> For organic compounds with no field or laboratory data available, recommended *BCF* values were estimated using the following regression equation:

$$\log BCF = 0.819 \log K_{ow} - 1.146 \qquad \text{Equation C-1-1}$$

- Southworth, G.R., J.J. Beauchamp, and P.K. Schmieder. 1978. "Bioaccumulation Potential of Polycyclic Aromatic Hydrocarbons in *Daphnia Pulex.*" *Water Research.* Volume 12. Pages 973-977.

<u>*Inorganics*</u> For inorganic compounds with no field or laboratory data available, the recommended *BCF* value is equal to the arithmetic average of the available *BCF* values for other inorganics as specified in Table C-1.

C-1.2 SOIL-TO-PLANT AND SEDIMENT-TO-PLANT BIOCONCENTRATION FACTORS

Soil-to-plant *BCF* values (see Table C-2) account for plant uptake of compounds from soil. Data for a variety of plants and food crops were used to determine recommended *BCF* values.

<u>*Organics*</u> For all organics (including PCDDs and PCDFs) with no available field or laboratory data, the following regression equation was used to calculate recommended values:

$$\log BCF = 1.588 - 0.578 \log K_{ow} \qquad \text{Equation C-1-2}$$

- Travis, C.C. and A.D. Arms. 1988. "Bioconcentration of Organics in Beef, Milk, and Vegetation." *Environmental Science and Technology.* 22:271-274.

<u>*Inorganics*</u> For most metals, *BCF* values were based on empirical data reported in the following:

- Baes, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shor. 1984. "Review and Analysis of Parameters and Assessing Transport of Environmentally Released Radionuclides Through Agriculture." Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The scientific literature also was searched to identify studies. Although U.S. EPA (1995a) provides values for certain metals calculated on the basis of plant uptake response slope factors, it is unclear how the *BCF*

values were calculated or which sources or references were used. Therefore, values reported in U.S. EPA (1995a) were not used.

C-1.3 WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS

Experimental data for crustaceans, aquatic insects, bivalves, and other aquatic invertebrates were used to determine recommended *BCF* values for water-to-aquatic invertebrate (see Table C-3). Both marine and freshwater exposures were reviewed. As necessary, available results were converted to wet tissue weight assuming that invertebrate moisture content (by mass) is 83.3 percent (Pietz et al. 1984).

Organics Reported field values for organic compounds were assumed to be total compound concentrations in water and, therefore, were converted to dissolved compound concentrations in water using the following equation from U.S. EPA (1995b):

$$BCF\,(\text{dissolved}) = (BCF\,(\text{total}) / f_{fd}) - 1 \qquad \text{Equation C-1-3}$$

where

BCF (dissolved)	=	*BCF* based on dissolved concentration of compound in water
BCF (total)	=	BCF based on the field derived data for total concentration of compound in water
f_{fd}	=	Fraction of compound that is freely dissolved in the water

and,

f_{fd}	=	$1 / [1 + ((DOC \times K_{ow}) / 10) + (POC \times K_{ow})]$
DOC	=	Dissolved organic carbon, kilograms of organic carbon / liter of water (2.0×10^{-06} Kg/L)
K_{ow}	=	Octanol-water partition coefficient of the compound, as reported in U.S. EPA (1994a)
POC	=	Particulate organic carbon, kilograms of organic carbon / liter of water (7.5×10^{-09} Kg/L)

Laboratory data were assumed to be based on dissolved compound concentrations.

For organic compounds with no field or laboratory data available, *BCF* values were determined from surrogate compounds or calculated using the following regression equation:

$$\log BCF = 0.819 \times \log K_{ow} - 1.146 \qquad \text{Equation C-1-4}$$

- Southworth, G.R., J.J. Beauchamp, and P.K. Schmieder. 1978. "Bioaccumulation Potential of Polycyclic Aromatic Hydrocarbons in *Daphnia Pulex.*" *Water Research.* Volume 12. Pages 973-977.

Inorganics For inorganic compounds with no field or laboratory data available, the recommended *BCF* values were estimated as the arithmetic average of the available *BCF* values for other inorganics, as specified in Table C-3.

C-1.4 WATER-TO-ALGAE BIOCONCENTRATION FACTORS

Experimental data for both marine and freshwater algal species were reviewed. As necessary, available results were converted to wet tissue weight assuming that algae moisture content (by mass) is 65.7 percent (Isensee et al. 1973).

Organics For organic compounds with no field or laboratory data available, *BCF* values were calculated using the following regression equation:

$$\log BCF = 0.819 \times \log K_{ow} - 1.146 \qquad \text{Equation C-1-5}$$

- Southworth, G.R., J.J. Beauchamp, and P.K. Schmieder. 1978. "Bioaccumulation Potential of Polycyclic Aromatic Hydrocarbons in *Daphnia Pulex.*" *Water Research.* Volume 12. Pages 973-977.

Inorganics For inorganics, available field or laboratory data were evaluated for each compound.

C-1.5 WATER-TO-FISH BIOCONCENTRATION FACTORS

Experimental data for a variety of marine and freshwater fish were used to determine recommended *BCF* values (see Table C-5). As necessary, values were converted to wet tissue weight assuming that fish moisture content (by mass) is 80.0 percent (Holcomb et al. 1976).

For both organic and inorganic compounds, reported field values were considered bioaccumulation factors (*BAF*s) based on contributions of compounds from food sources as well as media. Therefore, field values were converted to *BCF*s based on the trophic level of the test organism using the following equation:

$$BCF = (BAF_{TLn} / FCM_{TLn}) - 1 \qquad \text{Equation C-1-6}$$

where

BAF_{TLn}	=	The reported field bioaccumulation factor for the trophic level "n" of the study species.
FCM_{TLn}	=	The food chain multiplier for the trophic level "n" of the study species.

Organics Reported field values for organic compounds were assumed to be total compound concentrations in water and, therefore, were converted to dissolved compound concentrations in water using the following equation from U.S. EPA (1995b):

$$BAF\,(\text{dissolved}) = (BAF\,(\text{total}) / f_{fd}) - 1 \qquad \text{Equation C-1-7}$$

where

BAF (dissolved)	=	*BAF* based on dissolved concentration of compound in water
BAF (total)	=	*BAF* based on the field derived data for total concentration of compound in water
f_{fd}	=	Fraction of compound that is freely dissolved in the water

and,

f_{fd}	=	$1 / [1 + ((DOC \times K_{ow}) / 10) + (POC \times K_{ow})]$
DOC	=	Dissolved organic carbon, Kg of organic carbon / L of water (2.0×10^{-06} Kg/L)
K_{ow}	=	Octanol-water partition coefficient of the compound, as reported in U.S. EPA (1994a)
POC	=	Particulate organic carbon, Kg of organic carbon / L of water (7.5×10^{-09} Kg/L)

Laboratory data were assumed to be based on dissolved compound concentrations.

For organics for which no field or laboratory data were available, the following regression equation was used to calculate the recommended *BCF* values:

$$\log BCF = 0.91 \times \log K_{ow} - 1.975 \times \log (6.8E\text{-}07 \times K_{ow} + 1.0) - 0.786 \qquad \text{Equation C-1-8}$$

- Bintein, S., J. Devillers, and W. Karcher. 1993. "Nonlinear Dependence of Fish Bioconcentrations on n-Octanol/Water Partition Coefficients." *SAR and QSAR in Environmental Research.* Vol. 1. Pages 29-39.

<u>*Inorganics*</u> For inorganic compounds with no available field or laboratory data, the recommended *BCF* values were estimated as the arithmetic average of the available *BCF* values reported for other inorganics.

C-1.6 SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS

Experimental data for a variety of benthic infauna, worms, insects, and other invertebrates were used to determine the recommended *BCF* values for sediment-to-benthic invertebrate (see Table C-6). As necessary, values were converted to wet tissue weight assuming that benthic invertebrate moisture content (by mass) is 83.3 percent (Pietz et al. 1984).

<u>*Organics*</u> For organic compound (including PCDDs and PCDFs) with no available field or laboratory data, the recommended *BCF* values were determined using the following regression equation:

$$\log BCF = 0.819 \times \log K_{ow} - 1.146 \qquad \text{Equation C-1-9}$$

- Southworth, G.R., J.J. Beauchamp, and P.K. Schmieder. 1978. "Bioaccumulation Potential of Polycyclic Aromatic Hydrocarbons in *Daphnia Pulex.*" *Water Research.* Volume 12. Pages 973-977.

<u>*Inorganics*</u> For inorganic compound with no available field or laboratory data, the recommended *BCF* values were estimated as the arithmetic average of the available *BCF* values for other inorganics.

C-1.7 AIR-TO-PLANT BIOCONCENTRATION FACTORS

The air-to-plant bioconcentration (*Bv*) factor (see Table C-7) is defined as the ratio of compound concentrations in exposed aboveground plant parts to the compound concentration in air. Bv values in Table C-7 are reported on dry-weight basis since the plant concentration equations (see Chapter 3) already include a dry-weight to wet-weight conversion factor.

Organics For organics (excluding PCDDs and PCDFs), the air-to-plant bioconcentration factor was calculated using regression equations derived for azalea leaves in the following documents:

- Bacci E., D. Calamari, C. Gaggi, and M. Vighi. 1990. "Bioconcentration of Organic Chemical Vapors in Plant Leaves: Experimental Measurements and Correlation." *Environmental Science and Technology.* Volume 24. Number 6. Pages 885-889.

- Bacci E., M. Cerejeira, C. Gaggi, G. Chemello, D. Calamari, and M. Vighi. 1992. "Chlorinated Dioxins: Volatilization from Soils and Bioconcentration in Plant Leaves." *Bulletin of Environmental Contamination and Toxicology.* Volume 48. Pages 401-408.

Bacci et al. (1992) developed a regression equation using empirical data collected for the uptake of 1,2,3,4-TCDD in azalea leaves and data obtained from Bacci et al. (1990). The bioconcentration factor obtained was included in a series of 14 different organic compounds to develop a correlation equation with K_{ow} and H (defined below). Bacci et al. (1992) derived the following equations:

$$\log B_{vol} = 1.065 \log K_{ow} - \log \left(\frac{H}{RT}\right) - 1.654 \qquad (r = 0.957) \qquad \text{Equation C-1-10}$$

$$Bv = \frac{\rho_{air} \cdot B_{vol}}{(1 - f_{water}) \cdot \rho_{forage}} \qquad \text{Equation C-1-11}$$

where

B_{vol}	=	Volumetric air-to-plant biotransfer factor (fresh-weight basis)
Bv	=	Air-to-plant biotransfer factor (dry-weight basis)
ρ_{air}	=	1.19 g/L (Weast 1986)
ρ_{forage}	=	770 g/L (Macrady and Maggard 1993)
f_{water}	=	0.85 (fraction of forage that is water—Macrady and Maggard [1993])
H	=	Henry's Law constant (atm-m^3/mole)
R	=	Universal gas constant (atm-m^3/mole °K)
T	=	Temperature (25°C, 298°K)

Equations C-1-10 and C-1-11 are used to calculate Bv values (see Table C-7) using the recommended values of H and K_{ow} provided in Appendix A at a temperature (T) of 25 °C or 298.1 K. The following uncertainty should be noted with use of Bv values calculated using these equations:

- For organics (except PCDDs and PCDFs), U.S. EPA (1993) recommended that *Bv* values be reduced by a factor of 10 before use. This was based on the work conducted by U.S. EPA (1993) for U.S. EPA (1994b) as an interim correction factor. Welsch-Pausch, McLachlan, and Umlauf (1995) conducted experiments to determine concentrations of PCDDs and PCDFs in air and resulting biotransfer to welsh ray grass. This was documented in the following:

  - Welsch-Pausch, K.M. McLachlan, and G. Umlauf. 1995. "Determination of the Principal Pathways of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans to Lolium Multiflorum (Welsh Ray Grass)". *Environmental Science and Technology*. 29: 1090-1098.

  A follow-up study based on Welsch-Pausch, McLachlan, and Umlauf (1995) experiments was conducted by Lorber (1995) (see discussion below for PCDDs and PCDFs). In a following publication, Lorber (1997) concluded that the Bacci factor reduced by a factor of 100 was close in line with observations made by him through various studies, including the Welsch-Pausch, McLachlan, and Umlauf (1995) experiments. Therefore, this guidance recommends that *Bv* values be calculated using the Bacci, Cerejeira, Gaggi, Chemello, Calamari, and Vighi (1992) correlation equations and then reduced by a factor of 100 for all organics, excluding PCDDs and PCDFs.

PCDDs and PCDFs For PCDDs and PCDFs, *Bv* values, on a dry weight basis, were obtained from the following:

- Lorber, M., and P. Pinsky. 1999. "An Evaluation of Three Empirical Air-to-Leaf Models for Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans." National Center for Environmental Assessment (NCEA). U. S. EPA, 401 M St. SW, Washington, DC. *Accepted for Publication in Chemosphere.*

U.S. EPA (1993) stated that, for dioxin-like compounds, the use of the Bacci, Cerejeira, Gaggi, Chemello, Calamari, and Vighi (1992) equations may overpredict *Bv* values by a factor of 40. This was because the Bacci, Calamari, Gaggi, and Vighi (1990) and Bacci, Cerejeira, Gaggi, Chemello, Calamari, and Vighi (1992) experiments did not take photodegradation effects into account. Therefore, *Bv* values calculated using Equations C-10 and C-11 were recommended to be reduced by a factor of 40 for dioxin-like compounds.

However, according to Lorber (1995), the Bacci algorithm divided by 40 may not be appropriate because (1) the physical and chemical properties of dioxin congeners are generally outside the range of the 14 organic compounds used by Bacci, Calamari, Gaggi, and Vighi (1990), and (2) the factor of 40 derived from one experiment on 2,3,7,8-TCDD may not apply to all dioxin congeners.

Welsch-Pausch, McLachlan, and Umlauf (1995) conducted experiments to obtain data on uptake of PCDDs and PCDFs from air to *Lolium Multiflorum* (Welsh Ray grass). The data includes grass concentrations and air concentrations for dioxin-congener groups, but not the invidual congeners. Lorber (1995) used data from Welsch-Pausch, McLachlan, and Umlauf (1995) to develop an air-to-leaf transfer factor for each dioxin-congener group. *Bv* values developed by Lorber (1995) were about an order of magnitude less than values that would have been calculated using the Bacci, Calamari, Gaggi, and Vighi (1990; 1992) correlation equations. Lorber (1995) speculated that this difference could be attributed to several factors including experimental design, climate, and lipid content of plant species used.

Lorber (1999) conducted an evaluation of three empirical air-to-leaf models for estimating grass concentraions of PCDDs and PCDFs from air concentrations of these compounds described and tested against field data. *Bv* values recommended for PCDDs and PCDFs in this guidance were obtained from the experimentally derived values of Lorber (1999).

Metals For metals, no literature sources were available for *Bv* values. U.S. EPA (1995a) quoted from the following document, that metals were assumed not to experience air to leaf transfer:

- Belcher, G.D., and C.C. Travis. 1989. "Modeling Support for the RURA and Municipal Waste Combustion Projects: Final Report on Sensitivity and Uncertainty Analysis for the Terrestrial Food Chain Model." Interagency Agreement No. 1824-A020-A1. Office of Risk Analysis, Health and Safety Research Division. Oak Ridge National Laboratory. Oak Ridge, Tennessee. October.

Consistent with the above references, *Bv* values for metals (excluding elemental mercury) were assumed to be zero (see Table C-7).

Mercuric Compounds Mercury emissions are assumed to consist of both the elemental and divalent forms. However, only small amounts of elemental mercury is assumed to be deposited (see Chapter 2). Elemental mercury either dissipates into the global cycle or is converted to the divalent form. Methyl mercury is assumed not to exist in the stack emissions or in the air phase. Consistent with various discussions in Chapter 2 concerning mercury, (1) elemental mercury reaching or depositing onto the plant surfaces is negligible, and (2) biotransfer of methyl mercury from air is zero. This is based on assumptions made regarding speciation and fate and transport of mercury from stack emissions. Therefore, the *Bv* value for (1) elemental mercury was assumed to be zero, and (2) methyl mercury was assumed not to be applicable. *Bv* values for mercuric chloride (dry weight basis) were obtained from U.S. EPA (1997).

It should be noted that uptake of mercury from air into the aboveground plant tissue is primarily in the divalent form. A part of the divalent form of mercury is assumed to be converted to the methyl mercury form once in the plant tissue.

Bacci E., D. Calamari, C. Gaggi, and M. Vighi. 1990. "Bioconcentration of Organic Chemical Vapors in Plant Leaves: Experimental Measurements and Correlation." *Environmental Science and Technology*. Volume 24. Number 6. Pages 885-889.

Bacci E., M. Cerejeira, C. Gaggi, G. Chemello, D. Calamari, and M. Vighi. 1992. "Chlorinated Dioxins: Volatilization from Soils and Bioconcentration in Plant Leaves." *Bulletin of Environmental Contamination and Toxicology*. Volume 48. Pages 401-408.

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Bintein, S., J. Devillers, and W. Karcher. 1993. "Nonlinear Dependence of Fish Bioconcentrations on n-Octanol/Water Partition Coefficients." *SAR and QSAR in Environmental Research*. Vol. 1. Pages 29-39.

Holcombe, G.W., D.A. Benoit, E.N. Leonard, and J.M. McKim. 1976. "Long-term Effects of Lead Exposure on Three Generations of Brook Trout (*Salvenius fontinalis*)." *Journal, Fisheries Research Board of Canada*. Volume 33. Pages 1731-1741.

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Lorber, M. 1995. "Development of an Air-to-plant Vapor Phase Transfer for Dioxins and Furans. Presented at the 15th International Symposium on Chlorinated Dioxins and Related Compounds". August 21-25, 1995 in Edmonton, Canada. Abstract in *Organohalogen Compounds*. 24:179-186.

Lorber, M., and P. Pinsky. 1999. "An Evaluation of Three Empirical Air-to-Leaf Models for Polychlorinated Dibenzo-p-Dioxins and Dibenzofurans." National Center for Environmental Assessment (NCEA). U. S. EPA, 401 M St. SW, Washington, DC. *Accepted for Publication in Chemosphere*.

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Pietz, R.I., J.R. Peterson, J.E. Prater, and D.R. Zenz. 1984. "Metal Concentrations in Earthworms From Sewage Sludge-Amended Soils at a Strip Mine Reclamation Site." *J. Environmental Qual.* Vol. 13, No. 4. Pp 651-654.

Southworth, G.R., J.J. Beauchamp, and P.K. Schmieder. 1978. "Bioaccumulation Potential of Polycyclic Aromatic Hydrocarbons in *Daphnia Pulex.*" *Water Research*. Volume 12. Pages 973-977.

Travis, C.C., and A.D. Arms. 1988. "Bioconcentration of Organics in Beef, Milk, and Vegetation." *Environmental Science and Technology*. 22:271-274.

U.S. EPA. 1993. *Review Draft Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Office of Health and Environmental Assessment. Office of Research and Development. EPA-600-AP-93-003. November 10.

U.S. Environmental Protection Agency (U.S. EPA). 1994a. *Draft Report Chemical Properties for Soil Screening Levels*. Prepared for the Office of Emergency and Remedial Response. Washington, D.C. July 26.

U.S. EPA. 1994b. *Estimating Exposure to Dioxin-Like Compounds*. Draft Report. Office of Research and Development. Washington, D.C. EPA/600/6-88/005Ca,b,c. June.

U.S. EPA. 1995a. *Review Draft Development of Human Health-Based and Ecologically-Based Exit Criteria for the Hazardous Waste Identification Project.* Volumes I and II. Office of Solid Waste. March 3.

U.S. EPA. 1995b. Great Lakes Water Quality Initiative Technical Support Document for the Procedure to Determine Bioaccumulation Factors. EPA-820-B-95-005. Office of Water, Washington, D.C. March.

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TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

15Reported Values[a]	References	Experimental Parameters	Species
Dioxins and Furans			
Compound: 2,3,7,8-tetrachlorodibenzo-p-dioxin			**Recommended BCF Value: 1.59**
The BCF was calculated using the geometric mean of 5 laboratory values for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) as follows:			
14.5	Martinucci, Crespi, Omodeo, Osella, and Traldi (1983)	20-day exposure	Not specified
9.41 0.64 0.68 0.17	Reinecke and Nash (1984)	20-day exposure	*Allolobaphora caliginosa* *Lumbricus rubellus*
Compound: 1,2,3,7,8-pentachlorodibenzo-p-dioxin			**Recommended Value: 1.46**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.92 =1.46			
Compound: 1,2,3,4,7,8-hexachlorodibenzo-p-dioxin			**Recommended Value: 0.49**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.31 =0.49			
Compound: 1,2,3,6,7,8-hexachlorodibenzo-p-dioxin			**Recommended Value: 0.19**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.12 = 0.19			
Compound: 1,2,3,7,8,9-hexachlorodibenzo-p-dioxin			**Recommended Value: 0.22**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.14 = 0.22			
Compound: 1,2,3,4,6,7,8,-heptachlorodibenzo-p-dioxin			**Recommended Value: 0.081**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.051 = 0.081			
Compound: Octachlorodibenzo-p-dioxin			**Recommended Value: 0.019**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.012 = 0.019			
Compound: 2,3,7,8-tetrachlorodibenzofuran			**Recommended BCF Value: 1.27**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.80 =1.27			
Compound: 1,2,3,7,8-pentachlorodibenzofuran			**Recommended BCF Value: 0.32**

TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

16Reported Values[a]	References	Experimental Parameters	Species
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.22 = 0.32			
Compound: 2,3,4,7,8-pentachlorodibenzofuran			Recommended BCF Value: 2.54
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 1.6 =2.54			
Compound: 1,2,3,4,7,8-hexachlorodibenzofuran			Recommended BCF Value: 0.121
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.076 = 0.121			
Compound: 1,2,3,6,7,8-hexachlorodibenzofuran			Recommended BCF Value: 0.30
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.19 = 0.30			
Compound: 2,3,4,6,7,8-hexachlorodibenzofuran			Recommended BCF Value: 1.07
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.67 =1.07			
Compound: 1,2,3,7,8,9-hexachlorodibenzofuran			Recommended BCF Value: 1.00
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.63 = 1.00			
Compound: 1,2,3,4,6,7,8-heptachlorodibenzofuran			Recommended BCF Value: 0.017
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.011 = 0.017			
Compound: 1,2,3,4,7,8,9-heptachlorodibenzofuran			Recommended BCF Value: 0.62
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.39 = 0.62			
Compound: Octochlorodibenzofuran			Recommended BCF Value: 0.025
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1.59 x 0.016 = 0.025			
Polynuclear Aromatic Hydrocarbons (PAHs)			
Compound: Benzo(a)pyrene			Recommended BCF Value: 0.07
The BCF was calculated using the geometric mean of 6 laboratory values for benzo(a)pyrene. The values reported in Rhett, Simmers, and Lee (1988) were converted to earthworm wet weight over soil dry weight using a conversion factor of 5.99[a].			

TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

17Reported Values[a]	References	Experimental Parameters	Species
0.12 0.14 0.05 0.04 0.06 0.06	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
Compoound: Benzo(a)anthracene			**Recommended BCF Value: 0.03**
The BCF was calculated using the geometric mean of 15 values for benzo(a)anthracene. The values reported in Marquenie, Simmers, and Kay (1987) were converted to wet weight over dry weight using a conversion factor of 5.99 [a].			
0.07 0.02 0.08 0.02 0.05 0.07 0.07 0.003 0.07 0.05 0.02 0.01 0.01 0.01 0.09	Marquenie, Simmers, and Kay (1987)	32-day exposure	*Eisenia foetida*
Compound: Benzo(b)fluoranthene			**Recommended BCF Value: 0.07**
The BCF was calculated using the geometric mean of 6 laboratory values for benzo(b)fluoranthene. The values reported in Rhett, Simmers, and Lee (1988) were converted to wet weight over dry weight using a conversion factor of 5.99 [a].			
0.11 0.16 0.06 0.04 0.06 0.05	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
Compound: Benzo(k)fluoranthene			**Recommended BCF Value: 0.08**
The BCF was calculated using the geometric mean of 15 laboratory values for benzo(k)fluoranthene. The values reported in Marquenie, Simmers, and Kay (1987) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			
0.13 0.15 0.12 0.11 0.07 0.24 0.12 0.02 0.10 0.03 0.07 0.03 0.06 0.04	Marquenie, Simmers, and Kay (1987)	32-day exposure	*Eisenia foetida*

TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

18Reported Values[a]	References	Experimental Parameters	Species
Compound: Chrysene			**Recommended BCF Value: 0.04**
The BCF was calculated using the geometric mean of 15 laboratory values for chrysene. The values reported in Marquenie, Simmers, and Kay (1987) were converted to wet weight over dry weight using a conversion factor of 5.99 [a].			
0.06 0.03 0.09 0.04 0.09 0.07 0.14 0.007 0.14 0.02 0.04 0.02 0.03 0.01 0.10	Marquenie, Simmers, and Kay (1987)	32-day exposure	*Eisenia foetida*
Compound: Dibenzo(a,h)anthracene			**Recommended BCF Value: 0.07**
The BCF was calculated using the geometric mean of 15 laboratory values for Dibenz(a,h)anthrcene. The values reported in Marquenie, Simmers, and Kay (1987) were converted to wet weight over dry weight using a conversion factor of 5.99 [a].			
0.18 0.13 0.10 0.06 0.06 0.07 0.04 0.10 0.12 0.05 0.07 0.04 0.04 0.05 0.05	Marquenie, Simmers, and Kay (1987)	32-day exposure	*Eisenia foetida*
Compound: Indeno(1,2,3-cd)pyrene			**Recommended BCF Value: 0.08**
The BCF was calculated using the geometric mean of 6 laboratory values for indeno(1,2,3-cd)pyrene. The values reported in Rhett, Simmers, and Lee (1988) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			
0.07 0.13 0.08 0.09 0.06 0.05	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
Polychlorinated Biphenyls (PCBs)			
Compound: Aroclor 1016			**Recommended BCF Value: 1.13**

TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

19Reported Values[a]	References	Experimental Parameters	Species
The BCF was calculated using the geometric mean of 7 laboratory values for a mixture of PCB congeners. The values reported in Rhett, Simmers, and Lee (1988) and Kreis, Edwards, Cuendet, and Tarradellas (1987) were converted to wet weight over dry weight using a conversion factor of 5.99 [a].			
1.43 0.81 0.75 1.07 1.17	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
1.92 1.16	Kreis, Edwards, Cuendet, and Tarradellas (1987)	Chronic exposure	*Nicodrilus* sp.
Compound: Aroclor 1254			**Recommended BCF Value:** 1.13
The BCF was calculated using the geometric mean of 7 laboratory values for a mixture of PCB congeners. The values reported in Rhett, Simmers, and Lee (1988) and Kreis, Edwards, Cuendet, and Tarradellas (1987) were converted to wet weight over dry weight using a conversion factor of 5.99 [a].			
1.43 0.81 0.75 1.07 1.17	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
1.92 1.16	Kreis, Edwards, Cuendet, and Tarradellas (1987)	Chronic exposure	*Nicodrilus* sp.

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SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

20Reported Values*	References	Experimental Parameters	Species
Nitroaromatics			
Compound: 1,3-Dinitrobenzene			Recommended BCF Value: 1.19
No empirical data were available for 1,3-dinitrobenzene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.491 (U.S. EPA 1994b).			
Compound: 2,4-Dinitrotoluene			Recommended BCF Value: 3.08
No empirical data were available for 2,4-dinitrotoluene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.996 (U.S. EPA 1994b).			
Compound: 2,6-Dinitrotoluene			Recommended BCF Value: 2.50
No empirical data were available for 2,6-dinitrotoluene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.886 (U.S. EPA 1994b).			
Compound: Nitrobenzene			Recommended BCF Value: 2.26
No empirical data were available for nitrobenzene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.833 (U.S. EPA 1994b).			
Compound: Pentachloronitrobenzene			Recommended BCF Value: 451
No empirical data were available for pentachloronitrobenzene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 4.640 (U.S. EPA 1994b).			
Phthalate Esters			
Compound: Bis(2-ethylhexyl)phthalate			Recommended BCF Value: 1,309
No empirical data were available for bis(2-ethylhexyl)phthalate or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 5.205 (U.S. EPA 1994b).			
Compound: Di(n)octyl phthalate			Recommended BCF Value: 3,128,023
No empirical data were available for di(n)octyl phthalate or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 9.330 (U.S. EPA 1994b).			

TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

21 Reported Values[a]	References	Experimental Parameters	Species
Volatile Organic Compounds			
Compound: Acetone			Recommended BCF Value: 0.05
No empirical data were available for acetone or for a structurally-similar surrogate compound.The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder (1978), where log K_{ow} = -0.222 (Karickoff and Long 1995).			
Compound: Acrylonitrile			Recommended BCF Value: 0.11
No empirical data were available for acrylonitrile or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.250 (Karickoff and Long 1995).			
Compound: Chloroform			Recommended BCF Value: 2.82
No empirical data were available for chloroform or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.949 (U.S. EPA 1994b).			
Compound: Crotonaldehyde			Recommended BCF Value: 0.20
No empirical data were available for crotonaldehyde or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.55 (Based on equations developed by Hansch and Leo 1979, calculated in NRC (1981)).			
Compound: 1,4-Dioxane			Recommended BCF Value: 0.04
No empirical data were available for 1,4-dioxane or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = -0.268 (U.S. EPA 1995a).			
Compound: Formaldehyde			Recommended BCF Value: 0.14
No empirical data were available for formaldehyde or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.342 (U.S. EPA 1995a).			
Compound: Vinyl chloride			Recommended BCF Value: 0.62
No empirical data were available for vinyl chloride or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.146 (U.S. EPA 1994b).			

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SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

22Reported Values[a]	References	Experimental Parameters	Species
Other Chlorinated Organics			
Compound: Carbon Tetrachloride			Recommended BCF Value: 12.0
No empirical data were available for carbon tetrachloride or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 2.717 (U.S. EPA 1994b).			
Compound: Hexachlorobenzene			Recommended BCF Value: 2,296
No empirical data were available for hexachlorobenzene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 5.503 (U.S. EPA 1994b).			
Compound: Hexachlorobutadiene			Recommended BCF Value: 535
No empirical data were available for hexachlorobutadiene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978) where log K_{ow} = 4.731 (U.S. EPA 1994b).			
Compound: Hexachlorocyclopentadiene			Recommended BCF Value: 745
No empirical data were available for hexachlorocyclopentadiene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder (1978), where log K_{ow} = 4.907 (U.S. EPA 1994b).			
Compound: Pentachlorobenzene			Recommended BCF Value: 1,050
No empirical data were available for pentachlorobenzene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder (1978), where log K_{ow} = 5.088 (U.S. EPA 1994b).			
Compound: Pentachlorophenol			Recommended BCF Value: 1,034
No empirical data were available for pentachlorophenol or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder (1978), where log K_{ow} = 5.080 (U.S. EPA 1994b).			
Pesticides			
Compound: 4,4'-DDE			Recommended BCF Value: 1.26
Empirical data for 4,4'-DDE were not available. The BCF was calculated using the geometric mean of 13 laboratory values for 4,4'-DDT. The first six values reported in Gish (1970), Davis (1971), and Beyer and Gish (1980) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			
0.08 0.39 0.29 0.41	Davis (1971)	Chronic exposure	*Lumbricus terrestris*

TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

23Reported Values[a]	References	Experimental Parameters	Species
0.83	Beyer and Gish (1980)	Chronic exposure	*Aporrectodea trapezoides* *Aparrectodea turgida* *Allolobophora chlorotica* *Lumbricus terrestris*
0.85 1.20 2.40 4.60 2.50 1.60	Wheatley and Hardman (1968)	Chronic exposure	Not specified
10.00 14.46	Yadav, Mittad, Agarwal, and Pillai (1981)	Chronic exposure	*Pheretima posthuma*
Compound: Heptachlor			**Recommended BCF Value:** 1.40
Empirical data for heptachlor were not available. The BCF was calculated using 1 laboratory value for heptachlor epoxide. The value reported in Beyer and Gish (1980) was converted to wet weight over dry weight using a conversion factor of 5.99[a].			
1.40	Beyer and Gish (1980)	Chronic exposure	*Aporrectodea trapezoides* *Aparrectodea turgida* *Allolobophora chlorotica* *Lumbricus terrestris*
Compound: Hexachlorophene			**Recommended BCF Value:** 106,970
No empirical data were available for hexachlorophene or for a structurally-similar surrogate compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder (1978), where log K_{ow} = 7.540 (Karickoff and Long 1995).			
Inorganics			
Compound: Aluminum			**Recommended BCF Value:** 0.22
Empirical data for aluminum were not available. The recommended BCF is the arithmetic mean of the recommended values for those inorganics with empirical data available (arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, and zinc).			
Compound: Antimony			**Recommended BCF Value:** 0.22
Empirical data for antimony were not available. The recommended BCF is the arithmetic mean of the recommended values for those inorganics with empirical data available (arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, and zinc).			
Compound: Arsenic			**Recommended BCF Value:** 0.11

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SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

24Reported Values[a]	References	Experimental Parameters	Species
The BCF was calculated using the geometric mean of 5 laboratory values for arsenic as listed below. The values reported in Rhett, Simmers, and Lee (1988) were converted to wet weight over dry weight using a conversion factor of 5.99 [a].			
0.14 0.10 0.10 0.17 0.06	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
Compound: Barium			**Recommended BCF Value: 0.22**
Empirical data for barium were not available. The recommended BCF is the arithmetic mean of the recommended values for those inorganics with empirical data available (arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, and zinc).			
Compound: Beryllium			**Recommended BCF Value: 0.22**
Empirical data for beryllium were not available. The recommended BCF is the arithmetic mean of the recommended values for those inorganics with empirical data available (arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, and zinc).			
Compound: Cadmium			**Recommended BCF Value: 0.96**
The BCF was calculated using the geometric mean of 22 laboratory values for cadmium. The values reported in Rhett, Simmers, and Lee (1988) and Simmers, Rhett, and Lee (1983) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			
0.33 0.72 0.25 0.19 3.17 0.55 0.70 0.35	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
0.13 0.50 0.29 8.77 1.25 7.86 0.17 6.67 0.11 3.95 8.01 1.50 4.39 2.10	Simmers, Rhett, and Lee (1983)	Chronic exposure	*Allolobophora longa* *A. caliginosa* *A. rosea* *A. chlorotica* *Lumbricus terrestris* *A. lumbricus* *Octolasium* sp.
Compound: Chromium (total)			**Recommended BCF Value: 0.01**
The BCF was calculated using the geometric mean of 3 laboratory values for chromium. The values reported in Rhett, Simmers, and Lee (1988) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			

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SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

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25Reported Values[a]	References	Experimental Parameters	Species
0.004 0.004 0.05	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
Compound: Copper			**Recommended BCF Value:** 0.04
The BCF was calculated using the geometric mean of 9 laboratory values for copper. The values reported in Rhett, Simmers, and Lee (1988) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			
0.02 0.03 0.01 0.03 0.20 0.03 0.04 0.04	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
0.24	Ma (1987)	Chronic exposure	*Lumbricus rubellus*

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SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

26Reported Values[a]	References	Experimental Parameters	Species
Compound: Cyanide (total)			**Recommended BCF Value:** 1.12
Empirical data for cyanide were not available. The recommended BCF is the arithmetic mean of the recommended values for those inorganics with empirical data available (arsenic, cadmium, chromium, copper, lead, inorganic mercury, methyl mercury, nickel, and zinc).			
Compound: Lead			**Recommended BCF Value:** 0.03
The BCF was calculated using the geometric mean of 6 laboratory values for lead. The values reported in Rhett, Simmers, and Lee (1988), Ma (1987), and Van Hook (1974) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			
0.02 0.006 0.07	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
0.19	Ma (1987)	Chronic exposure	Not specified
0.12	Ma (1982)		Not specified
0.03	Van Hook (1974)	Chronic exposure	*Alabophera* sp. *Lumbricus* sp. *Octolasium* sp.
Compound: Mercuric chloride			**Recommended BCF Value:** 0.04
The BCF was calculated using the geometric mean of 5 laboratory values for mercuric chloride. The values reported in Rhett, Simmers, and Lee (1988) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			
0.04 0.04 0.06 0.04 0.02	Rhett, Simmers, and Lee (1988)	28-day exposure; tissue concentrations of <0.05 were reported for the first three ratios, however, a concentration of 0.05 was used in order to calculate a conservative BCF value.	*Eisenia foetida*
Compound: Methyl mercury			**Recommended BCF Value:** 8.50
The BCF was calculated using the geometric mean of 3 laboratory values as presented below. The values reported in Beyer, Cromartie, and Moment (1985) were earthworm wet weight over soil wet weight with 60 percent soil moisture. The soil weight was converted to dry weight to result in the values presented below:			
8.25 8.31 8.95	Beyer, Cromartie, and Moment (1985)	6 to 12-week exposure	*Eisenia foetida*

TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

27Reported Values[a]	References	Experimental Parameters	Species
Compound: Nickel			Recommended BCF Value: 0.02
The BCF was calculated using the geometric mean of 3 laboratory values for nickel. The values reported in Rhett, Simmers, and Lee (1988) were converted to wet weight over dry weight using a conversion factor of 5.99[a].			
0.03 0.01 0.04	Rhett, Simmers, and Lee 1988	28-day exposure	*Eisenia foetida*
Compound: Selenium			Recommended BCF Value: 0.22
Empirical data for selenium were not available. The recommended BCF is the arithmetic mean of the recommended values for those inorganics with empirical data available (arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, and zinc).			
Compound: Silver			Recommended BCF Value: 0.22
Empirical data for silver were not available. The recommended BCF is the arithmetic mean of the recommended values for those inorganics with empirical data available (arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, and zinc).			
Compound: Thallium			Recommended BCF Value: 0.22
Empirical data for thallium were not available. The recommended BCF is the arithmetic mean of the recommended values for those inorganics with empirical data available (arsenic, cadmium, chromium, copper, lead, inorganic mercury, nickel, and zinc).			

TABLE C-1

SOIL-TO-SOIL INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC/kg wet tissue) / (mg COPC/kg dry soil)

28Reported Values[a]	References	Experimental Parameters	Species
Compound: Zinc			Recommended BCF Value: 0.56
The BCF was calculated using the geometric mean of 5 laboratory values for zinc. The values reported in Rhett, Simmers, and Lee (1988), Ma (1987), and Van Hook (1974) were converted to wet weight over dry weight using a conversion factor of 5.99 [a].			
0.11 0.06 0.58	Rhett, Simmers, and Lee (1988)	28-day exposure	*Eisenia foetida*
10.79	Ma (1987)	Chronic exposure	Not specified
1.28	Van Hook (1974)	Chronic exposure	*Alabophera* sp. *Lumbricus* sp. *Octolasium* sp.

Notes:

(a) The reported values are presented as the amount of COPC in invertebrate tissue divided by the amount of COPC in the soil. If the values reported in the studies were presented as dry tissue weight over dry soil weight, they were converted to wet weight over dry weight by dividing the concentration in dry earthworm tissue weight by 5.99. This conversion factor assumes an earthworm's total weight is 83.3 percent moisture (Pietz et al. 1984).

The conversion factor was calculated as follows:

$$\textit{Conversion factor} = \frac{1.0 \textit{ gram (g) earthworm total weight}}{1.0 \textit{ g earthworm total weight} - 0.833 \textit{ g earthworm wet weight}}$$

TABLE C-2

SOIL-TO-PLANT AND SEDIMENT-TO- PLANT BIOCONCENTRATION FACTORS
(mg COPC/kg dry tissue) / (mg COPC/kg dry soil or sediment)

Reported Values	References	Experimental Parameters	Species
Dioxins and Furans			
Compound: 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)			Recommended BCF Value: 0.0056
The BCF for these constituents were calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 6.64 (U.S. EPA 1994a).			
Compound: 1,2,3,7,8-Tetrachlorodibenzo-p-dioxin (1,2,3,7,8-PeCDD)			Recommended BCF Value: 0.0052
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x 0.92 =0.0052			
Compound: 1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)			Recommended BCF Value: 0.0017
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.31 = 0.0017			
Compound: 1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)			Recommended BCF Value: 0.00067
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.12 = 0.00067			
Compound: 1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)			Recommended BCF Value: 0.00078
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x 0.14 = 0.00078			
Compound: 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)			Recommended BCF Value: 0.00029
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.051 = 0.00029			
Compound: Octachlorodibenzo-p-dioxin (OCDD)			Recommended BCF Value: 0.000067
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x 0.012 = 0.000067			
Compound: 2,3,7,8-Tetrachlorodibenzo-p-furan (2,3,7,8-TCDF)			Recommended BCF Value: 0.0045
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.80 = 0.0045			
Compound: 1,2,3,7,8-Pentachlorodibenzo-p-furan (1,2,3,7,8-PeCDF)			Recommended BCF Value: 0.0011
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.22 = 0.0011			
Compound: 2,3,4,7,8-Pentachlorodibenzo-p-furan (2,3,4,7,8-PeCDF)			Recommended BCF Value: 0.0090
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x1.6 = 0.0090			

TABLE C-2

SOIL-TO-PLANT AND SEDIMENT-TO- PLANT BIOCONCENTRATION FACTORS
(mg COPC/kg dry tissue) / (mg COPC/kg dry soil or sediment)

Reported Values	References	Experimental Parameters	Species
Compound: 1,2,3,4,7,8-Hexachlorodibenzo-p-furan (1,2,3,4,7,8-HxCDF)			Recommended BCF Value: 0.00043
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x 0.076 = 0.00043			
Compound: 1,2,3,6,7,8-Hexachlorodibenzo-p-furan (1,2,3,6,7,8-HxCDF)			Recommended BCF Value: 0.0011
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.19 = 0.0011			
Compound: 2,3,4,6,7,8-Hexachlorodibenzo-p-furan (2,3,4,6,7,8-HxCDF)			Recommended BCF Value: 0.0038
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.67 = 0.0038			
Compound: 1,2,3,7,8,9-Hexachlorodibenzo-p-furan (1,2,3,7,8,9-HxCDF)			Recommended BCF Value: 0.0035
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.63 = 0.0035			
Compound: 1,2,3,4,6,7,8-Heptachlorodibenzo-p-furan (1,2,3,4,6,7,8-HpCDF)			Recommended BCF Value: 0.000062
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =0.0056 x0.011 = 0.00062			
Compound: 1,2,3,4,7,8,9-Heptachlorodibenzo-p-furan (1,2,3,4,7,8,9-HpCDF)			Recommended BCF Value: 0.0022
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.39 = 0.0022			
Compound: Octachlorodibenzo-p-furan (OCDF)			Recommended BCF Value: 0.000090
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 0.0056 x0.016 = 0.000090			
Polynuclear Aromatic Hydrocarbons (PAH)			
Compound: Benzo(a)pyrene			Recommended BCF Value: 0.0
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 6.129 (U.S. EPA 1994b).			
Compound: Benzo(a)anthracene			Recommended BCF Value: 0.0202
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 5.679 (U.S. EPA 1994b).			
Compound Benzo(b)fluoranthene			Recommended BCF Value: 0.0101
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 6.202 (U.S. EPA 1994b).			
Compound: Benzo(k)fluoranthene			Recommended BCF Value: 0.0101

TABLE C-2

SOIL-TO-PLANT AND SEDIMENT-TO- PLANT BIOCONCENTRATION FACTORS
(mg COPC/kg dry tissue) / (mg COPC/kg dry soil or sediment)

Reported Values	References	Experimental Parameters	Species
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 6.2 (Karickhoff and Long 1995).			
Compound:	Chrysene		Recommended BCF Value: 0.0187
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 5.739 (U.S. EPA 1994b).			
Compound:	Dibenzo(a,h)anthracene		Recommended BCF Value: 0.0064
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 6.547 (U.S. EPA 1994b).			
Compound:	Indeno(1,2,3-cd)pyrene		Recommended BCF Value: 0.0039
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 6.915 (U.S. EPA 1994b).			
Polychlorinated Biphenyls (PCBs)			
Compound:	Aroclor 1016		Recommended BCF Value: 0.01
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988); using the log K_{ow} for Aroclor 1254, where log K_{ow}= 6.207 (U.S. EPA 1994b).			
Compound:	Aroclor 1254		Recommended BCF Value: 0.01
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988); using the log K_{ow} for Aroclor 1254, where log K_{ow}= 6.207 (U.S. EPA 1994b).			
Nitroaromatics			
Compound:	1,3-Dinitrobenzene		Recommended BCF Value: 5.32
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 1.491 (U.S. EPA 1994b).			
Compound:	2,4-Dinitrotoluene		Recommended BCF Value: 2.72
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} =1.996 (U.S. EPA 1994b).			
Compound	2,6-Dinitrotoluene		Recommended BCF Value: 3.15
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 1.886 (U.S. EPA 1994b).			
Compound:	Nitrobenzene		Recommended BCF Value: 3.38

TABLE C-2

SOIL-TO-PLANT AND SEDIMENT-TO- PLANT BIOCONCENTRATION FACTORS
(mg COPC/kg dry tissue) / (mg COPC/kg dry soil or sediment)

Reported Values	References	Experimental Parameters	Species
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 1.833 (U.S. EPA 1994b).			
Compound:	Pentachloronitrobenzene		Recommended BCF Value: 0.08
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 4.640 (U.S. EPA 1994b).			
		Phthalate Esters	
Compound:	Bis(2-ethylhexyl)phthalate		Recommended BCF Value: 0.038
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 5.205 (U.S. EPA 1994b).			
Compound:	Di(n)octyl phthalate		Recommended BCF Value: 0.000157
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 9.33 (U.S. EPA 1994b).			
		Volatile organic compounds	
Compound:	Acetone		Recommended BCF Value: 52
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = -0.222 (U.S. EPA 1994c).			
Compound:	Acrylonitrile		Recommended BCF Value: 27.77
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 0.250 (Karickhoff and Long 1995).			
Compound:	Chloroform		Recommended BCF Value: 2.9
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 1.949 (U.S. EPA 1994b).			
Compound:	Crotonaldehyde		Recommended BCF Value: 18.63
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 0.55 (Hansch and Leo 1979).			
Compound:	1,4-Dioxane		Recommended BCF Value: 55.32
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = -0.268 (U.S. EPA 1995c).			
Compound:	Formaldehyde		Recommended BCF Value: 24.57
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 0.342 (U.S. EPA (1995c).			
Compound:	Vinyl chloride		Recommended BCF Value: 8.43

TABLE C-2

SOIL-TO-PLANT AND SEDIMENT-TO- PLANT BIOCONCENTRATION FACTORS
(mg COPC/kg dry tissue) / (mg COPC/kg dry soil or sediment)

Reported Values	References	Experimental Parameters	Species
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988). where log K_{ow} = 1.146 (U.S. EPA 1994b).			
Other Chlorinated Organics			
Compound:	Carbon tetrachloride		Recommended BCF Value: 1.04
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 2.717 (U.S. EPA 1994b).			
Compound:	Hexachlorobenzene		Recommended BCF Value: 0.0255
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 5.503 (U.S. EPA 1994b).			
Compound:	Hexachlorobutadiene		Recommended BCF Value: 0.0714
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 4.731 (U.S. EPA 1994b).			
Compound:	Hexachlorocyclopentadiene		Recommended BCF Value: 0.0565
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 4.907 (U.S. EPA 1994b).			
Compound:	Pentachlorobenzene		Recommended BCF Value: 0.044
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 5.088 (U.S. EPA 1994b).			
Compound:	Pentachlorophenol		Recommended BCF Value: 0.0449
The BCF was calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988), where log K_{ow} = 5.08 (U.S. EPA 1994b).			
Pesticides			
Compound:	4,4-DDE		Recommended BCF Value: 0.00937
The BCF for these constituents were calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988)., where log K_{ow} = 6.256 (U.S. EPA 1994b).			
Compound:	Heptachlor		Recommended BCF Value: 0.0489
The BCF for these constituents were calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988)., where log K_{ow} = 5.015 (U.S. EPA 1994b).			
Compound:	Hexachlorophene		Recommended BCF Value: 0.0017

TABLE C-2

SOIL-TO-PLANT AND SEDIMENT-TO- PLANT BIOCONCENTRATION FACTORS
(mg COPC/kg dry tissue) / (mg COPC/kg dry soil or sediment)

Reported Values	References	Experimental Parameters	Species
The BCF for these constituents were calculated using the following regression equation: log BCF = 1.588 - 0.578 x log K_{ow} (Travis and Arms 1988)., where log K_{ow} = 7.54 (Karickhoff and Long 1995).			
Inorganics			
Compound: Aluminum			Recommended BCF Value: 0.004
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Antimony			Recommended BCF Value: 0.2
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Arsenic			Recommended BCF Value: 0.036
The BCF for this constituent was based on empirical data reported in U.S. EPA (1992c). Experimental parameters were not reported.			
Compound Barium			Recommended BCF Value: 0.15
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Beryllium			Recommended BCF Value: 0.01
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Cadmium			Recommended BCF Value: 0.364
The BCF for this constituent was based on empirical data reported in U.S. EPA (1992c). Experimental parameters were not reported.			
Compound: Chromium (total)			Recommended BCF Value: 0.0075
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Copper			Recommended BCF Value: 0.4
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Cyanide (total)			Recommended BCF Value: No data
No empirical or K_{ow} data were available for this constituent.			
Compound: Lead			Recommended BCF Value: 0.045

TABLE C-2

SOIL-TO-PLANT AND SEDIMENT-TO- PLANT BIOCONCENTRATION FACTORS
(mg COPC/kg dry tissue) / (mg COPC/kg dry soil or sediment)

Reported Values	References	Experimental Parameters	Species
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Mercuric chloride			Recommended BCF Value: 0.0375
The BCF was calculated using the geometric mean of 3 values for mercuric chloride ($HgCl_2$).			
0.022 0.032 0.075	Cappon (1981)	The values were derived from studies during one growing season using 20 food crop vegetables.	Not specified.
Compound: Methyl mercury			Recommended BCF Value: 0.137
The BCF was calculated using the geometric mean of 3 values for methyl mercury.			
0.062 0.149 0.277	Cappon (1981)	The values were derived from studies during one growing season using 20 food crop vegetables.	Not specified.
Compound: Nickel			Recommended BCF Value: 0.032
The BCF for this constituent was based on empirical data reported in U.S. EPA (1992c). Experimental parameters were not reported.			
Compound: Selenium			Recommended BCF Value: 0.016
The BCF for this constituent was based on empirical data reported in U.S. EPA (1992c). Experimental parameters were not reported.			
Compound: Silver			Recommended BCF Value: 0.4
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Thallium			Recommended BCF Value: 0.004
The BCF for this constituent was based on empirical data reported in Baes, Sharp, Sjoreen and Shor (1984). Experimental parameters were not reported.			
Compound: Zinc			Recommended BCF Value: 0.0000000000012
The BCF for this constituent was based on empirical data reported in U.S. EPA (1992c). Experimental parameters were not reported.			

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Dioxins and Furans			
Compound: 2,3,7,8-Tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD)			Recommended BCF Value: 1,560
The BCF value was calculated using the geometric mean of 2 values from data reported for 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD).			
1,762 1,381	Yockim, Isensee, and Jones (1978)	32-day exposure duration	Daphnid; *Heliosoma* sp.
Compound: 1,2,3,7,8-Pentachlorodibenzo(p)dioxin (1,2,3,7,8-PeCDD)			Recommended BCF Value: 1,435
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.92 =1,435			
Compound: 1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin (1,2,3,4,7,8-HxCDD)			Recommended BCF Value: 483.6
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.31 =483.6			
Compound: 1,2,3,6,7,8-Hexachlorodibenzo(p)dioxin (1,2,3,6,7,8-HxCDD)			Recommended BCF Value: 187.2
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.12 =187.2			
Compound: 1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin (1,2,3,7,8,9-HxCDD)			Recommended BCF Value: 218.4
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.14 = 218.4			
Compound: 1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin (1,2,3,4,6,7,8-HpCDD)			Recommended BCF Value: 79.6
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.051 = 79.6			
Compound: Octachlorodibenzo(p)dioxin (OCDD)			Recommended BCF Value: 18.7
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.012 = 18.7			
Compound: 2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)			Recommended BCF Value: 1248
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.80 = 124			
Compound: 1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PeCDF)			Recommended BCF Value: 343.2
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.22 = 343.2			
Compound: 2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PeCDF)			Recommended BCF Value: 2,496

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 1.6 = 2,496			
Compound: 1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)			Recommended BCF Value: 118.6
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.076 = 118.6			
Compound: 1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)			Recommended BCF Value: 296.4
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.19 = 296.4			
Compound: 2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)			Recommended BCF Value: 1,045
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.67 = 1,045			
Compound: 1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)			Recommended BCF Value: 982.8
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.63 = 982.8			
Compound: 1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)			Recommended BCF Value: 17.2
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.011 = 17.2			
Compound: 1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)			Recommended BCF Value: 608.4
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.39 = 608.4			
Compound: Octachlorodibenzofuran (OCDF)			Recommended BCF Value: 25.0
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =1,560 x 0.016 = 25.0			
Polynuclear Aromatic Hydrocarbons (PAHs)			
Compound: Benzo(a)pyrene			Recommended BCF Value: 4,697
The BCF value was calculated using the geometric mean of 6 laboratory values as follows:			
55,000	Eadie, Landrum, and Faust (1982)	Reported as the mean of the measured PAH concentrations in the test species and the sediment	*Pontoporcia hoyi*
12,761	Newsted and Giesy (1987)	24-hour exposure duration	*Daphnia magna*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values*	Reference	Experimental Parameters	Species
861	Roesijadi, Anderson, and Blaylock (1978)	7-day exposure duration	*Macoma inquinata*
3,000	Lee, Gardner, Anderson, Blaytock, and Barwell-Clarke (1978)	8-day exposure duration. The reported value was calculated by dividing the wet tissue concentration by the medium concentration [(μg/g)/(μg/L)] conversion factor of 1 x 10^3 was applied to the value.	*Crassostrea virginica*
2,745 2,158	Leversee, Landrum, Giesy, and Fannin (1983)	6-hour exposure duration; 0.2 ppm concentrated humic acid added to test medium	*Daphnia magna*
Compound: Benzo(a)anthracene			**Recommended BCF Value: 12,299**
The BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
18,000	Lee, Gardner, Anderson, Blaytock, and Barwell-Clarke (1978)	8-day exposure duration; The reported value was calculated by dividing the wet tissue concentration by the medium concentration [(μg/g)/(μg/L)] conversion factor of 1 x 10^3 was applied to the value.	*Crassostrea virginica*
10,225	Newsted and Giesy (1987)	24-hour exposure duration	*Daphnia magna*
10,109	Southworth, Beauchamp, and Schmieder (1978)	24-hour exposure duration	*Daphnia pulex*
Compound: Benzo(b)fluoranthene			**Recommended BCF Value: 4,697**
Laboratory data were not available for this constituent. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Benzo(k)fluoranthene			**Recommended BCF Value: 13,225**
The BCF value was based on one laboratory value as follows:			
13,225	Newsted and Giesy (1987)	24-hour exposure duration	*Daphnia magna*
Compound: Chrysene			**Recommended BCF Value: 980**
The BCF value was calculated using the geometric mean of 7 laboratory values as follows:			
5,500	Eastmond, Booth, and Lee (1984)	Not reported	*Daphnia magna*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
248 199 1,809 418	Millea, Corliss, Farragut, and Thompson (1982)	28-day exposure duration; reported values were based on accumulation in the cephalothorax and abdomen at exposures of 1 or 5 µg/L in a cloed seawater system.	*Penaeus duorarum*
6,088	Newsted and Giesy (1987)	24-hour exposure duration	*Daphnia magna*
694	Roesijadi, Anderson, and Blaylock (1978)	7-day exposure duration	*Macoma inquinata*
Compound: Dibenzo(a,h)anthracene			**Recommended BCF Value: 710**
The BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
652 773	Leversee, Landrum, Giesy, and Fannin (1983)	6-hour exposure duration	*Daphnia magna*
Compound: Indeno(1,2,3-cd)pyrene			**Recommended BCF Value: 4,697**
Laboratory data were not available for this constituent. The BCF for benzo(a)pyrene was used as a surrogate.			
Polychlorinated Biphenyls (PCBs)			
Compound: Aroclor 1016			**Recommended BCF Value: 13,000**
The BCF value for Aroclor 1016 was calulated using one laboratory value as follows:			
13,000	Parrish et al. (1974) as cited in EPA (1980b)	84 day exposure Edible portion	*Crassostrea virginica*
Compound: Aroclor 1254			**Recommended BCF Value: 5,538**
The BCF value for Aroclor 1254 was calulated using the geometric mean 13 laboratory values as follows:			
41,857 6,900 5,679	Rice and White (1987)	Field study	*Sphaerium striatum*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
750 740 3,800 1,500 6,200 3,500 2,600 2,700	Mayer, Mehrle, and Sanders (1977)	4 to 21-day exposure	*Orconectes nais; Daphnia magna; Gammarus pseudolimnaeus; Palaemontes kadiakensis; Corydalus cornutus; Culex tarsalis; Chaoborus punctipennis*
120,000	Veith, Kuehl, Puglisi, Glass, and Eaton (177)	Field samples	Zooplankton
340,000 in lipid 51,000 dry tissue	Scura and Theilacker (1977)	45 days exposure	*Brachionus plicatilis*
>27,000	Nimmo et al. (1977) as cited in EPA (1980b)	Field data Whole body	Invertebrates
740	Mayer et al. (1977) as cited in EPA (1980b)	21 days exposure	*Pteronarcys dorsata*
1,500	Mayer et al. (1977) as cited in EPA (1980b)	7 days exposre	*Corydalus cornutus*
750	Mayer et al. (1977) as cited in EPA (1980b)	21 days exposure	*Orconectes nais*
373	Mayer et al. (1977) as cited in EPA (1980b)	5 days exposure	*Nereis diversicolor*
140	Duke et al. (1970) as cited in EPA (1980b)	2 day exposure	*Penaeus duorarum*
8,100	Duke et al. (1970) as cited in EPA (1980b)	2 days exposure	*Crassostrea virginica*
236	Courtney and Langston (1978) as cited in EPA (1980b)	5 days exposure	*Arenicola marina*
Nitroaromatics			
Compound: 1,3-Dinitrobenzene			**Recommended BCF Value: 13**

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Laboratory data were not available for this constituent. BCF for 2,4-dinitrotoluene was used as a surrogate.			
Compound: 2,4-Dinitrotoluene			**Recommended BCF Value: 13**
The recommended BCF value is based on one study as follows:			
13	Liu, Bailey, and Pearson (1983)	4-day exposure duration	*Daphnia magna*
Compound: 2,6-Dinitrotoluene			**Recommended BCF Value: 13**
Laboratory data were not available for this constituent. BCF for 2,4-dinitrotoluene was used as a surrogate.			
Compound: Nitrobenzene			**Recommended BCF Value: 13**
Laboratory data were not available for this constituent. BCF for 2,4-dinitrotoluene was used as a surrogate.			
Compound: Pentachloronitrobenzene			**Recommended BCF Value: 13**
Laboratory data were not available for this constituent. BCF for 2,4-dinitrotoluene was used as a surrogate.			
Phthalate Esters			
Compound: Bis(2-ethylhexyl)phthalate			**Recommended BCF Value: 318**
The BCF value was calculated using the geometric mean of 12 laboratory values as follows:			
2,497	Brown and Thompson (1982)	14 to 28-day exposure duration	*Mytilus edulis*
257	Perez, Davey, Lackie, Morrison, Murphy, Soper, and Winslow (1983)	30-day exposure duration	*Pitar morrhauna*
48 2237	Sanders, Mayer, and Walsh (1973)	14-day exposure duration; The reported value was calculated by dividing the wet tissue concentration by the medium concentration [(μg/g)/(μg/L)], and a conversion factor of 1 x 10^3 was applied to the value. The reported value was also converted from dry weight to wet weight using a conversion factor of 5.99[a].	*Gammarus pseudolimnacus*
1,214 17,473 2,271 24,456	Sodergren (1982)	27-day exposure duration	*Chironomus* sp.; *Sialis* sp.; *Phanorbis corneus*; *Gammarus pulex*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
11 10 7 17	Wofford, Wilsey, Neff, Giam, and Neff (1981)	24-hour exposure duration	*Crassostrea virginica*; *Penaeus aztecus*
Compound: Di(n)octyl phahalate			Recommended BCF Value: 5,946
The BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
13,600 2,600	Sanborn, Metcalf, Yu, and Lu (1975)	Not reported	*Physia* sp.; *Daphnia* sp.
Volatile Organic Compounds			
Compound: Acetone			Recommended BCF Value: 0.05
Laboratory data were not available for this constituent. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = -0.222 (Karickoff and Long 1995).			
Compound: Acrylonitrile			Recommended BCF Value: 0.11
Laboratory data were not available for this constituent. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where Log K_{ow} = 0.250 (Karickoff and Long 1995).			
Compound: Chloroform			Recommended BCF Value: 2.82
Laboratory data were not available for this constituent. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.949 (U.S. EPA 1994b).			
Compound: Crotonaldehyde			Recommended BCF Value: 0.20
Laboratory data were not available for this constituent. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978) where, log K_{ow} = 0.55 (Based on equation developed by Hansch and Leo (1979), as calculated in NRC (1981)).			
Compound: 1,4-Dioxane			Recommended BCF Value: 0.043
Laboratory data were not available for this constituent. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978) where, log K_{ow} = -0.268 (U.S. EPA 1995a).			
Compound: Formaldehyde			Recommended BCF Value: 0.14
Laboratory data were not available for this constituent. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978) where, log K_{ow} = 0.342 (U.S. EPA 1995a).			

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Compound: Vinyl chloride			**Recommended BCF Value: 0.62**
Laboratory data were not available for this constituent.The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978) where, log K_{ow} = 1.146 (U.S. EPA 1994b).			
Other Chlorinated Organics			
Compound: Carbon tetrachloride			**Recommended BCF Value: 12**
Laboratory data were not available for this constituent. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978) where, log K_{ow} = 2.717 (U.S. EPA 1994b).			
Compound: Hexachlorobenzene			**Recommended BCF Value: 2,595**
The BCF value was calculated using the geometric mean of 16 laboratory values as follows:			
215,331 8,051 11,064	Baturo and Lagadic (1996)	48 to 120-hour exposure duration	*Lymnaea palustris*
1,360 770 1,510 940 1,630 1,030	Isensee, Holden, Woolson, and Jones (1976)	31-day exposure duration	*Heliosoma* sp.; *Daphnia magna*
287 1,247	Metcalf, Kapoor, Lu, Schuth, and Sherman (1973)	1 to 33-day exposure duration	*Daphnia magna; Physa* sp.
17,140 21,820 5,000	Nebeker, Griffis, Wise, Hopkins, and Barbitta (1989)	28-day exposure duration	*Oligochaete*
24,000	Oliver (1987)	79-day exposure duration	*Oligochaete*
5.5	Schauerte, Lay, Klein, and Korte (1982)	4 to 6-week exposure duration	*Dytiscus marginalis*
Compound: Hexachlorobutadiene			**Recommended BCF Value: 10.5**
The BCF value was based on four laboratory values from one study as follows:			

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
6.27 45.4 11.1 3.86	Laseter, Bartell, Laska, Holmquist, Condie, Brown, and Evans (1976)	10-day exposure duration	*Procambarus clarki*
Compound: Hexachlorocyclopentadiene			**Recommended BCF Value: 1,232**
The BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
929 1,634	Lu, Metcalf, Hirwe, and Williams (1975)	Not reported	*Physa* sp. *Culex* sp.
Compound: Pentachlorobenzene			**Recommended BCF Value: 2,595**
Laboratory data were not available for this constituent. The BCF for hexachlorobenzene was used as a surrogate.			
Compound: Pentachlorophenol			**Recommended BCF Value: 52**
The BCF value was calculated using the geometric mean of 13 laboratory values as follows:			
145 342	Makela and Oikari (1990)	1-day exposure duration	*Anodonta anatina*
165	Lu and Metcalf (1975)	1-day exposure duration	*Daphnia magna*
81 461	Makela, Petanen, Kukkonen, and Oikari (1991)	Multiple exposure durations	*Anodonta anatina*
80 61 121 85	Makela and Oikari (1995)	2 to 36-week exposure duration	*Anodonta anatina*; *Pseudanodonta complanta*
42 0.26 72 1.7	Schimmel, Patrick, and Faas (1978)	28-day exposure duration	*Crassostrea virginica*; *Penaeus aztecus*; *Palaemonetes pugio*
Pesticides			
Compound: 4,4'-DDE			**Recommended BCF Value: 11,930**
The recommended BCF value was calculated using the geometric mean of 14 field values[b] (Reich, Perkins, and Cutter 1986).			

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
19,400 207,070 67,641 5,099 8,344 15,369 4,983 4,421 8,782 2,374 2,197 46,953 35,373 3,972	Reich, Perkins, and Cutter (1986)	Field samples.	*Tubificidae; Chironomidae; Corixidae*
36,342 39,390	Metcalf, Sanborn, Lu, and Nye (1975)	33-day exposure duration	*Physa* sp.; *Culex pipiens quinquefasciatus*
28,600 63,500 1310 51,600 36,400	Hamelink, Waybrant, and Yant (1977)	Not reported	Zooplankton
19,528 5,024	Metcalf, Sangha, and Kapoor (1971)	33-day exposure duration; The value reported in Hamelink and Waybrant (1976) was converted to wet weight over dry weight using a conversion factor was 5.99[a].	*Physa* sp.; *Culex pipiens quinquefasciatus*
19,529	Metcalf, Kapoor, Lu, Schuth, and Sherman (1973)	33-day exposure duration	*Physa* sp.
Compound: Heptachlor			**Recommended BCF Value: 3,807**
The BCF value was calculated using the geometric mean of 4 laboratory values as follows:			
37,153 31,403	Lu, Metcalf, Plummer, and Mandel (1975)	Not reported	*Physa* sp. *Culex* sp.
300 600	Schimmel, Patrick, and Forester (1976)	96 hour exposure duration	*Penaeus duorarum*
Compound: Hexachloropehene			**Recommended BCF Value: 970**
The BCF value was based on one study as follows:			
970	Sanborn (1974)	Not reported	*Physa* sp.
Inorganics			
Compound: Aluminum			**Recommended BCF Value: 4,066**

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Laboratory data were not available for this constituent. The recommended BCF is the arithmetic mean of the recommended values for 14 inorganics with laboratory data available (antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc).			
Compound: Antimony			**Recommended BCF Value: 7**
The BCF value was calculated using the geometric means of 2 laboratory values as follows:			
10	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Freshwater and marine invertebrates
Compound: Arsenic			**Recommended BCF Value: 73**
The BCF value was calculated using the geometric mean of 5 laboratory values as follows:			
33 45 131 50 219	Spehar, Fiandt, Anderson, and DeFoe (1980)	21 to 28-day exposure duration	*Pteronarcys dorsata*; *Daphnia magna*
Compound: Barium			**Recommended BCF Value: 200**
The BCF was based on one study as follows:			
200	Thompson, Burton, Quinn and Ng (1972)	Not reported	Freshwater invertebrate
Compound: Beryllium			**Recommended BCF Value: 45**
The BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
10 200	Thompson, Burton, Quinn and Ng (1972)	Not reported	Freshwater invertebrate
Compound: Cadmium			**Recommended BCF Value: 3,461**
The BCF value was calculated using the geometric mean of 8 field values as follows:			
238 894 11,383 9,897 549 3,577 15,936 27,427	Saiki, Castleberry, May, Martin, and Bullard (1995)	Field samples.	*Chironomidea; Ephermeroptera*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
1,490 2,460 720	Eisler, Zaroogian, and Hennekey (1972)	3-week exposure duration	*Crassostrea virginica*; *Aquipecten irradians*; *Homarus americanus*
165	George and Coombs (1977)	28-day exposure duration	*Mytilus edulis*
1,359 137 2,939 217 615 1,850 573 1,530 1,082 781 775 553	Giesy, Kanio, Boling, Knight, Mashburn, and Clarkin (1977)	52-week exposure duration; the reported value was calculated by dividing the dry tissue concentration by the medium concentration [(μg/g)/(μg/L)] conversion factor of 1 x 10^3 was applied to the value. A conversion factor or 5.99[(a)] was used to convert dry weight to wet weight.	*Ceratopogonidae; Chironomidae;* Beetle*; Anisotptera; Zygoptera; Ephemeroptera*
1,840	Gillespie, Reisine, and Massaro (1977)	8-day exposure duration; the reported value was calculated by dividing the dry tissue concentration by the medium concentration [(ppm)/(ppb)] and a conversion factor of 1 x 10^3 was applied to the value.	*Orconectes propinquos propinquos*
3,770 1,752	Graney, Cherry, and Cairns (1983)	28-day exposure duration	*Corbicula fluminea*
1.86 6.88 7.18	Jennings and Rainbow (1979)	40-day exposure duration; the reported value was calculated by dividing the dry tissue concentration by the medium concentration [(mg/g)/(ppm)] conversion factor of 1 x 10^3 was applied to the value. A conversion factor or 5.99[(a)] was used to convert dry weight to wet weight.	*Carcinus maenas*
660 3400	Klockner (1979)	64-day exposure duration	*Ophryothochadiadema* sp.
48 33 57 34 55 23	Nimmo, Lightner, and Bahner (1977)	28 to 30-day exposure duration	*Penaeus duorarum*
1,023 17.7 1,477 17.5 2,412 30 3,406 28.7 37.2	Pesch and Stewart (1980)	42-day exposure duration; the values reported in Pesch and Stewart (1980) were converted to wet weight using a conversion factor of 5.99[(a)].	*Argopecten irradians*; *Palaemonetes pugio*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
57 301 341 167	Phillips (1976)	35-day exposure duration; the reported value was calculated by dividing the wet tissue concentration by the medium concentration [(μg/g)/(μg/L)] conversion factor of 1 x 10^3 was applied to the value.	*Mytilus edulis*
160	Pringle, Hissong, Katz, and Mulawka (1968)	70-day exposure duration	*Mya arenaria*
3,500	Sundelin (1983)	66-week exposure duration	*Pontoporeia affinis*
123 89 93 67 48 115	Theede, Scholz, and Fischer (1979)	7 and 10-day exposure duration; the reported value was calculated by dividing the dry tissue concentration by the medium concentration [(μg/g)/(μg/L)] conversion factor of 1 x 10^3 was applied to the value. A conversion factor or 5.99[a] was used to convert dry weight to wet weight.	*Laomedea loveni*
2,150 13,600	Zaroogian and Cheer (1976)	40-week exposure	*Crassostrea virginica*
Compound: Chromium (total)			**Recommended BCF Value: 3,000**
The BCF value was based on 1 field value as follows:			
3,000	Namminga and Wilhm (1977)	Field samples.	*Chironomidae*
1,900	NAS (1974)	Not reported	Zooplankton
2,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Freshwater invertebrates
Compound: Copper			**Recommended BCF Value: 3,718**
The BCF value was calculated using the geometric mean of 9 field values as follows:			
546	Namminga and Wilhm (1977)	Field samples.	*Chironomidae*
2,896 3,066 5,111 4,940 11,130 4,174 8,347 2,862	Saiki, Castleberry, May, Martin, and Bullard (1995)	Field samples.	*Chironomidae*; *Ephemeroptera*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
373	Eisler (1977)	14-day exposure duration	*Mya arenara*
17,720 22,571	Graney, Cherry, and Cairns (1983)	28-day exposure duration	*Corbicula fluminea*
54 53 87 48 70 57 35 44	Jones, Jones and Radlett (1976)	25-day exposure duration	*Nereis diversicolor*
800	Majori and Petronio (1973)	8-day exposure duration	*Mytilus galloprovincialis*
104 2,792	McLusky and Phillips (1975)	21-day exposure duration	*Phylloduce maculata*
37 40 43 42	Nehring (1976)	14-day exposure duration; the value reported was converted to wet weight using a conversion factor of 5.99[(a)].	*Pteronarcys californica*
2,462	Pesch and Morgan (1978)	28-day exposure duration	*Nereis arenaceodentata*
35 185.5 69 26.5	Phillips (1976)	35-day exposure duration; the reported value was calculated by dividing the wet tissue concentration by the medium concentration [(μg/g)/(μg/L)], a conversion factor of 1×10^3 was applied to the value.	*Mytilus edulis*
5,160 11,800 6,800 19,000 11,560 27,800 12,540 22,500	Shuster and Pringle (1968)	35, 70, 105, and 140-day exposure duration	*Crassostrea virginica*
160	Pringle, Hissong, Katz, and Mulawka (1968)	70-day exposure duration	*Mya arenaria*
Compound: Cyanide (total)			**Recommended BCF Value: 4,066**
Laboratory data were not available for this constituent. The recommended BCF is the arithmetic mean of the recommended values for 14 inorganics with laboratory data available (antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc).			
Compound: Lead			**Recommended BCF Value: 5,059**
The BCF value was calculated using the geometric mean of 6 field values as follows:			

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

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Reported Values[a]	Reference	Experimental Parameters	Species
8,076 7,237 3,636 3,575 5,671 3,890	Nehring, Nisson, and Minasian (1979)	Field samples.	*Tipulidae; Para quetina* sp.; *Heptageniidae; Nemoura* sp.; *Macronenum* sp.; *Anisoptera*
2500	Borgmann, Kramar, and Loveridge (1978)	120-day exposure duration	*Lymnaea palustris*
357	Eisler (1977)	14-day exposure duration	*Mya arenara*
111 50 63 71 63	Nehring (1976)	14-day exposure duration; the reported value was converted from dry weight to wet weight using a conversion factor of 5.99[(a)].	*Petronarcys californica*
1520 502.5 765 555	Phillips (1976)	35-day exposure duration; the reported value was calculated by dividing the wet tissue concentration by the medium concentration [(μg/g)/(μg/L)], and an unit conversion factor of 1 x 10^3 was applied to the value.	*Mytilus edulis*
578 1,097	Zaroogian, Morrison, Heltshe (1979)	20-day exposure duration; The reported value was calculated by dividing the dry tissue concentration by the medium concentration [(μg/g)/(μg/kg)], and an unit conversion factor of 1 x 10^3 was applied to the value. A conversion factor or 5.99[(a)] was used to convert dry weight to wet weight.	*Crassostrea virginica*
Compound: Mercuric chloride			Recommended BCF Value: 20,184
The BCF value was based on 6 laboratory values as follows:			
100,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Marine and freshwater invertebrates
12,000	Kopfter (1974)	74-day exposure duration; the reported value was calculated by dividing the dry tissue concentration by the medium concentration [(ppm)/(ppb)], and an unit conversion factor of 1 x 10^3 was applied to the value.	*Crassostrea virginica*
13,633 14,600 14,217 19,916	Thurberg, Calabrese, Gould, Greig, Dawson, and Tucker (1977)	30 to 60-day exposure duration; The reported value was calculated by dividing the dry tissue concentration by the medium concentration [(ppm)/(ppb)], and an unit conversion factor of 1 x 10^3 was applied to the value.	*Homarus americanus*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Compound: Methyl mercury			**Recommended BCF Value: 55,000**
The BCF value was based on 1 laboratory value as follows:			
55,000	Kopfter (1974)	74-day exposure duration; The reported value was calculated by dividing the dry tissue concentration by the medium concentration [(ppm)/(ppb)] and a conversion factor of 1 x 10^3 was applied to the value.	*Crassostrea virginica*
Compound: Nickel			**Recommended BCF Value: 28**
The BCF value was calculated using the geometric mean of 4 laboratory values as follows:			
100 250	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Freshwater and marine invertebrates
2 12	Watras, MacFarlane, and Morel (1985)	Reported values adopted from a high and low range.	*Daphnia magna*
Compound: Selenium			**Recommended BCF Value: 1,262**
The BCF value was calculated using the geometric mean of 5 laboratory values as follows:			
229,000	Besser, Canfield, and LaPoint (1993)	96-hour exposure duration	*Daphnia magna*
90 930	Hermanutz, Allen, Roush, and Hedtke (1992)	365-day exposure duration	*Lepomis macrochirus*
167 1,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Freshwater and marine invertebrates
Compound: Silver			**Recommended BCF Value: 298**
The BCF value was calculated using the geometric mean of 12 laboratory values as follows:			
1,391 5,100 2,203 1,056 6,500 1,435	Calabrese, MacInnes, Nelson, Greig, and Yevich (1984)	540 to 630 day exposure duration; he reported value was calculated by dividing the wet tissue concentration by the medium concentration [(mg/kg)/(µg/L)], and an unit conversion factor of 1 x 10^3 was applied to the value.	*Mytilus edulis*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
1,711	Metayer, Amiard-Triquet and Baud (1990)	14-day exposure duration	*Crassostrea gigas*
30 22 18 13 12	Nehring (1976)	14-day exposure duration; the reported value in Nehring (1976) was converted from dry weight to wet weight using a conversion factor of 5.99[a].	*Pteronarcys californica*
Compound: Thallium			**Recommended BCF Value: 15,000**
The BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
15,000 15,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Freshwater and marine invertebrates
Compound: Zinc			**Recommended BCF Value: 4,578**
The BCF value was calculated using the geometric mean of 9 field values as follows:			
30,036	Namminga and Wilhm (1977)	Field samples.	*Chironomidae* sp.
2,613 2,199 1,282 3,210 4,718 6,625 3,876 10,274	Saiki, Castleberry, May, Martin, and Bullard (1995)	Field samples; the reported value was converted from dry weight to wet weight using a conversion factor of 5.99[a].	*Chironomidae* sp.; *Ephemeroptera* sp.
50 3,000	Deutch, Borg, Kloster, Meyer, and Moller (1980)	9-day exposure duration	Marine invertebrates
143	Eisler (1977)	14-day exposure duration	*Mya arenaria*
358 511 631	Graney, Cherry, and Cairns (1983)	28-day exposure duration	*Corbicula fluminea*
499 326 159 92 43 95 53 25 15 7	Nehring (1976)	14-day exposure duration; the reported value was converted from dry weight to wet weight using a conversion factor of 5.99[a].	*Ephemerella grandis*; *Pteronarcys californica*

TABLE C-3

WATER-TO-AQUATIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
519 2,615 315 184	Phillips (1976)	35-day exposure duration	Mytilus edulis
85	Pringle, Hissong, Katz, and Mulawka (1968)	50-day exposure duration	*Mya arenaria*

Notes:

(a) The reported values are presented as the amount of COPC in invertebrate tissue divided by the amount of COPC in the water. If the values reported in the studies were presented as dry tissue weight over amount of COPC in water, they were converted to wet weight by dividing the concentration in dry invertebrate tissue weight by 5.99. This conversion factor assumes an invertebrate's total weight is 83.3 percent moisture, which is based on the moisture content of the earthworm (Pietz et al. 1984).

The conversion factor was calculated as follows:

$$\textit{Conversion factor} = \frac{1.0\ \textit{gram (g) invertebrate total weight}}{1.0\ \textit{gram (g) invertebrate total weight} - 0.833\ \textit{g invertebrate wet weight}}$$

(b) Reported field values for organic COPCs are assumed to be total COPC concentration in water and, therefore, were converted to dissolved COPC concentration in water using the following equation from U.S.EPA (1995b):

BCF (dissolved) = (BCF (total) / f_{fd}) - 1

where: BCF (dissolved) = BCF based on dissolved concentration of COPC in water
BCF (total) = BCF based on the field derived data for total concentration of COPC in water
f_{fd} = Fraction of COPC that is freely dissolved in the water

where: $f_{fd} = 1 / [1 + ((DOC \times K_{ow}) / 10) + (POC \times K_{ow})]$
DOC = Dissolved organic carbon, kilograms of organic carbon / liter of water (2.0×10^{-06} Kg/L)
K_{ow} = Octanol-water partition coefficient of the COPC, as reported in U.S. EPA (1994b)
POC = Particulate organic carbon, kilograms of organic carbon / liter of water (7.5×10^{-09} Kg/L)

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Dioxins and Furans			
Compound: 2,3,7,8-Tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD)			Recommended BCF value: 3,302
The recommended BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
4,000 9,000	Yockim, Isensee, and Jones (1978)	Values adopted from a high to low range; reported values were for 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD).	*Leona minor*
1,000	Yockim, Isensee, and Jones (1978)	32-day exposure duration; reported values were for 2,3,7,8-TCDD.	*Oedogonium cardiacum*
Compound: 1,2,3,7,8-Pentachlorodibenzo(p)dioxin (1,2,3,7,8-PeCDD)			Recommended BCF value: 3,038
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 0.92 = 3,038			
Compound: 1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin (1,2,3,4,7,8-HxCDD)			Recommended BCF value: 1,024
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x0.31 = 1,024			
Compound: 1,2,3,6,7,8-Hexachlorodibenzo(p)dioxin (1,2,3,6,7,8-HxCDD)			Recommended BCF value: 396.2
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x0.12 = 396.2			
Compound: 1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin (1,2,3,7,8,9-HxCDD)			Recommended BCF value: 462.3
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x0.14 = 462.3			
Compound: 1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin (1,2,3,4,6,7,8-HpCDD)			Recommended BCF value: 168.4
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x0.051 = 168.4			
Compound: Octachlorodibenzo(p)dioxin (OCDD)			Recommended BCF value: 39.6
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x0.012 = 39.6			
Compound: 2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)			Recommended BCF value: 2,642
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x0.80 = 2,642			
Compound: 1,2,3,7,8-Pentachlorodibenzofuran 1,(2,3,7,8-PeCDF)			Recommended BCF value: 726.4
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x0.22 =726.4			

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Compound: 2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PeCDF)			Recommended BCF value: 5,283
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 1.6 = 5,283			
Compound: 1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)			Recommended BCF value: 251.0
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 0.076 = 251.0			
Compound: 1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)			Recommended BCF value: 627.4
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 0.19 = 627.4			
Compound: 2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)			Recommended BCF value: 2,212
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 0.67 = 2,212			
Compound: 1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)			Recommended BCF value: 2,080
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 0.63 = 2,080			
Compound: 1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)			Recommended BCF value: 36.3
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 0.011 = 36.3			
Compound: 1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)			Recommended BCF value: 1,288
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 0.39 = 1,288			
Compound: Octachlorodibenzofuran (OCDF)			Recommended BCF value: 52.8
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF = 3,302 x 0.016 = 52.8			
Polynuclear Aromatic Hydrocarbons (PAHs)			
Compound: Benzo(a)pyrene			Recommended BCF value: 5,258
The recommended BCF value was based on a single measured value for benzo(a)pyrene. This value was also used as a surrogate for all high molecular weight PAHs for which laboratory data were not available.			
5,258	Lu, Metcalf, Plummer, and Mandel (1977)	3-day exposure duration	*Oedogonium cardiacum*
Compound: Benzo(a)anthracene			Recommended BCF value: 5,258

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Laboratory data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Benzo(b)fluoranthene			Recommended BCF value: 5,258
Laboratory data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Benzo(k)fluoranthene			Recommended BCF value: 5,258
Laboratory data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Chrysene			Recommended BCF value: 5,258
Laboratory data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Dibenz(a,h)anthracene			Recommended BCF value: 5,258
Laboratory data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Indeno(1,2,3-cd)pyrene			Recommended BCF value: 5,258
Laboratory data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Polychlorinated Biphenyls (PCBs)			
Compound: Aroclor 1016			Recommended BCF value: 476,829
The reported value was calculated by dividing the wet tissue concentration by the medium concentration (ppm/pptr). A conversion factor of 1 x 10^6 was applied to the value. The BCF value is based on Aroclor 1254 since there was no available data for total PCB.			
476,829	Scura and Theilacker (1977)	45-day exposure to Aroclor 1254	*Dunaliella* sp.
Compound: Aroclor 1254			Recommended BCF value: 476,829
The reported value was calculated by dividing the wet tissue concentration by the medium concentration (ppm/pptr). A conversion factor of 1 x 10^6 was applied to the value. The BCF value is based on Aroclor 1254 since there was no available data for total PCB.			
476,829	Scura and Theilacker (1977)	45-day exposure to Aroclor 1254	*Dunaliella* sp.

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Nitroaromatics			
Compound: 1,3-Dinitrobenzene			Recommended BCF value: 2,507
Laboratory data were not available for this compound. The BCF for 2,4-dinitrotoluene was used as a surrogate.			
Compound: 2,4-Dinitrotoluene			Recommended BCF value: 2,507
The recommended BCF value was based on one study as follows:			
2,507	Liu, Bailey, and Pearson (1983)	4-day exposure duration	*Selanastrum capricornatum*
Compound: 2,6-Dinitrobenzene			Recommended BCF value: 2,507
Laboratory data were not available for this compound. The BCF for 2,4-dinitrotoluene was used as a surrogate.			
Compound: Nitrobenzene			Recommended BCF value: 24
The recommended BCF value was based on one study as follows:			
24	Geyer, Viswanathan, Freitag, and Korte (1981)	1-day exposure duration	*Chlorella fusca*
Compound: Pentachloronitrobenzene			Recommended BCF value: 4,740
The recommended BCF value calculated using the geometric mean of 4 laboratory values as follows:			
3,100	Geyer, Viswanathan, Freitag, and Korte (1981)	1-day exposure duration	*Chlorella fusca*
4,795 7,534	Korte, Freitag, Geyer, Klein, Kraus, and Lahaniatis (1978)	1-day exposure duration; The values reported in Korte, Freitag, Geyer, Klein, Kraus, and Lahaniatis (1978) were converted to wet weight using a conversion factor of 2.92 [a].	*Chlorella fusca*
4,508	Wang, Harada, Watanabe, Koshikawa, and Geyer (1996)	Not reported	*Chlorella fusca*
Phthalate Esters			
Compound: Bis(2-ethylhexyl)phthalate			Recommended BCF value: 9,931

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
The recommended BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
5,400	Geyer, Viswanathan, Freitag, and Korte (1981)	1-day exposure duration	*Chlorella fusca*
18,263	Sodergren (1982)	27-day exposure duration	*Chara chara*
Compound:	**Di(n)octyl phthalate**		**Recommended BCF value: 28,500**
The recommended BCF value was based on one study as follows:			
28,500	Sanborn, Metcalf, Yu, and Lu (1975)	33-day exposure duration	*Oedogonium cardiacum*
		Volatile Organic Compounds	
Compound:	**Acetone**		**Recommended BCF value: 0.05**
Laboratory data were not available for this compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = -0.222 (Karickoff and Long 1995)			
Compound:	**Acrylonitrile**		**Recommended BCF value: 0.11**
Laboratory data are not available for this compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.250 (Karickoff and Long 1995)			
Compound:	**Chloroform**		**Recommended BCF value: 2.82**
Laboratory data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.949 (U.S. EPA 1994b)			
Compound:	**Crotonaldehyde**		**Recommended BCF value: 0.20**
Laboratory data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.55 (based on equation developed by Hansch and Leo 1979, calculated in NRC (1981))			
Compound:	**1,4-Dioxane**		**Recommended BCF value: 0.04**
Laboratory data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = -0.268 (U.S. EPA 1995a)			
Compound:	**Formaldehyde**		**Recommended BCF value: 0.14**

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Laboratory data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.342 (U.S. EPA 1995a)			
Compound: Vinyl chloride			**Recommended BCF value: 0.62**
Laboratory data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.146 (U.S. EPA 1994b)			
Other Chlorinated Organics			
Compound: Carbon tetrachloride			**Recommended BCF value: 300**
The recommended BCF value was based on laboratory data as follows:			
300	Geyer, Politzki and Freitag (1984)	1-day exposure duration	*Chlorella fusca*
Compound: Hexachlorobenzene			**Recommended BCF value: 11,134**
The recommended BCF value was calculated using the geometric mean of 4 laboratory values as follows:			
24,800	Geyer, Politzki, and Freitag (1984)	1-day exposure duration	*Chlorella fusca*
610	Isensee, Holden, Woolson and Jones (1976)	31-day exposure duration	*Oedogonium cardiacum*
41,096	Korte, Freitag, Geyer, Klein, Kraus, and Lahaniatis (1978)	1-day exposure duration; the values reported in Korte, Freitag, Geyer, Klein, Kraus, and Lahaniatis (1978) were converted to wet weight using an unit conversion factor of 2.92 [a].	*Chlorella fusca*
24,717	Wang, Harada, Watanabe, Koshikawa, and Geyer (1996)	Not reported	*Chlorella fusca*
Compound: Hexachlorobutadiene			**Recommended BCF value: 160**
The recommended BCF value calculated using the geometric mean of 2 laboratory values as follows:			
160	Laseter, Bartell, Laska, Holmquist, Condie, Brown, and Evans (1976)	7-day exposure duration	*Oedogonium cardiacum*
160	U.S. EPA (1976)	Not reported	Algae
Compound: Hexachlorocyclopentadiene			**Recommended BCF value: 610**

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
The recommended BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
1,090	Geyer, Viswanathan, Freitag, and Korte (1981)	Not reported	*Chlorella fusca*
341	Lu, Metcalf, Hirwe, and Williams (1975)	Not reported	*Oedogonium cardiacum*
Compound: Pentachlorobenzene			**Recommended BCF value: 4,000**
The recommended BCF value was based on one study as follows:			
4,000	Geyer, Politzki, and Freitag (1984)	1-day exposure duration	*Chlorella fusca*
Compound: Pentachlorophenol			**Recommended BCF value: 1,711**
The recommended BCF value calculated using the geometric mean of 4 laboratory values as follows:			
1,250	Geyer, Viswanathan, Freitag, and Korte (1981)	1-day exposure duration	*Chlorella fusca*
2,055 2,534 1,781	Korte, Freitag, Geyer, Klein, Kraus, and Lahaniatis (1978)	1-day exposure duration; the values reported in Korte, Freitag, Geyer, Klein, Kraus, and Lahaniatis (1978) were converted to wet weight using an unit conversion factor of 2.92 [a].	*Chlorella fusca*
1,266	Wang, Harada, Watanabe, Koshikawa, and Geyer (1996)	Not reported	*Chlorella fusca*
Pesticides			
Compound: 4,4'-DDE			**Recommended BCF value: 11,251**
The recommended BCF value was based on one study as follows:			
11,251	Metcalf, Sanborn, Lu, and Nye (1975)	33-day exposure duration	*Oedogonium cardiacum*
Compound: Heptachlor			**Recommended BCF value: 21,000**
The recommended BCF value was based on one study as follows:			
21,000	U.S. EPA (1979)	Not reported	Algae

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Compound: Hexachlorophene			**Recommended BCF value: 1,500**
The recommended BCF value was based on one study as follows:			
1,500	Sanborn (1974)	Not reported	Algae
Inorganics			
Compound: Aluminum			**Recommended BCF value: 833**
The recommended BCF value was based on one study as follows:			
600	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Algae (marine plants)
Compound: Antimony			**Recommended BCF value: 1,475**
The recommended value was calculated using the geometric mean of 2 laboratory values as follows:			
1,500 1,450	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported
Compound: Arsenic			**Recommended BCF value: 293**
The recommended value was calculated using the geometric mean of 3 laboratory values as follows:			
5	Anderson et al. (1979)	42-day exposure duration	*Lemna minor*
3,000 1,670	Thompson, Burton, Quinn, and Ng 1972	Not reported	Not reported
Compound: Barium			**Recommended BCF value: 260**
The recommended BCF value was based on one study as follows:			
260	Schroeder (1970)	Not reported	Brown algae
Compound: Beryllium			**Recommended BCF value: 141**
The recommended value was calculated using the geometric mean of 2 laboratory values as follows:			
20 1,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Compound: Cadmium			**Recommended BCF value: 782**
The recommended BCF value was calculated using the geometric mean of 6 laboratory values as follows:			
300 1,000 370 1,000	Fisher, Bohe, and Teyessie (1984)	Not reported	*Thalassiosira pseudonana* *Dunaliella tertiolecta* *Emiliania huxleyi* *Oscillatoria woronichinii*
2,065	Hutchinson and Czyrska (1972)	21-day exposure duration; The values reported in Hutchinson and Czyrska (1972) were converted to wet weight using a conversion factor of 2.92[a].	*Lemna valdiviana*
1,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported
Compound: Chromium (total)			**Recommended BCF value: 4,406**
The recommended BCF value was calculated using the geometric mean of 8 laboratory values as follows:			
343	Jouany, Vasseur, and Ferard (1982)	28-day exposure duration; the values reported in Jouany, Vasseur, and Ferard (1982) were converted to wet weight using an unit conversion factor of 2.92[a].	*Chlorella vulgaris*
1,600	NAS (1974)	Not reported	Benthic algae
26,316 8,485 29,000 5,000	Patrick, Bott, and Larson (1975)	4 experiments consisting of 1-month exposure durations	Mixed algae
4,000 2,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported
Compound: Copper			**Recommended BCF value: 541**
The recommended BCF value was calculated using the geometric mean of 5 laboratory values as follows:			
17	Bastien and Cote (1989)	50-day exposure duration	*Scenedesmus quadricauda*
827 1,644	Stokes, Hutchinson, and Krauter (1973)	2-day exposure duration	*Scenedesmus* sp.

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
2,000 1,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Freshwater and marine plants
Compound: Cyanide (total)			Recommended BCF value: 22
The recommended BCF value was based on one study as follows:			
22	Low and Lee (1981)	72-hour exposure duration	*Eichhornia crassipes*
Compound: Lead			Recommended BCF value: 1,706
The recommended BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
100 5,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported
9,931	Vighi (1981)	28-day exposure duration; the values reported in Vighi (1981) were converted to wet weight using an unit conversion factor of 2.92[a].	*Selenastrum capricornutum*
Compound: Mercury chloride			Recommended BCF value: 24,762
The recommended BCF value was based on one study as follows:			
24,762	Watras and Bloom (1992)	Field samples	Phytoplankton
Compound: Methyl mercury			Recommended BCF value: 80,000
The recommended BCF value was based on one study as follows:			
80,000	Watras and Bloom (1992)	Field samples	Phytoplankton
Compound: Nickel			Recommended BCF value: 61
The recommended BCF value was calculated using the geometric mean of 4 laboratory values as follows:			
32 34	Hutchinson and Stokes (1975)	6-day exposure duration	*Scenedesmus* sp.
50 250	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
Compound: Selenium			**Recommended BCF value: 1,845**
The recommended BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
15,700	Besser, Canfield, and LaPoint (1993)	24-hour exposure duration	*Chlamydomonas reinhardtii*
400	Dobbs, Cherry, and Cairns (1996)	25-day exposure duration	*Chlorella vulgaris*
1,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported
Compound: Silver			**Recommended BCF value: 10,696**
The recommended BCF value was calculated using the geometric mean of 5 laboratory values as follows:			
34,000 13,000 24,000 66,000	Fisher, Bohe, and Teyssie (1984)	Not reported	*Thalassiosira pseudonana* *Dunaliella tertiolecta* *Emiliania huxleyi* *Oscillatoria woronichinii*
200	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported
Compound: Thallium			**Recommended BCF value: 15,000**
The recommendedBCF was based on one study as follows:			
15,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported
Compound: Zinc			**Recommended BCF value: 2,175**
The recommended BCF value was calculated using the geometric mean of 17 laboratory values as follows:			
285 4,395	Andryushhenko and Polikarpou (1973)	5-day exposure duration	*Ulva rigida*
4,680	Baudin (1974)	34-day exposure duration	*Cladophoea*
70 600 1,200 1,400 170,000	Deutch, Borg, Kloster, Meyer, and Moller (1980)	9-day exposure duration	*Codium fragile* *Enteromorpha* sp. *Ulva lactuca* *Fucus serratus* Marine plankton

TABLE C-4

WATER-TO-ALGAE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values[a]	Reference	Experimental Parameters	Species
12,000 10,000 4,600 5,200	Fisher, Bohe, and Teyssie (1984)	Not reported	*Thalassiosira pseudonana* *Dunaliella tertiolecta* *Emiliania huxleyi* *Oscillatoria woronichinii*
524 1,015	Munda (1979)	12-day exposure; The values reported in Munda (1979) were converted to wet weight using a conversion factor of 2.92 [a].	*Enteromorpha prolifera* *Fucus vivsoides*
255	U.S. EPA (1987a)	6-day exposure duration	*Ulva lactuca*
20,000 1,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Not reported

Notes:

(a) The reported values are presented as the amount of COPC in algae divided by the amount of COPC in water. If the values reported in the studies were presented as dry tissue weight over the amount of COPC in water, they were converted to wet weight over dry weight by dividing the concentration in dry algae tissue weight by 2.92. This conversion factor assumes an algae total weight is 65.7 percent moisture (Isensee, Kearney, Woolson, Jones and Williams 1973). The conversion factor was calculated as follows:

$$Conversion\ factor = \frac{1.0\ g\ algae\ total\ weight}{1.0\ g\ algae\ total\ weight\ -\ 0.675\ g\ algae\ wet\ weight}$$

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Dioxins and Furans			
Compound:	**2,3,7,8-Tetrachlorinated dibenzo(p)dioxin (2,3,7,8-TCDD)**		**Recommended BCF value: 4,235**
The recommended value was calculated using the geometric mean of 12 laboratory values for several PCDD compounds as follows:			
5,800	Adams, DeGraeve, Sabourin, Cooney, and Mosher (1986)	28-day exposure duration, 20-day elimination; reported data were for 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD)	*Pimephales promelas*
9,270	Branson, Takahashi, Parker, and Blau (1985)	6-hour exposure duration, 139-day depuration	*Oncorhynchus mykiss*
39,000	Mehrle, Buckler, Little, Smith, Petty, Peterman, Stalling, DeGraeve, Coyle, and Adams (1988)	28-day exposure duration	*Oncorhynchus mykiss*
810 2,840 513 5,834	Muir, Marshall, and Webster (1985)	4 to 5-day exposure duration, 24 to 28-day depuration; values are based on a high to low range of reported values.	*Oncorhynchus mykiss* *Pimephales promelas*
2,769 2,269	Yockim, Isensee, and Jones (1978)	15-day exposure duration	*Gambusia affinis* *Ictalurus* sp.
5,000 9,300 7,900	U.S. EPA (1985)	Not reported	*Pimephales promelas*
Compound:	**1,2,3,7,8-Pentachlorodibenzo(p)dioxin (1,2,3,7,8-PeCDD)**		**Recommended BCF value: 3,896**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.92 =3,896			
Compound:	**1,2,3,4,7,8-Hexachlorodibenzo(p)dioxin (1,2,3,4,7,8-HxCDD)**		**Recommended BCF value: 1,313**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.31 =1313			
Compound:	**1,2,3,6,7,8-Hexachlorodibenzo(p)dioxin (1,2,3,6,7,8-HxCDD)**		**Recommended BCF value: 508.2**
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.12 =508.2			

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Compound:	1,2,3,7,8,9-Hexachlorodibenzo(p)dioxin (1,2,3,7,8,9-HxCDD)	Recommended BCF value:	592.9
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.14 =592.9			
Compound:	1,2,3,4,6,7,8-Heptachlorodibenzo(p)dioxin (1,2,3,4,6,7,8-HpCDD)	Recommended BCF value:	215.9
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.051 =215.9			
Compound:	Octachlorodibenzo(p)dioxin (OCDD)	Recommended BCF value:	50.8
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.012 =50.8			
Compound:	2,3,7,8-Tetrachlorinated dibenzofuran (2,3,7,8-TCDF)Compound:	Recommended BCF value:	3,388
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.80 =3,388			
Compound:	1,2,3,7,8-Pentachlorodibenzo(p)furan (1,2,3,7,8-PeCDF)	Recommended BCF value:	931.7
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.22 =931.7			
Compound:	2,3,4,7,8-Pentachlorodibenzo(p)furan (2,3,4,7,8-PeCDF)	Recommended BCF value:	6,776
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x1.6 =6,776			
Compound:	1,2,3,4,7,8-Hexachlorodibenzo(p)furan (1,2,3,4,7,8-HxCDF)	Recommended BCF value:	3,21.9
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.076 =3,21.9			
Compound:	1,2,3,6,7,8-Hexachlorodibenzo(p)furan (1,2,3,6,7,8-HxCDF)	Recommended BCF value:	804.7
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.19 =804.7			
Compound:	2,3,4,6,7,8-Hexachlorodibenzo(p)furan (2,3,4,6,7,8-HxCDF)	Recommended BCF value:	2,837
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.67 = 2,837			
Compound:	1,2,3,7,8,9-Hexachlorodibenzo(p)furan (1,2,3,7,8,9-HxCDF)	Recommended BCF value:	2,668
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.63 =2,668			

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Compound:	1,2,3,4,6,7,8,-Heptachlorodibenzo(p)furan (1,2,3,4,6,7,8-HpCDF)		Recommended BCF value: 46.6
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.011 =46.6			
Compound:	1,2,3,4,7,8,9-Heptachlorodibenzo(p)furan (1,2,3,4,7,8,9-HpCDF)		Recommended BCF value: 1,651
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.39 =1,651			
Compound:	Octachlorodibenzo(p)furan (OCDF)		Recommended BCF value: 67.8
The BCF was calculated using the TCDD BCF and a bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =4,235 x 0.016 =67.8			
		Polynuclear Aromatic Hydrocarbons (PAHs)	
Compound:	Benzo(a)pyrene		Recommended BCF value: 500
The recommended value is that presented in Stephan (1993), which was the geometric mean of 16 laboratory values. This BCF for benzo(a)pyrene is also recommended for high molecular weight PAH for which empirical data are not available.			
500	Stephan (1993)	Not reported	Not reported
Compound:	Benzo(a)anthracene		Recommended BCF value: 500
Empirical data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound:	Benzo(b)fluoranthene		Recommended BCF value: 500
Empirical data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound:	Benzo(k)fluoranthene		Recommended BCF value: 500
Empirical data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound:	Chrysene		Recommended BCF value: 500
Empirical data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
Compound:	Dibenz(a,h)anthracene		Recommended BCF value: 500
Empirical data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Compound: Indeno(1,2,3-cd)pyrene			Recommended BCF value: 500
Empirical data were not available for this compound. The BCF for benzo(a)pyrene was used as a surrogate.			
		Polychlorinated Biphenyls (PCBs)	
Compound: Aroclor 1016			Recommended BCF value: 22,649
The recommended BCF value was calculated using the geometric mean of 4 field values as follows[b, c, d]:			
25,000	Hansen et al. (1975) as cited in U.S. EPA (1980b)	28 days exposure 1.1 percent lipid Adult	*Cyprinodon variegatus*
43,000	Hansen et al. (1975) as cited in U.S. EPA (1980b)	28 days exposure Whole body Juvenile	*Cyprinodon variegatus*
14,400	Hansen et al. (1975) as cited in U.S. EPA (1980b)	28 days exposure Whole body Fry	*Cyprinodon variegatus*
17,000	Hansen et al. (1974) as cited in U.S. EPA (1980b)	21 to 28 days exposure Whole body	*Lagodon rhomboides*
Compound: Aroclor 1254			Recommended BCF value: 230,394
The recommended BCF value was calculated using the geometric mean of 7 field values as follows[b, c, d]:			
238,000 females 235,000 males	Nebeker, Puglisi, and DeFoe (1974)	Fish exposed for eight months. Residues measured in males and females.	*Pimephales promeles*
35,481 354,813 281,838	Rice and White (1987)	Field study	*Pimephales promeles*
46,000	Bills and Marking (1987)	30-day exposure duration Whole body	*Oncorhynchus mykiss*

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
13,000,000 in lipid 1,030,000 dry tissue	Scura and Theilacker (1977)	45 days exposure	*Engraulis mordex*
370,000 1,200,000	Veith et al. (1977)	Field samples	Sculpins (bottom fish) Pelagic fish
47,000	Mauck et al. (1978) as cited in U.S. EPA (1980b)	118 days exposure Whole body	*Salvellnus fontinalis*
42,000	Snarski and Puglisi (1976) as cited in U.S. EPA (1980b)	500 days exposure Body lipid 2.9 percent Whole body	*Salvellnus fontinalis*
37,000	Hansen et al. (1971) as cited in EPA (1980b)	28 days exposure 1.1 percent lipid Whole body	*Leiostomus xanthurus*
30,000	Hansen et al. (1973) as cited in EPA (1980b)	28 days exposure 3.6 percent lipid Whole body	*Cyprinodon variegatus*
>670,00	Duke et al. (1970) and Nimmo et al. (1977) as cited in EPA (1980b)	Field data Whole body	*Cynoscion nebulosus*
>133,000	Nimmo et al. (1977) as cited in EPA (1980b)	Field data	Fishes
38,000	Halter (1974) as cited in EPA (1980b)	24 days exposure	*Salmo gairdneri*
61,200	Mayer et al. (1977) as cited in EPA (1980b)	77 days exposure Whole body	*Ictalurus punctatus*
Nitroaromatics			
Compound: 1,3-Dinitrobenzene			**Recommended BCF value: 74**
The BCF for 1,3 -dinitrobenzene was based on one laboratory value as follows:			
74	Deener, Sinnige, Seinen, and Hemens (1987)	3-day exposure duration	*Poecilia reticulata*
Compound: 2,4-Dinitrotoluene			**Recommended BCF value: 21.04**

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Empirical data for this compound were not available. The BCF for nitrobenzene was used as a surrogate.			
Compound: 2,6-Dinitrotoluene			**Recommended BCF value:** 21.04
Empirical data for this compound were not available. The BCF for nitrobenzene used as a surrogate.			
Compound: Nitrobenzene			**Recommended BCF value:** 21.04
The recommended BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
29.5	Deneer, Sinnige, Seinen, and Hermens (1987)	3-day exposure duration	*Poecilia reticulata*
15	Veith, DeFoe, and Bergstedt (1979)	28-day exposure duration	*Pimephales promelas*
Compound: Pentachloronitrobenzene			**Recommended BCF value:** 214
The recommended BCF value was calculated using the geometric mean of 7 laboratory values as follows:			
238	Kanazawa (1981)	Continuous flow test	*Pseudorasbora parva*
250 320 380	Korte, Freitag, Geyer, Klein, Kraus, and Lahaniatis (1978)	24-hr exposure duration	*Leucisens idus melanotus*
114 147 169	Niimi, Lee, and Kissoon (1989)	20, 28, and 36-day exposure duration	*Oncorhynchus mykiss*
Phthalate Esters			
Compound: Bis(2-ethylhexyl)phthalate			**Recommended BCF value:** 70
The recommended BCF value was calculated using the geometric mean of 14 laboratory values as follows:			
91 569	Mayer (1976)	56-day exposure duration; based on a high to low range of reported values.	*Pimephales promelas*
155 42	Mehrle and Mayer (1976)	36 to 56-day exposure	*Pimephales promelas* *Oncorhynchus mykiss*

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
178 10,563 306	Sodergren (1982)	27-day exposure duration	*Phoxinus phoxinus* *Lampetra planeri* *Pungitis pungitis*
51.5 8.9 1.6	Tarr, Barron, and Hayton (1990)	Not reported	*Salmo gairdneri*
4	U.S. EPA (1992a)	Not reported	Fish
851	Veith, DeFoe, and Bergstedt (1979)	Not reported	*Pimephales promelas*
10.7 13.5	Wofford, Wilsey, Neff, Giam, and Neff (1981)	24-hour exposure duration	*Cypinodon variegatus*
Compound:	**Di(n)octyl phthalate**		**Recommended BCF value: 9,400**
The recommended BCF value was based on data from one study as follows:			
9,400	Sanborn, Metcalf, Yu, and Lu (1975)	Not reported	*Gambusia affinis*
		Volatile Organic Compounds	
Compound:	**Acetone**		**Recommended BCF value: 0.10**
Empirical data were not available for this compound. The BCF was calculated using the following regression equation: log BCF = 0.91 x log K_{ow} - 1.975 x log(6.8E-07 x K_{ow} + 1.0) - 0.786 (Bintein et al. 1993), where log K_{ow} = -0.222 (Karickoff and Long 1995)			
Compound:	**Acrylonitrile**		**Recommended BCF value: 48**
The recommended BCF value was based on data from one study as follows:			
48	Barrows, Petrocelli, Macek, and Carroll (1978)	28-day exposure duration	*Lepomis macrochirus*
Compound:	**Chloroform**		**Recommended BCF value: 3.59**
The recommended BCF value was calculated using the geometric mean of 3 laboratory values follows:			
5.6 3.44 2.4	Anderson and Lusty (1980)	24-hr exposure, 24-hr depuration	*Oncorhynchus mykiss* *Leponis macrochinus* *Micropterus salmoides*

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Compound: Crotonaldehyde			Recommended BCF value: 0.52
Empirical data were not available for this compound. The BCF was calculated using the following regression equation: log BCF = 0.91 x log K_{ow} - 1.975 x log(6.8E-07 x K_{ow} + 1.0) - 0.786 (Bintein et al. 1993), where log K_{ow} = 0.55 (based on equation in Hansch and Leo 1979, as calculated in NRC (1981)).			
Compound: Formaldehyde			Recommended BCF value: 0.34
Empirical data were not available for this compound. The BCF was calculated using the following regression equation: log BCF = 0.91 x log K_{ow} - 1.975 x log(6.8E-07 x K_{ow} + 1.0) - 0.786 (Bintein et al. 1993), where log K_{ow} = 0.342 (U.S. EPA 1995a)			
Compound: Vinyl chloride			Recommended BCF value: 1.81
Empirical data were not available for this compound. The BCF was calculated using the following regression equation: log BCF = 0.91 x log K_{ow} - 1.975 x log(6.8E-07 x K_{ow} + 1.0) - 0.786 (Bintein et al. 1993), where log K_{ow} =1.146 (U.S. EPA 1994b)			
Other Chlorinated Organics			
Compound: Carbon tetrachloride			Recommended BCF value: 30
The recommended BCF value was based on 1 laboratory values as follows:			
30	Barrows, Petrocelli, Macek, and Carroll (1978)	28-day exposure duration	*Lepomis macrochirus*
Compound: Hexachlorobenzene			Recommended BCF value: 253
The recommended BCF value on 1 field value as follows[b, c]			
253	Oliver and Niimi (1988)	Field samples.	Freshwater fish
22,000	Carlson and Kosian (1987)	32-day exposure duration	*Pimephales promelas*
1,260 2,040 6,160 15,850	Isensee, Holden, Woolson, and Jones (1976)	31-day exposure duration	*Gambusia affinis* *Ictalurus punctatus*
290,000	Koneman and van Leeuwen (1980)	Not reported	*Poecilia reticulata*
400 420	Korte, Freitag, Geyer, Klein, Kraus, and Lahaniatis (1978)	1-day exposure duration	*Zeucisens idus melanotus*

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
32,000 39,000	Kosian, Lemke, Studders, and Veith (1981)	28-day exposure duration	*Pimephales promelas*
5,200 6,970	Lores, Patrick, and Summers (1993)	30-day exposure duration; based on a high to low range of reported values.	*Cyprinodon variegatus*
93 287	Metcalf, Kapoor, Lu, Schuth, and Sherman (1973)	3 to 32-day exposure duration	*Gambusia affinis*
12,240 12,600 15,250 13,330 21,140	Nebeker, Griffis, Wise, Hopkins, and Barbittas (1989)	28-day exposure duration	*Pimephales promelas*
253,333	Oliver and Niimi (1983)	119-day exposure duration	*Oncorhynchus mykiss*
27,000	Schrap and Opperhuizen (1990)	Not reported	*Poecilia reticulata*
18,500	Veith, DeFoe, and Bergstedt (1979)	32-day exposure duration	*Pimephales promelas*
7,800	U.S. EPA (1987)	Not reported	*Oncorhynchus mykiss*
8,690	U.S. EPA (1980h)	Not reported	*Pimephales promelas*
253	Oliver and Niimi (1988)	Field samples.	Freshwater fish
Compound:	**Hexachlorobutadiene**		**Recommended BCF value: 783**
The recommended BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
920 1,200	Leeuwangh, Bult, and Schneiders (1975)	49-day exposure duration; 15-day depuration. The values reported in Leeuwangh, Bult, and Schneiders (1975) were converted to wet weight using an unit conversion factor of 5.0 [a].	*Carassius auratus*
435	Laska, Bartell, Laseter (1976)	Not reported	*Gambusia affinis*
Compound:	**Hexachlorocyclopentadiene**		**Recommended BCF value: 165**
The recommended BCF value was calculated using the geometric mean of 6 laboratory values as follows:			

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
1,230	Freitag, Geyer, Kraus, Viswanathan, Kotzias, Attar, Klein, and Korte (1982)	3-day exposure duration	*Leuciscus idus*
448	Lu and Metcalf (1975)	Not reported. The values reported in Lu and Metcalf (1975) were converted to wet weight using an unit conversion factor of 5.0 [a]	*Gambusia affinis*
100 1,148	Podowski and Khan (1984)	16-day exposure duration	*Carassius auratus*
11	Spehar, Veith, DeFoe, and Bergstedt (1979)	30-day exposure duration	*Pimephales promelas*
29	Veith, DeFoe, and Bergstedt (1979)	32-day exposure duration	*Pimephales promelas*
Compound:	**Pentachlorobenzene**		**Recommended BCF value: 12,690**
The recommended BCF value was calculated using the geometric mean of 12 laboratory values as follows:			
5,100 7,100 7,300	Banerjee, Suggatt, and O'Grady (1984)	2-day exposure duration	*Lepomis macrochirus* *Oncorynchus mykiss* *Poecilia reticulata*
26,000	Bruggeman, Oppenhuizen, Wijbenga, and Hutzinger (1984)	Not reported	*Poecilia reticulata*
8,400	Carlson and Kosian (1987)	31-day exposure duration	*Pimephales promelas*
28,183	Ikemoto, Motoba, Suzuki, Uchida (1992)	24-hour exposure duration	*Oryzias latipes*
260,000	Konemann and van Leeuwen (1980)	Not reported	*Poecilia reticulata*
17,000	Opperhuizen, Velde, Gobas, Liem, and Steen (1985)	Multiple exposure durations	*Poecilia reticulata*
6,600	Qiao and Farrell (1996)	10-day exposure duration	*Oncorhynchus mykiss*
23,000	Schrap and Opperhuizen (1990)	Not reported	*Poecilia reticulata*
4,700	Van Hoogen and Opperhuizen (1988)	5-day exposure duration; 21-day depuration	*Poecilia reticulata*
3,400	Veith, Macek, Petrocelli, and Carroll (1980)	28-day exposure duration	*Lepomis macrochirus*

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Compound: Pentachlorophenol			Recommended BCF value: 109
The recommended BCF value was calculated using the geometric mean of 20 laboratory values as follows:			
128 776	Garten and Trabalka (1983)	Not reported	Fish
189.5	Gates and Tjeerdema (1993)	1-day exposure duration	*Morone saxatilis*
2 131	Kobayashi and Kishino (1980)	1-hour exposure duration	*Carassius auratus*
350	Korte, Freitag, Geyer, Klein, Karus, and Lahaniatis (1978)	1-day exposure duration	*Zeucisens idus melanotus*
16 48 5 27	Parrish, Dyar, Enos, and Wilson (1978)	28 to 151-day exposure duration	*Cyprinodon variegatus*
30 38	Schimmel, Patrick, and Faas (1978)	28-day exposure duration	*Funidulus similis* *Mugil cephalus*
216	Smith, Bharath, Mallard, Orr, McCarty, and Ozburn (1990)	28-day exposure; 14-day depuration	*Jordanella floridae*
1,066 434 426 281	Spehar , Nelson, Swanson, and Renoos (1985)	32-day exposure duration	*Pimephales promelas*
52.3 607	Stehly and Hayton (1990)	96-hour exposure	*Carassius auratus*
770	Veith, DeFoe, and Bergstedt (1979)	32-day exposure	*Pimephales promelas*
Pesticides			
Compound: 4,4-DDE			Recommended BCF value: 25,512

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
The recommended BCF value was calculated using the geometric mean of 11 laboratory values as follows:			
12,037	Metcalf, Sanborn, Lu, and Nye (1975)	Not reported	Fish
51,285 27,542	Garten and Trabalka (1983)	Freshwater	Fish
5,010 110,000 106,000 181,000	Hamelink and Waybrant (1976)	Not reported	*Lepomis macrochirus* *Oncorhynchus mykiss*
27,358	Metcalf, Sangha, and Kapoor (1971)	33-day exposure duration	*Gambusia affinis*
217 27,358	Metcalf, Kapoor, Lu, Schuth, and Sherman (1973)	3 to 33-day exposure duration	*Gambusia affinis*
81,000	Oliver and Niimi (1985)	96-day exposure duration	*Oncorhynchus mykiss*
51,000	Veith, DeFoe, and Bergstedt (1979)	32-day exposure duration	*Pimephales promelas*
Compound: Heptachlor			**Recommended BCF value:** 5,522
The recommended BCF value was calculated using the geometric mean of 7 laboratory values as follows:			
3,700 2,400 4,600	Goodman, Hansen, Couch, and Forester (1978)	28-day exposure duration	*Cyprinodon variegatus*
3,600 10,000	Schimmel, Patrick, and Forester (1976)	96-hour exposure duration	*Leiostomus xanthurus*
11,200	U.S. EPA (1980a)	Not reported	Fish
9,500	Veith, DeFoe, and Bergstedt (1979)	32-day exposure duration	*Pimephales promelas*
Compound: Hexachlorophene			**Recommended BCF value:** 278
The recommended BCF value was based on data from one study as follows:			
278	Sanborn (1974)	Not reported	*Oncorhychus mykiss*

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Inorganics			
Compound: Aluminum			**Recommended BCF value:** 2.70
The recommended BCF value was calculated using the geometric mean of 7 laboratory values as follows:			
0.05 1.25 0.05 0.35	Cleveland, Little, Hamilton, Buckler, and Hunn (1986)	37-day exposure duration	*Salvelinus fontinalis*
36 123 215	Cleveland, Buckler, and Brumbaugh (1991)	56-day exposure duration; 28-day depuration	*Salvelinus fontinalis*
Compound: Antimony			**Recommended BCF value:** 40
The recommended BCF value was based on one study as follows:			
40	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
Compound: Arsenic			**Recommended BCF value:** 114
The recommended BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
333 100	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
44	U.S. EPA (1992b)	Not reported	Fish
Compound: Barium			**Recommended BCF value:** 633
Empirical data for this compound were not available. The recommended BCF is the arithmetic mean of the recommended values for 14 inorganics with empirical data available (aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc).			
Compound: Beryllium			**Recommended BCF value:** 62
The recommended BCF value was calculated using the geometric mean of 4 laboratory values as follows:			

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
200 200	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
19	U.S. EPA (1992b)	Not reported	Fish
19	U.S. EPA (1978)	28-day exposure duration	Fish
Compound: Cadmium			Recommended BCF value: 907
The recommended BCF value was calculated using the geometric mean of 4 field values.			
558 1,295 729 1,286	Saiki, Castleberry, May, Martin, and Ballard (1995)	Field samples. The field values reported in Saiki, Castleberry, May, Martin, and Ballard (1995) were converted to wet weight using a conversion factor of 5.0[a]. The field values are also based on mean values calculated for each of the 4 fish species.	*Catostomus occidentalis* *Gasterosteus aculeatus* *Ptychocheilus grandis* *Oncorhynchus tshawytasch*
716	Benoit, Leonard, Christensen, and Fiandt (1976)	38-week exposure duration; based on mean values calculated from various tissue concentrations in the kidney, liver, spleen, gonad, gills, and muscle/red blood cells. A unit conversion of 1,000 was applied to the value.	*Salvelinus fontanilis*
480	Eisler, Zaroogian, and Hennekey (1972)	3-week exposure duration	*Fundulus heteroclitus*
161 51	Harrison and Klaverkamp (1989)	72-day exposure duration, 25 and 63-day depuration	*Oncorhynchus mykiss* *Coregonus clupeatormis*
33	Kumada, Kimura, and Yokote (1980)	10 week exposure duration	*Oncorhynchus mykiss*
8 3,333	Kumada, Kimura, Yokote, and Matida (1973)	280-day exposure; values are based on a high to low range of values. The values reported in Kumada, Kimura, Yokote, and Matida (1973) were converted to wet weight using a conversion factor of 5.0[a].	*Oncorhynchus mykiss*
4.4	Spehar (1976)	30-day exposure duration	*Jordanella floridae*
3,000 200	Thompson, Burton, Quinn and Ng (1972)	Not reported	Fish

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
4,100	Williams and Giesy (1979)	56-day exposure duration	Fish
Compound: Chromium (total)			Recommended BCF value: 19
The recommended BCF value was calculated using the geometric mean of 4 laboratory values as follows:			
1.27 1.34	Fromm and Stokes (1962)	30-day exposure duration; values are based on a high to low range of reported values.	*Oncorhynchus mykiss*
200 400	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
Compound: Copper			Recommended BCF value: 710
The recommended BCF value was calculated using the geometric mean of 4 field values as follows:			
761 697 1,236 387	Saiki, Castleberry, May, Martin, and Ballard (1995)	Field samples	*Catostomus occidentalis* *Gasterosteus aculeatus* *Ptychocheilus grandis* *Oncorhynchus tshawytasch*
50 500 667	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
36	U.S. EPA (1992b)	Not reported	Fish

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Compound: Cyanide (total)			Recommended BCF value: 633
Empirical data for this compound were not available. The recommended BCF is the arithmetic mean of the recommended values for 14 inorganics with empirical data available (aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc).			
Compound: Lead			Recommended BCF value: 0.09
The recommended BCF value based on one field value:			
0.09	Atchinson, Murphy, Bishop, McIntosh, and Mayes (1977)	Field samples. The values reported in Atchinson, Murphy, Bishop, McIntosh, and Mayes (1977) were converted to wet weight using a conversion factor of 5.0[a].	*Lepomis macrochiras*
0.15 0.17	Holcombe, Benoit, Leonard, and McKim (1976)	266-day exposure duration. The values reported in Holcombe, Benoit, Leonard, and McKim (1976) were converted to wet weight using a conversion factor of 5.0[a]. Mean values were calculated based on tissue concentrations in the red blood cells, kidney, and muscle.	*Salvelinus fontanilis*
300 100	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
Compound: Mercuric chloride			Recommended BCF value: 3,530
The recommended BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
1,800	Boudou and Ribeyre (1984)	60-day exposure duration	*Oncorhynchus mykiss*
4,380 5,580	Snarski and Olson (1982)	287-day exposure duration; values are based on a high to low range of reported values.	*Pimephales promelas*
Compound: Methyl mercury			Recommended BCF value: 11,168
The recommended BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
11,000	Boudou and Ribeyre (1984)	60-day exposure duration	*Oncorhynchus mykiss*

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
10,800 11,724	McKim, Olson, Holcome, and Hunt (1976)	756-day exposure duration	*Salvelinus fontinalis*
Compound: Nickel			**Recommended BCF value: 78**
The recommended BCF value was calculated using the geometric mean of 3 laboratory values as follows:			
100 100	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
47	U.S. EPA (1992b)	Not reported	Fish
Compound: Selenium			**Recommended BCF value: 129**
The recommended BCF value was calculated using the geometric mean of 12 laboratory values as follows:			
18	Adams (1976)	96-day exposure duration	Fish
4,900	Besser, Canfield, and LaPoint (1993)	30-day exposure duration	*Lepomis reinhardtii*
5 7	Cleveland , Little, Buckler, and Wiedmeyer (1993)	60-day exposure duration; values are based on a high to low range of reported values.	*Lepomis macrochirus*
154 711	Dobbs, Cherry, and Cairns (1996)	25-day exposure duration	*Pimephales promelas*
3 240	Hodson, Spry, and Blunt (1980)	351-day exposure duration; values represent a high to low range of reported values based on BCFs for peritoneal fat and the liver.	*Oncorhynchus mykiss*
285 465	Lemly (1982)	120-day exposure duration	*Micropterus salmoides* *Lepomis macrochirus*
4,000 167	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
Compound: Silver			**Recommended BCF value: 87.71**
The recommended BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
3,330	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

Reported Values	Reference	Experimental Parameters	Species
Compound: Thallium			Recommended BCF value: 10,000
The recommended BCF value was calculated using the geometric mean of 2 laboratory values as follows:			
10,000 10,000	Thompson, Burton, Quinn, and Ng (1972)	Not reported	Fish
Compound: Zinc			Recommended BCF value: 2,059
The recommended BCF value was calculated using the geometric mean of 4 field values as follows:			
2,299 2,265 4,290 804	Saiki, Castleberry, May, Martin, and Ballard (1995)	Field samples.	*Catostomus occidentalis* *Gasteroteus aculeatus* *Ptychocheilus grandis* *Oncorhynchus tshawytasch*
50 130 130 200	Deutch, Borg, Kloster, Meyer, and Moller (1980)	9-day exposure duration	*Spinachia vulgaris* *Gasterosteus acul.* *Pungitius pungitius* *Cottus scorpius*
373 8,853	Pentreath (1973)	180-day exposure duration; values are based on a high to low range of reported values	*Pleuronectes platessa*
1,000 2,000 2,000	Thompson, Burton, Quinn and Ng (1972)	Not reported	Fish
47	U.S. EPA (1992b)	Not reported	Fish

Notes:

(a) The reported values are presented as the amount of COPC in fish tissue divided by the amount of COPC in water. If the values reported in the studies were presented as dry tissue weight, they were converted to wet weight by dividing the concentration in dry fish tissue weight by 5.0. This conversion factor assumes a fish's total weight is 80.0 percent moisture (Holcomb, Benoit, Leonard, and McKim 1976).

TABLE C-5

WATER-TO-FISH BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg dissolved COPC / L water)

The conversion factor was calculated as follows:

$$Conversion\ factor = \frac{1.0\ g\ fish\ total\ weight}{1.0\ g\ fish\ total\ weight\ -\ 0.80\ g\ fish\ wet\ weight}$$

(b) The equation used to convert the total organic COPC concentrations in field samples to dissolved COPC concentrations is from U.S. EPA (1995a) as follows:

$BAF\ (dissolved) = (BAF\ (total) / f_{fd}) - 1$

where: $BAF\ (dissolved) = BAF$ based on dissolved concentration of COPC in water
$BAF\ (total) = BAF$ based on the field derived data for total concentration of COPC in water
f_{fd} = Fraction of COPC that is freely dissolved in the water
where: $f_{fd} = 1 / [1 + ((DOC \times K_{ow}) / 10) + (POC \times K_{ow})]$
DOC = Dissolved organic carbon, Kg of organic carbon / L of water (2.0×10^{-06} kg/L)
K_{ow} = Octanol-water partition coefficient of the COPC, as reported in U.S. EPA (1994b)
POC = Particulate organic carbon, Kg of organic carbon / L of water (7.5×10^{-09} Kg/L)

(c) The reported field *BAF*s were converted to *BCF*s as follows:

$BCF = (BAF_{TLn} / FCM_{TLn}) - 1$

where: BAF_{TLn} = The reported field bioaccumulation factor for the trophic level "n" of the study species.
FCM_{TLn} = The food chain multiplier for the trophic level "n" of the study species.

(d) PCB values were converted to dissolved COPC BCFs based on the K_{ow} for Aroclor 1254.

(e) The geometric mean of the converted field derived BCFs was compared to the geometric mean of the laboratory derived BCFs. The higher of the two values was selected as the COPC BCF.

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]	Reference	Experimental Parameters	Species
Dioxins and Furans			
Compound: 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)			Recommended BCF value: 19,596
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 6.64 (U.S. EPA 1994a)			
Compound: 1,2,3,7,8-Pentachlorodibenzo(p)dioxin (1,2,3,7,8-PeCDD)			Recommended BCF value: 18,023
The BCF was calculated using the TCDD BCF and a congener-speccific bioaccumulation equivalency factor (BEF) (U.S. EPA 1995b) as follows: BCF =19,596 x 0.92 =3,896			
Compound: 1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)			Recommended BCF value: 6,075
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.31 =1313			
Compound: 1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)			Recommended BCF value: 2,351
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.12 =2,351			
Compound: 1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)			Recommended BCF value: 2,743
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.14 =2,743			
Compound: 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)			Recommended BCF value: 99.4
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.051 =99.4			
Compound: Octachlorodibenzo-p-dioxin (OCDD)			Recommended BCF value: 23.5
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.012 =23.5			
Compound: 2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)			Recommended BCF value: 2,642
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF = 3,302 x0.80 = 2,642			
Compound: 1,2,3,7,8-Pentachlorodibenzo-p-furan (1,2,3,7,8-PeCDF)			Recommended BCF value: 4,311
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.22 =4,311			
Compound: 2,3,4,7,8-Pentachlorodibenzo-p-furan (2,3,4,7,8-PeCDF)			Recommended BCF value: 31,354
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 1.6 =31,354			

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]	Reference	Experimental Parameters	Species
Compound: 1,2,3,4,7,8-Hexachlorodibenzo-p-furan (1,2,3,4,7,8-HxCDF)			Recommended BCF value: 1,489
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.076 =1,489			
Compound: 1,2,3,6,7,8-Hexachlorodibenzo-p-furan (1,2,3,6,7,8-HxCDF)			Recommended BCF value: 3,723
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.19 =3,723			
Compound: 2,3,4,6,7,8-Hexachlorodibenzo-p-furan (2,3,4,6,7,8-HxCDF)			Recommended BCF value: 13,129
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.67 = 13,129			
Compound: 1,2,3,7,8,9-Hexachlorodibenzo-p-furan (1,2,3,7,8,9-HxCDF)			Recommended BCF value: 12,345
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.63 =12,345			
Compound: 1,2,3,4,6,7,8,-Heptachlorodibenzo-p-furan (1,2,3,4,6,7,8-HpCDF)			Recommended BCF value: 215.6
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.011 =215.6			
Compound: 1,2,3,4,7,8,9-Heptachlorodibenzo-p-furan (1,2,3,4,7,8,9-HpCDF)			Recommended BCF value: 7,642
The BCF was calculated using the TCDD BCF and a congener-specific (U.S. EPA 1995b) as follows: BCF =19,596 x 0.39 =7,642			
Compound: Octachlorodibenzo-p-furan (OCDF)			Recommended BCF value: 313.5
The BCF was calculated using the TCDD BCF and a congener-specific BEF (U.S. EPA 1995b) as follows: BCF =19,596 x 0.016 =313.5			
Polynuclear Aromatic Hydrocarbons (PAHs)			
Compound: Benzo(a)pyrene			Recommended BCF value: 1. 59
The recommended BCF value was calculated using the geometric mean of 8 values as follows:			
5.2 2.8	Augenfeld, Anderson, Riley, and Thomas (1982)	60-day exposure duration	*Macoma inquinata* *Abarenicola pacifica*
0.4 0.65 7.4	Driscoll and McElroy (1996)	6 to 12-day exposure duration	*Nereis diversicolor* *Scolecolipides virdis* *Leitoscoloplos fragilis*

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]	Reference	Experimental Parameters	Species
2.3 6.9	Landrum, Eadie, and Faust (1991)	Mixture of PAH at four concentrations	*Diporeia* sp.
0.09	Roesijadi, Anderson, and Blaylock (1978)	7-day exposure duration	*Macoma inquinata*
Compound: Benzo(a)anthracene			**Recommended BCF value:** 1.45
Empirical data for this compound were not available. Therefore, the BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Benzo(b)fluoranthene			**Recommended BCF value:** 1.61
Empirical data for this compound were not available. Therefore, the BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Benzo(k)fluoranthene			**Recommended BCF value:** 1.61
Empirical data for this compound were not available. Therefore, the BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Chrysene			**Recommended BCF value:** 1.38
BCF value was calculated using the geometric mean of 3 values as follows:			
0.04	Roesijadi, Anderson, and Blaylock (1978)	7-day exposure duration	*Macoma inquinata*
11.6 5.64	Augenfeld, Anderson, Riley, and Thomas (1982)	60-day exposure duration	*Macoma inquinata* *Abarenicola pacifica*
Compound: Dibenz(a,h)anthracene			**Recommended BCF value:** 1.61
Empirical data for this compound were not available. Therefore, the BCF for benzo(a)pyrene was used as a surrogate.			
Compound: Indeno(1,2,3-cd)pyrene			**Recommended BCF value:** 1.61
Empirical data for this compound were not available. Therefore, the BCF for benzo(a)pyrene was used as a surrogate.			
Polychlorinated Biphenyls (PCBs)			
Compound: Aroclor 1016			**Recommended BCF value:** 0.53
The recommended BCF value was calculated using the geometric mean of 2 empirical values as follows:			

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]	Reference	Experimental Parameters	Species
0.2 1.4	Wood, O'Keefe, and Bush (1997)	12-day exposure duration; 1-day depuration	*Chironomus tentans*
Compound: Aroclor 1254			**Recommended BCF value:** 0.53
The recommended BCF value was calculated using the geometric mean of 2 empirical values as follows:			
0.2 1.4	Wood, O'Keefe, and Bush (1997)	12-day exposure duration; 1-day depuration	*Chironomus tentans*
Nitroaromatics			
Compound: 1,3-Dinitrobenzene			**Recommended BCF value:** 1.19
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.491 (U.S. EPA 1994b)			
Compound: 2,4-Dinitrotoluene			**Recommended BCF value:** 58
The recommended BCF value was based on 1 study as follows:			
58	Liu, Bailey, and Pearson (1983)	4-day exposure duration	*Lumbriculus variegatus*
Compound: 2,6-Dinitrotoluene			**Recommended BCF value:** 2.50
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.886 (U.S. EPA 1994b)			
Compound: Nitrobenzene			**Recommended BCF value:** 2.27
Empirical data were not available for this compound. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.833 (U.S. EPA 1994b)			
Compound: Pentachloronitrobenzene			**Recommended BCF value:** 451
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 4.640 (U.S. EPA 1994b)			
Phthalate Esters			
Compound: Bis(2-ethylhexyl)phthalate			**Recommended BCF value:** 1,309

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]	Reference	Experimental Parameters	Species
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 5.205 (U.S. EPA 1994b)			
Compound:	Di(n)octyl phthalate	Recommended BCF value:	3,128,023
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 9.330 (U.S. EPA 1994b)			
Volatile Organic Compounds			
Compound:	Acetone	Recommended BCF value:	0.05
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = -0.222 (Karickoff and Long 1995)			
Compound:	Acrylonitrile	Recommended BCF value:	0.11
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.250 (Karickoff and Long 1995)			
Compound:	Chloroform	Recommended BCF value:	2.82
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.949 (U.S. EPA 1994b)			
Compound:	Crotonaldehyde	Recommended BCF value:	0.20
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.55 (based on equations developed by Hansch and Leo 1979, as calculated in NRC 1981)			
Compound:	1,4-Dioxane	Recommended BCF value:	0.04
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = -0.268 (U.S. EPA 1995a)			
Compound:	Formaldehyde	Recommended BCF value:	0.14
Empirical data for this compound were not available.The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 0.342 (U.S. EPA 1995a)			
Compound:	Vinyl chloride	Recommended BCF value:	0.62

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]	Reference	Experimental Parameters	Species
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 1.146 (U.S. EPA 1994b)			
Other Chlorinated Organics			
Compound:	**Carbon tetrachloride**		**Recommended BCF value: 12**
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 2.717 (U.S. EPA 1994b)			
Compound:	**Hexachlorobenzene**		**Recommended BCF value: 2,296**
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 5.503 (U.S. EPA 1994b)			
Compound:	**Hexachlorobutadiene**		**Recommended BCF value: 0.44**
The recommended BCF value was based on empirical data from one study as follows:			
0.44	Oliver (1987)	79-day exposure duration; The values reported in Oliver (1987) were converted to wet weight over dry weight using a conversion factor of 5.99[a].	Oligochaetes
Compound:	**Hexachlorocyclopentadiene**		**Recommended BCF value: 746**
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 4.907 (U.S. EPA 1994b)			
Compound:	**Pentachlorobenzene**		**Recommended BCF value: 0.32**
The recommended BCF value is based on 1 study as follows:			
0.32	Oliver (1987)	79-day exposure duration; The values reported in Oliver (1987) were converted to wet weight over dry weight using a conversion factor of 5.99[a].	Oligochaetes
Compound:	**Pentachlorophenol**		**Recommended BCF value: 1,034**
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 5.080 (U.S. EPA 1994b)			

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]	Reference	Experimental Parameters	Species
Pesticides			
Compound: 4,4'-DDE			Recommended BCF value: 0.95
The recommended BCF value was calculated using the geometric mean of 13 values as follows:			
2.9 1.3 0.4 0.2 2.2 0.1 1.2 9.6 2.1 24.6 1.8 0.1 0.07	Reich, Perkins, and Cutter (1986)	Field samples	Tubificidae Chironomidae Croixidae
Compound: Heptachlor			Recommended BCF value: 1.67
Empirical data for heptachlor were not available. The BCF was calculated from 1 field-derived value for heptachlor epoxide as follows:			
10.0	Beyer and Gish (1980)	Field samples; The value reported in Beyer and Gish (1980) was converted to wet weight over dry weight using a conversion factor of 5.99[a].	*Aporrectodea trapezoides* *Aparrectodea turgida* *Allolobophora chlorotica* *Lumbricus terrestris*
Compound: Hexachlorophene			Recommended BCF value: 106,970
Empirical data for this compound were not available. The BCF was calculated using the following regression equation: log BCF = 0.819 x log K_{ow} - 1.146 (Southworth, Beauchamp, and Schmieder 1978), where log K_{ow} = 7.540 (Karickoff and Long 1995)			
Inorganics			
Compound: Aluminum			Recommended BCF value: 0.90
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).			
Compound: Antimony			Recommended BCF value: 0.90
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).			

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]		Reference	Experimental Parameters	Species
Compound:	Arsenic			Recommended BCF value: 0.90
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).				
Compound:	Barium			Recommended BCF value: 0.90
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).				
Compound:	Beryllium			Recommended BCF value: 0.90
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).				
Compound:	Cadmium			Recommended BCF value: 3.4
The recommended BCF value was calculated using the geometric mean of 8 field-derived values as follows:				
3.33 1.79 1.67 2.27	7.68 7.15 2.34 6.29	Saiki, Castleberry, May, Martin, and Bullard (1995)	Field samples; The values reported in Saiki, Castleberry, May, Martin, and Bullard (1995) were converted to wet weight over dry weight using a conversion factor of 5.99[a].	Chironomidae Epheroptera
Compound:	Chromium (total)			Recommended BCF value: 0.39
The recommended BCF value was based on 1 field-derived value as follows:				
0.39		Namminga and Wilhm (1977)	Field samples	Chironomidae
0.03 0.001	0.07 0.003	Capuzzo and Sasner (1977)	168-day exposure duration; The reported value was calculated by dividing the tissue concentration by the media concentration [(μg/g)/(mg/g)] and a conversion factor of $1x10^{-3}$ was applied to the value. A conversion factor of 5.99[a] was applied to convert dry tissue weight to wet weight.	*Mya arenaria*
Compound:	Copper			Recommended BCF value: 0.30

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]	Reference	Experimental Parameters	Species
The recommended BCF value was calculated using the geometric mean of 9 field values as follows:			
0.11 0.22 0.13 0.32	Jones, Jones, and Radlett (1976)	25-day exposure duration; The values reported in Jones, Jones, and Radlett (1976) were converted to wet weight over dry weight using a conversion factor of 5.99[a].	*Nereis diveriscolor*
1.1	Namminga and Wilhm (1977)	Field samples	Chironomidae
0.29 0.36 0.16 0.73 0.31 0.36 0.06 0.25	Saiki, Castleberry, May, Martin and Bullard (1995)	Field samples; The values reported in Saiki, Castleberry, May, Martin and Bullard (1995) were converted to wet weight over dry weight using a conversion factor of 5.99[a].	Chironomidae Ephemeroptera
Compound:	**Cyanide (total)**		**Recommended BCF value: 0.90**
Empirical data were not available for this compound. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).			
Compound:	**Lead**		**Recommended BCF value: 0.63**
The recommended BCF value was based on 1 study follows:			
0.4 1.0	Harrahy and Clements (1997)	14-day exposure duration	*Chironomus tentans*
Compound:	**Mercuric chloride**		**Recommended BCF value: 0.068**
The recommended BCF value was based on 6 field values as follows:			
0.08	Saouter, Hare, Campbell, Boudou, and Ribeyre (1993)	9-day exposure duration	*Hexagenia rigida*
0.16 0.08 0.04 0.04 0.08 0.06	Hildebrand, Strand, and Huckabee (1980)	Field samples	Hydropsychidae, Corydalus, Decapoda, Aterix, Psephenidae, and unspecified other benthic invertebrates
Compound:	**Methyl mercury**		**Recommended BCF value: 0.48**
The recommended BCF value was based on 6 field values as follows:			

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Reported Values[a]		Reference	Experimental Parameters	Species
4.0		Saouter, Hare, Campbell, Boudou, and Ribeyre (1993)	9-day exposure duration	*Hexagenia rigida*
1.45 0.50 0.26	0.41 0.37 0.44	Hildebrand, Strand, and Huckabee (1980)	Field samples	Hydropsychidae, Corydalus, Decapoda, Aterix, Psephenidae, and unspecified other benthic invertebrates
Compound:	**Nickel**			**Recommended BCF value: 0.90**
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).				
Compound:	**Selenium**			**Recommended BCF value: 0.90**
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).				
Compound:	**Silver**			**Recommended BCF value: 0.90**
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).				
Compound:	**Thallium**			**Recommended BCF value: 0.90**
Empirical data for this compound were not available. The recommended BCF value is the arithmetic average of 6 recommended values for those metals with empirical data (cadmium, chromium, copper, lead, inorganic mercury, and zinc).				
Compound:	**Zinc**			**Recommended BCF value: 0.57**
The recommended BCF value was calculated using the geometric mean of 8 field values as follows:				
3.6		Namminga and Wilhm (1977)	Not reported	Chironomidae
0.46 0.38 0.13 0.79	0.83 1.16 0.39 1.57	Saiki, Castleberry, May, Martin, and Bullard (1995)	Field samples; the values reported in Saiki, Castleberry, May, Martin and Bullard (1995) were converted to wet weight over dry weight using an unit conversion factor of 5.99[a].	Chironomidae Ephemeroptera

TABLE C-6

SEDIMENT-TO-BENTHIC INVERTEBRATE BIOCONCENTRATION FACTORS
(mg COPC / kg wet tissue) / (mg COPC / kg dry sediment)

Notes:

(a) The reported values are presented as the amount of compound in invertebrate tissue divided by the amount of compound in the sediment. If the values reported in the studies were presented as dry tissue weight over dry sediment weight, they were converted to wet weight over dry weight by dividing the concentration in dry invertebrate tissue weight by 5.99. This conversion factor assumes an earthworm's total weight is 83.3 percent moisture (Pietz et al. 1984).

The conversion factor was calculated as follows:

$$\textit{Conversion factor} = \frac{1.0\ g\ \textit{invertebrate total weight}}{1.0\ g\ \textit{invertebrate total weight} - 0.833\ g\ \textit{invertebrate wet weight}}$$

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APPENDIX F

BCF VALUES FOR MAMMAL AND BIRD MEASURMENT RECEPTORS
from Appendix D of EPA, 1999b

FOOD CHAIN MULTIPLIERS
from EPA, 1999a

APPENDIX D

WILDLIFE MEASUREMENT RECEPTOR *BCF*s

Appendix D provides recommended guidance for determining values for compound-specific, media to receptor, bioconcentration factors (*BCF*s) for wildlife measurement receptors. Wildlife measurement receptor *BCF*s should be based on values reported in the scientific literature, or estimated using physical and chemical properties of the compound. Guidance on use of *BCF* values in the screening level ecological risk assessment is provided in Chapter 5.

Section D-1.0 provides the general guidance recommended to select or estimate compound *BCF* values for wildlife measurement receptors. Sections D-1.0 through D-1.3 further discuss determination of *BCF*s for specific media and receptors. References cited in Sections D-1.1 through D-1.3 are located following Section D-1.3.

For the compounds commonly identified in risk assessments for combustion facilities (identified in Chapter 2) and the mammal and bird example measurement receptors listed in Chapter 4, *BCF* values have been determined following the guidance in Sections D-1.0 through D-1.3. *BCF* values for these limited number of compounds and pathways are included in this appendix (see Tables D-1 through D-3) to facilitate the completion of screening ecological risk assessments. However, it is expected that *BCF* values for additional compounds and receptors may be required for evaluation on a site specific basis. In such cases, *BCF* values for these additional compounds could be determined following the same guidance (Sections D-1.0 through D-1.3) used in determination of the *BCF* values reported in this appendix. For the calculation of *BCF* values for measurement receptors not represented in Sections D-1.1 through D1-3 (e.g., amphibians and reptiles), an approach consistent to that presented in this appendix could be utilized by applying data applicable to those measurement receptors being evaluated.

For additional discussion on some of the references and equations cited in Sections D-1.0 through D-1.3, the reader is recommended to review the Human Health Risk Assessment Protocol (HHRAP) (U.S. EPA 1998) (see Appendix A-3), and the source documents cited in the reference section of this appendix.

D-1.0 GENERAL GUIDANCE

This section describes general procedures for developing compound-specific *BCF*s from biotransfer factors (*Ba*) for assessing exposure of measurement receptors. A biotransfer factor is the ratio of the compound concentration in fresh (wet) weight animal tissue to the daily intake of compound by the animal through ingestion of food items and media (soil, sediment, surface water). Therefore, as discussed in Chapter 5, biotransfer factors and receptor-specific ingestion rates can be used to calculate food item- and media-to-animal *BCF*s. This approach provides an estimate of biotransfer of compounds from applicable food items and media to measurement receptors ingesting these items.

Biotransfer factors could also be used directly in equations to calculate dose to measurement receptors. However, in order to promote consistency in evaluating exposure across all trophic levels within complex food webs, *BCF*s calculated from *Ba* values are recommended in this guidance for evaluating measurement receptors. The use of *Ba* values to determine *BCF* values, and the use of *BCF* values in general, for the estimation of compound concentrations in measurement receptors may introduce

uncertainty. Major factors that influence the uptake of a compound by an animal, and therefore uncertainty, include bioavailability, metabolic rate, type of digestive system, and feeding behavior. Uncertainties also should be considered regarding the development of biotransfer values in comparison to how they are being applied for estimating exposure. For example, biotransfer values may be used to estimate contaminant uptake to species from items ingested that differ from the species and intakes used to empirically develop the values. Also, biotransfer data reported in literature may be specific to tissue or organ analysis versus whole body. As a result, *BCF*s may be under- or over-estimated to an unknown degree.

BCFs for Measurement Receptors Ingesting Food Items *BCF* values for measurement receptors ingesting food items (plants or prey) can be calculated using the compound specific *Ba* value applicable to the animal (e.g., mammal, bird, etc.) and the measurement receptor-specific ingestion rate as follows:

$$BCF_{F\text{-}A} = Ba_A \cdot IR_F \qquad \text{Equation D-1-1}$$

where

$BCF_{F\text{-}A}$	=	Bioconcentration factor for food item (plant or prey)-to-animal (measurement receptor) [(mg COPC/kg FW tissue)/(mg COPC/kg FW food item)]
Ba_A	=	COPC-specific biotransfer factor applicable for the animal (day/kg FW tissue)
IR_F	=	Measurement receptor food item ingestion rate (kg FW/day)

As an example of applying the above equation, *BCF* values for plants-to-wildlife measurement receptors listed in Chapter 4 are provided in Table D-1 at the end of this appendix. Measurement-receptor specific ingestion rates used to calculate *BCF*s are presented in Table 5-1. *Ba* values applicable to the mammal and bird measurement receptors in Table D-1 are discussed in Sections D-1.1 and D-1.2, respectively.

BCFs for Measurement Receptors Ingesting Media *BCF* values for measurement receptors in trophic levels 2, 3, and 4 ingesting media (i.e., soil, surface water, and sediment) can be calculated using the compound specific *Ba* value applicable to the animal (e.g., mammal, bird, etc.) and the measurement receptor-specific ingestion rate as follows:

$$BCF_{M\text{-}A} = Ba_A \cdot IR_M \qquad \text{Equation D-1-2}$$

where

$BCF_{M\text{-}A}$	=	Bioconcentration factor for media-to-animal (measurement receptor) [(mg COPC/kg FW tissue)/(mg COPC/kg WW or DW media)]
Ba_A	=	COPC-specific biotransfer factor applicable for the animal (day/kg FW tissue)

IR_M = Measurement receptor media ingestion rate (WW or DW kg/day)

Equation D-1-2 assumes that Ba_A provides a reasonable estimate of the uptake of a compound from incidental ingestion of abiotic media during foraging.

As an example of applying the above equation, *BCF* values for various wildlife measurement receptors listed in Chapter 4 are provided in Table D-2 (water) and Table D-3 (soil and sediment). Measurement-receptor specific ingestion rates used to calculate *BCF*s are presented in Table 5-1. *Ba* values applicable to the mammal and bird measurement receptors for which values were calculated are discussed in Sections D-1.1 and D-1.2, respectively.

BCFs for Dioxins and Furans As discussed in Chapter 2, the *BCF* values for PCDDs and PCDFs are calculated using bioaccumulation equivalency factors (*BEF*s). Consistent with U.S. EPA (1995b), *BEF*s are expressed relative to the *BCF* for 2,3,7,8-TCDD as follows:

$$BCF_j = BCF_{2,3,7,8\text{-}TCDD} \cdot BEF_j \qquad \text{Equation D-1-3}$$

where

BCF_j = Food item-to-animal or media-to-animal *BCF* for *j*th PCDD or PCDF congener for food item-to-animal pathway [(mg COPC/kg FW tissue)/(mg COPC/kg FW plant)]or media-to-animal pathway [(mg COPC/kg FW tissue)/(mg COPC/kg WW media)]

$BCF_{2,3,7,8\text{-}TCDD}$ = Food item-to-animal or media-to-animal *BCF* for 2,3,7,8-TCDD

$BEFj$ = Bioaccumulation equivalency factor for *j*th PCDD or PCDF congener (unitless)

The use of *BEF*s for dioxin and furan congeners is further discussed in Chapter 2.

D-1.1 BIOTRANSFER FACTORS FOR MAMMALS (Ba_{mammal})

As discussed in Section D-1.0, calculation of *BCF* values to be used in pathways for mammals ingesting food items and media requires the determination of COPC-specific biotransfer factors for mammal measurement receptors (Ba_{mammal}). This section discusses selection of the Ba_{mammal} values used to calculate the COPC and measurement receptor specific BCF values presented in Tables D-1 through D-3.

Organics For organics (except PCDDs and PCDFs), the following correlation equation from Travis and Arms (1988) was used to derrive Ba_{mammal} values on a FW basis:

$$\log Ba_{mammal} = -7.6 + \log K_{ow} \qquad \text{Equation D-1-4}$$

where

Ba_{mammal}	=	Biotransfer factor for mammals (day/kg FW tissue)
K_{ow}	=	Octanol-water partition coefficient (unitless)

To calculate the values presented in Tables D-1 through D-3, COPC-specific K_{ow} values were obtained from Appendix A-2.

Biotransfer factors obtained from Travis and Arms (1988) were derived from correlation equations developed from data on experiments conducted with beef cattle ingesting food items and media containing compound classes such as DDT, pesticides, PCDDs, PCDFs, and PCBs. As further literature is developed for other species and compounds, the Travis and Arms (1988) correlation equation should be compared for applicability to species and compound, and best fit correlation for estimation of uptake.

PCDDs and PCDFs Ba_{mammal} values for PCDD and PCDFs were derrived from *Ba* values for cattle as presented in:

- U.S. EPA 1995a. "Further Studies for Modeling the Indirect Exposure Impacts from Combustor Emissions." Memorandum from Matthew Lorber, Exposure Assessment Group, and Glenn Rice, Environmental Criteria and Assessment Office, Washington, D.C. January 20.

U.S. EPA (1995a) determined *Ba* values for cattle from McLachlan, Thoma, Reissinger, and Hutzinger (1990). These empirically determined *Ba* values were recommended by U.S. EPA (1995a) over the Travis and Arms (1988) correlation equation for dioxins and furans.

Inorganics For metals (except cadmium, mercury, selenium, and zinc), *Ba* values on a fresh weight basis were obtained from Baes, Sharp, Sjoreen, and Shor (1984). For cadmium, selenium, and zinc, U.S. EPA (1995a) indicated that *Ba* values were derived by dividing uptake slopes [(g compound/kg DW tissue)/(g compound/kg DW feed)], obtained from U.S. EPA (1992), by a daily consumption rate of 20 kilograms DW per day by cows.

For use in calculating *BCF* values presented in Tables D-1 through D-3 of this appendix, dry weight *Ba* values were converted to fresh weight basis by assuming a tissue moisture content (by mass) of 70 percent for cows. Moisture content information was obtained from the following:

- U.S. EPA. 1997a. *Exposure Factors Handbook.* "Food Ingestion Factors". Volume II. EPA/600/P-95/002Fb. August.

- Pennington, J.A.T. 1994. *Food Value of Portions Commonly Used.* Sixteenth Edition. J.B. Lippincott Company, Philadelphia.

Mercuric Compounds Based on assumptions made regarding speciation and fate and transport of mercury from stack emissions (as discussed in Chapter 2), elemental mercury is assumed not to deposit onto soils, water, or plants. Therefore, it is also not available in food items or media for ingestion and subsequent uptake by measurement receptors. As a result, no *BCF* values for elemental mercury are

presented in Tables D-1 through D-3 of this appendix. If site-specific field data suggest otherwise, *Ba* values for elemental mercury can be derived from uptake slope factors provided in U.S. EPA (1992) and U.S. EPA (1995a), using the same consumption rates as were discussed earlier for the metals like cadmium, selenium, and zinc.

Ba_{mammal} values for mercuric chloride and methyl mercury were derived from data in U.S. EPA (1997b). U.S. EPA (1997b) provides *Ba* values for mercury in cows, but does not specify the form of mercury. To obtain the *Ba* values for mercuric chloride and methyl mercury presented in Tables D-1 through D-3 of this guidance, consistent with U.S. EPA (1997b) total mercury was assumed to be composed of 87 percent divalent mercury (as mercuric chloride) and 13 percent methyl mercury in herbivore animal tissue. Also, assuming that the *Ba* value provided in U.S. EPA (1997b) is for the total mercury in the animal tissue, then biotransfer factors in U.S. EPA (1997b) can be determined for mercuric chloride and methyl mercury, as follows:

- The default *Ba* value of 0.02 day/kg DW for total mercury obtained from U.S. EPA (1997b) was converted to a fresh weight basis assuming a 70 percent moisture content in cow tissue (U.S. EPA 1997a; Pennington 1994). The fresh weight *Ba* value for total mercury was multiplied by 0.13 to obtain a Ba_{mammal} value for methyl mercury, and by 0.87 to obtain a Ba_{mammal} value for mercuric chloride.

D-1.2 BIOTRANSFER FACTORS FOR BIRDS (Ba_{bird})

As discussed in Section D-1.0, calculation of *BCF* values to be used in pathways for birds ingesting food items and media requires the determination of COPC-specific biotransfer factors for bird measurement receptors (Ba_{bird}). This section discusses selection of the Ba_{bird} values used to calculate the COPC and measurement receptor specific *BCF* values presented in Tables D-1 through D-3.

Organics Ba_{bird} values for organic compounds (except PCDDs and PCDFs) were derived from Ba_{mammal} values by assuming that the lipid content (by mass) of birds and mammals is 15 and 19 percent, respectively. Therefore, Ba_{bird} values presented in Tables D-1 through D-3 were determined by multiplying Ba_{mammal} values by the bird and mammal fat content ratio of 0.8 (15/19).

Notable uncertainties associated with this approach include (1) extent to which specific organic compounds bioconcentrate in fatty tissues, and (2) differences in lipid content, metabolism, and feeding characteristics between species.

PCDDs and PCDFs Ba_{bird} values presented in Tables D-1 through D-3 for PCDD and PCDF congeners were derived from data provided in the following:

- Stephens, R.D., M. Petreas, and G.H. Hayward. 1995. "Biotransfer and Bioaccumulation of Dioxins and Furans from Soil: Chickens as a Model for Foraging Animals." *The Science of the Total Environment.* Volume 175. Pages 253-273.

Stephens, Petreas, and Hayward (1995) conducted experiments to determine the bioavailability and the rate of PCDDs and PCDFs uptake from soil by foraging chickens. Three groups of White Leghorn

chickens were studied—control group, low exposure group, and high exposure group. Eggs, tissues (liver, adipose, and thigh), feed, and feces were analyzed.

Congener specific Ba_{bird} values were derived from the Stephens, Petreas, and Hayward (1995) study by dividing estimated whole body bioconcentration values for the high exposure group by a daily consumption rate of soil. If congener specific *BCF* values were not reported for the high exposure group, then estimated whole body values were determined using reported data for the low exposure group, if available. A default consumption rate of soil by chicken of 0.02 kg DW/day was determined as follows:

(1) Consumption rate of feed by chicken was obtained from U.S. EPA (1995a), which cites a value of 0.2 kg (DW) feed/day obtained from various literature sources.

(2) The fraction of feed that is soil (0.1) was obtained from Stephens, Petreas, and Hayward (1995).

(3) Feed consumption rate of 0.2 kg/day was multiplied by fraction of feed that is soil (0.1), to obtain the soil consumption rate by chicken of 0.2 x 0.1 = 0.02 kg DW soil/day.

Inorganics For metals (except cadmium, selenium, and zinc), Ba_{bird} values were not available in the literature. For cadmium, selenium, and zinc, U.S. EPA (1995a) cites *Ba* values that were derived by dividing uptake slopes [(g compound/kg dry DW tissue)/(g compound/kg DW feed)], obtained from U.S. EPA (1992), by a daily ingestion rate of 0.2 kilograms DW per day by poultry. To determine *BCF* values presented in Tables D-1 through D-3 in this appendix, reported dry weight *Ba* values were converted to fresh weight basis by assuming a tissue moisture content (by mass) of 75 percent for poultry (U.S. EPA 1997a; Pennington 1994).

Mercuric Compounds Based on assumptions made regarding speciation and fate and transport of mercury from stack emissions (as discussed in Chapter 2), elemental mercury is assumed not to deposit onto soils, water, or plants. Therefore, it is also not available in food items or media for ingestion and subsequent uptake by measurement receptors. As a result, no *BCF* values for elemental mercury are presented in Tables D-1 through D-3 of this appendix. If site-specific field data suggest otherwise, *Ba* values for elemental mercury can be derived from uptake slope factors provided in U.S. EPA (1992) and U.S. EPA (1995a), using the same consumption rates as were discussed earlier for the metals like cadmium, selenium, and zinc.

Ba_{bird} values for mercuric chloride and methyl mercury were derived from data in U.S. EPA (1997b). U.S. EPA (1997b) provides *Ba* values for mercury in poultry, but does not specify the form of mercury. To obtain the *Ba* values for mercuric chloride and methyl mercury presented in Tables D-1 through D-3 of this guidance, consistent with U.S. EPA (1997b) total mercury was assumed to be composed of 87 percent divalent mercury (as mercuric chloride) and 13 percent methyl mercury in herbivore animal tissue. Also, assuming that the *Ba* value provided in U.S. EPA (1997b) is for the total mercury in the animal tissue, then biotransfer factors in U.S. EPA (1997b) can be determined for mercuric chloride and methyl mercury, as follows:

- The default *Ba* value of 0.02 day/kg DW for total mercury obtained from U.S. EPA (1997b) was converted to a fresh weight basis assuming a 75 percent moisture content in poultry tissue (U.S. EPA 1997a; Pennington 1994). The fresh weight *Ba* value for total mercury was multiplied by 0.13 to obtain a Ba_{bird} value for methyl mercury, and by 0.87 to obtain a Ba_{bird} value for mercuric chloride.

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Stephens, R.D., M. Petreas, and G.H. Hayward. 1995. "Biotransfer and Bioaccumulation of Dioxins and Furans from Soil: Chickens as a Model for Foraging Animals." *The Science of the Total Environment.* Volume 175. Pages 253-273.

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TABLE D-1

BIOCONCENTRATION FACTORS FOR PLANTS TO WILDLIFE MEASUREMENT RECEPTORS

(Page 1 of 3)

Compound	Measurement Receptor													
	American Robin (BCF_{TP-OR})	Canvas Back (BCF_{TP-HR})	Deer Mouse (BCF_{TP-HM})	Least Shrew (BCF_{TP-OM})	Mallard Duck (BCF_{TP-OR})	Marsh Rice Rat (BCF_{TP-OM})	Marsh Wren (BCF_{TP-OR})	Mourning Dove (BCF_{TP-HR})	Muskrat (BCF_{TP-OM})	Northern Bobwhite (BCF_{TP-OR})	Salt-marsh Harvest Mouse (BCF_{TP-HM})	Short-tailed Shrew (BCF_{TP-OM})	Western Meadow Lark (BCF_{TP-OM})	White-footed Mouse (BCF_{TP-OM})
Dioxins and Furans														
2,3,7,8-TCDD	1.53e+02	6.85e+01	3.25e-02	3.37e-02	6.16e+01	2.39e-02	3.19e+02	1.20e+02	1.45e-02	1.20e+02	4.02e-02	3.37e-02	1.45e+02	3.33e-02
1,2,3,7,8-PeCDD	1.41e+02	6.30e+01	2.99e-02	3.10e-02	5.67e+01	2.20e-02	2.93e+02	1.11e+02	1.33e-02	1.11e+02	3.70e-02	3.10e-02	1.33e+02	3.07e-02
1,2,3,4,7,8-HxCDD	4.74e+01	2.12e+01	1.01e-02	1.04e-02	1.91e+01	7.41e-03	9.88e+01	3.72e+01	4.50e-03	3.72e+01	1.25e-02	1.04e-02	4.49e+01	1.03e-02
1,2,3,6,7,8-HxCDD	1.83e+01	8.22e+00	3.91e-03	4.04e-03	7.39e+00	2.87e-03	3.83e+01	1.44e+01	1.74e-03	1.44e+01	4.83e-03	4.04e-03	1.74e+01	4.00e-03
1,2,3,7,8,9-HxCDD	2.14e+01	9.59e+00	4.56e-03	4.71e-03	8.63e+00	3.35e-03	4.46e+01	1.68e+01	2.03e-03	1.68e+01	5.63e-03	4.71e-03	2.03e+01	4.67e-03
1,2,3,4,6,7,8-HpCDD	7.79e+00	3.49e+00	1.66e-03	1.72e-03	3.14e+00	1.22e-03	1.63e+01	6.13e+00	7.40e-04	6.13e+00	2.05e-03	1.72e-03	7.39e+00	1.70e-03
OCDD	1.83e+00	8.22e-01	3.91e-04	4.04e-04	7.39e-01	2.87e-04	3.83e+00	1.44e+00	1.74e-04	1.44e+00	4.83e-04	4.04e-04	1.74e+00	4.00e-04
2,3,7,8-TCDF	1.22e+02	5.48e+01	2.60e-02	2.69e-02	4.93e+01	1.91e-02	2.55e+02	9.61e+01	1.16e-02	9.61e+01	3.22e-02	2.69e-02	1.16e+02	2.67e-02
1,2,3,7,8-PeCDF	3.36e+01	1.51e+01	7.16e-03	7.41e-03	1.36e+01	5.26e-03	7.01e+01	2.64e+01	3.19e-03	2.64e+01	8.85e-03	7.41e-03	3.19e+01	7.34e-03
2,3,4,7,8-PeCDF	2.44e+02	1.10e+02	5.21e-02	5.39e-02	9.86e+01	3.83e-02	5.10e+02	1.92e+02	2.32e-02	1.92e+02	6.44e-02	5.39e-02	2.32e+02	5.34e-02
1,2,3,4,7,8-HxCDF	1.16e+01	5.21e+00	2.47e-03	2.56e-03	4.68e+00	1.82e-03	2.42e+01	9.13e+00	1.10e-03	9.13e+00	3.06e-03	2.56e-03	1.10e+01	2.53e-03
1,2,3,6,7,8-HxCDF	2.90e+01	1.30e+01	6.18e-03	6.40e-03	1.17e+01	4.54e-03	6.06e+01	2.28e+01	2.76e-03	2.28e+01	7.64e-03	6.40e-03	2.75e+01	6.34e-03
2,3,4,6,7,8-HxCDF	1.02e+02	4.59e+01	2.18e-02	2.26e-02	4.13e+01	1.60e-02	2.14e+02	8.05e+01	9.72e-03	8.05e+01	2.70e-02	2.26e-02	9.70e+01	2.23e-02
1,2,3,7,8,9-HxCDF	9.63e+01	4.32e+01	2.05e-02	2.12e-02	3.88e+01	1.51e-02	2.01e+02	7.57e+01	9.14e-03	7.57e+01	2.53e-02	2.12e-02	9.13e+01	2.10e-02
1,2,3,4,6,7,8-HpCDF	1.68e+00	7.54e-01	3.58e-04	3.70e-04	6.78e-01	2.63e-04	3.51e+00	1.32e+00	1.60e-04	1.32e+00	4.43e-04	3.70e-04	1.59e+00	3.67e-04
1,2,3,4,7,8,9-HpCDF	5.96e+01	2.67e+01	1.27e-02	1.31e-02	2.40e+01	9.33e-03	1.24e+02	4.69e+01	5.66e-03	4.69e+01	1.57e-02	1.31e-02	5.65e+01	1.30e-02
OCDF	2.44e+00	1.10e+00	5.21e-04	5.39e-04	9.86e-01	3.83e-04	5.10e+00	1.92e+00	2.32e-04	1.92e+00	6.44e-04	5.39e-04	2.32e+00	5.34e-04
Polynuclear Aromatic Hydrocarbons (PAHs)														
Benzo(a)pyrene	1.19e-02	5.32e-03	2.03e-02	2.10e-02	4.78e-03	1.49e-02	2.47e-02	9.32e-03	9.03e-03	9.32e-03	2.50e-02	2.10e-02	1.12e-02	2.08e-02
Benzo(a)anthracene	4.20e-03	1.88e-03	7.19e-03	7.44e-03	1.69e-03	5.28e-03	8.76e-03	3.30e-03	3.21e-03	3.30e-03	8.89e-03	7.44e-03	3.98e-03	7.37e-03
Benzo(b)fluoranthene	1.40e-02	6.29e-03	2.40e-02	2.48e-02	5.66e-03	1.76e-02	2.93e-02	1.10e-02	1.07e-02	1.10e-02	2.96e-02	2.48e-02	1.33e-02	2.46e-02
Benzo(k)fluoranthene	1.39e-02	6.25e-03	2.39e-02	2.47e-02	5.62e-03	1.75e-02	2.91e-02	1.10e-02	1.06e-02	1.10e-02	2.95e-02	2.47e-02	1.32e-02	2.44e-02
Chrysene	4.84e-03	2.17e-03	8.27e-03	8.56e-03	1.95e-03	6.08e-03	1.01e-02	3.81e-03	3.69e-03	3.81e-03	1.02e-02	8.56e-03	4.59e-03	8.47e-03
Dibenz(a,h)anthracene	3.11e-02	1.39e-02	5.31e-02	5.49e-02	1.25e-02	3.90e-02	6.48e-02	2.44e-02	2.37e-02	2.44e-02	6.57e-02	5.49e-02	2.95e-02	5.44e-02
Indeno(1,2,3-cd)pyrene	7.24e-02	3.25e-02	1.24e-01	1.28e-01	2.92e-02	9.12e-02	1.51e-01	5.69e-02	5.53e-02	5.69e-02	1.53e-01	1.28e-01	6.86e-02	1.27e-01
Polychlorinated Biphenyls (PCBs)														
Aroclor, 1016	2.23e-03	1.00e-03	3.82e-03	3.95e-03	9.01e-04	2.81e-03	4.66e-03	1.76e-03	1.70e-03	1.76e-03	4.72e-03	3.95e-03	2.12e-03	3.91e-03
Aroclor, 1254	1.42e-02	6.35e-03	2.43e-02	2.51e-02	5.71e-03	1.78e-02	2.96e-02	1.11e-02	1.08e-02	1.11e-02	3.00e-02	2.51e-02	1.34e-02	2.49e-02
Nitroaromatics														
1,3-Dinitrobenzene	2.73e-07	1.22e-07	4.67e-07	4.83e-07	1.10e-07	3.43e-07	5.70e-07	2.15e-07	2.08e-07	2.15e-07	5.77e-07	4.83e-07	2.59e-07	4.78e-07
2,4-Dinitrotoluene	8.70e-07	3.90e-07	1.49e-06	1.54e-06	3.51e-07	1.10e-06	1.82e-06	6.84e-07	6.65e-07	6.84e-07	1.85e-06	1.54e-06	8.25e-07	1.53e-06

TABLE D-1

BIOCONCENTRATION FACTORS FOR PLANTS TO WILDLIFE MEASUREMENT RECEPTORS

(Page 2 of 3)

Compound	Measurement Receptor													
	American Robin (BCF_{TP-OB})	Canvas Back (BCF_{TP-BB})	Deer Mouse (BCF_{TP-RM})	Least Shrew (BCF_{TP-OM})	Mallard Duck (BCF_{TP-OB})	Marsh Rice Rat (BCF_{TP-OM})	Marsh Wren (BCF_{TP-OB})	Mourning Dove (BCF_{TP-BB})	Muskrat (BCF_{TP-OM})	Northern Bobwhite (BCF_{TP-OB})	Salt-marsh Harvest Mouse (BCF_{TP-RM})	Short-tailed Shrew (BCF_{TP-OM})	Western Meadow Lark (BCF_{TP-OB})	White-footed Mouse (BCF_{TP-OM})
2,6-Dinitrotoluene	6.79e-07	3.05e-07	1.16e-06	1.20e-06	2.74e-07	8.50e-07	1.42e-06	5.34e-07	5.16e-07	5.34e-07	1.43e-06	1.20e-06	6.44e-07	1.19e-06
Nitrobenzene	5.99e-07	2.69e-07	1.03e-06	1.06e-06	2.42e-07	7.53e-07	1.25e-06	4.71e-07	4.57e-07	4.71e-07	1.27e-06	1.06e-06	5.68e-07	1.05e-06
Pentachloronitrobenzene	3.85e-04	1.72e-04	6.59e-04	6.82e-04	1.55e-04	4.84e-04	8.02e-04	3.02e-04	2.94e-04	3.02e-04	8.15e-04	6.82e-04	3.65e-04	6.76e-04
Phthalate Esters														
Bis(2-ethylhexyl)phthalate	1.41e-03	6.33e-04	2.42e-03	2.50e-03	5.69e-04	1.77e-03	2.95e-03	1.11e-03	1.08e-03	1.11e-03	2.99e-03	2.50e-03	1.34e-03	2.47e-03
Di(n)octyl phthalate	1.88e+01	8.44e+00	3.22e+01	3.33e+01	7.59e+00	2.36e+01	3.93e+01	1.48e+01	1.43e+01	1.48e+01	3.98e+01	3.33e+01	1.78e+01	3.30e+01
Volatile Organic Compounds														
Acetone	5.28e-09	2.37e-09	9.05e-09	9.36e-09	2.13e-09	6.65e-09	1.10e-08	4.15e-09	4.03e-09	4.15e-09	1.12e-08	9.36e-09	5.01e-09	9.27e-09
Acrylonitrile	1.57e-08	7.03e-09	2.68e-08	2.77e-08	6.32e-09	1.97e-08	3.27e-08	1.23e-08	1.19e-08	1.23e-08	3.31e-08	2.77e-08	1.49e-08	2.75e-08
Chloroform	7.82e-07	3.50e-07	1.34e-06	1.39e-06	3.15e-07	9.87e-07	1.63e-06	6.14e-07	5.98e-07	6.14e-07	1.66e-06	1.39e-06	7.41e-07	1.38e-06
Crotonaldehyde	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dioxane	4.75e-09	2.13e-09	8.15e-09	8.43e-09	1.92e-09	5.99e-09	9.91e-09	3.74e-09	3.63e-09	3.74e-09	1.01e-08	8.43e-09	4.50e-09	8.35e-09
Formaldehyde	1.94e-08	8.68e-09	3.31e-08	3.43e-08	7.81e-09	2.44e-08	4.04e-08	1.52e-08	1.48e-08	1.52e-08	4.10e-08	3.43e-08	1.84e-08	3.40e-08
Vinyl chloride	1.23e-07	5.53e-08	2.11e-07	2.18e-07	4.98e-08	1.55e-07	2.58e-07	9.71e-08	9.40e-08	9.71e-08	2.61e-07	2.18e-07	1.17e-07	2.16e-07
Other Chlorinated Organics														
Hexachlorobenzene	2.80e-03	1.26e-03	4.79e-03	4.95e-03	1.13e-03	3.52e-03	5.85e-03	2.20e-03	2.13e-03	2.20e-03	5.92e-03	4.95e-03	2.66e-03	4.91e-03
Hexachlorobutadiene	4.75e-04	2.13e-04	8.09e-04	8.37e-04	1.92e-04	5.95e-04	9.91e-04	3.74e-04	3.61e-04	3.74e-04	1.00e-03	8.37e-04	4.50e-04	8.29e-04
Hexachlorocyclopentadiene	7.11e-04	3.19e-04	1.22e-03	1.26e-03	2.87e-04	8.94e-04	1.48e-03	5.59e-04	5.42e-04	5.59e-04	1.50e-03	1.26e-03	6.74e-04	1.25e-03
Pentachlorobenzene	1.08e-03	4.84e-04	1.84e-03	1.90e-03	4.35e-04	1.35e-03	2.25e-03	8.48e-04	8.20e-04	8.48e-04	2.27e-03	1.90e-03	1.02e-03	1.89e-03
Pentachlorophenol	1.06e-03	4.76e-04	1.81e-03	1.87e-03	4.28e-04	1.33e-03	2.21e-03	8.34e-04	8.07e-04	8.34e-04	2.24e-03	1.87e-03	1.01e-03	1.85e-03
Pesticides														
4,4-DDE	1.59e-02	7.13e-03	2.72e-02	2.81e-02	6.41e-03	2.00e-02	3.32e-02	1.25e-02	1.21e-02	1.25e-02	3.36e-02	2.81e-02	1.51e-02	2.78e-02
Heptachlor	9.10e-04	4.08e-04	1.56e-03	1.61e-03	3.67e-04	1.15e-03	1.90e-03	7.16e-04	6.95e-04	7.16e-04	1.93e-03	1.61e-03	8.63e-04	1.60e-03
Hexachlorophene	3.06e-01	1.37e-01	5.22e-01	5.40e-01	1.23e-01	3.84e-01	6.37e-01	2.40e-01	2.33e-01	2.40e-01	6.45e-01	5.40e-01	2.90e-01	5.35e-01
Inorganics														
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony	NA	NA	5.99e-04	6.20e-04	NA	4.40e-04	NA	NA	2.67e-04	NA	7.41e-04	6.20e-04	NA	6.14e-04
Arsenic	NA	NA	1.20e-03	1.24e-03	NA	8.81e-04	NA	NA	5.34e-04	NA	1.48e-03	1.24e-03	NA	1.23e-03
Barium	NA	NA	8.99e-05	9.30e-05	NA	6.61e-05	NA	NA	4.01e-05	NA	1.11e-04	9.30e-05	NA	9.21e-05
Beryllium	NA	NA	5.99e-04	6.20e-04	NA	4.40e-04	NA	NA	2.67e-04	NA	7.41e-04	6.20e-04	NA	6.14e-04
Cadmium	4.71e-02	2.11e-02	7.19e-05	7.44e-05	1.90e-02	5.28e-05	9.82e-02	3.70e-02	3.21e-05	3.70e-02	8.89e-05	7.44e-05	4.46e-02	7.37e-05
Chromium (hexavalent)	NA	NA	3.30e-03	3.41e-03	NA	2.42e-03	NA	NA	1.47e-03	NA	4.08e-03	3.41e-03	NA	3.38e-03

TABLE D-1

BIOCONCENTRATION FACTORS FOR PLANTS TO WILDLIFE MEASUREMENT RECEPTORS

(Page 3 of 3)

Compound	Measurement Receptor													
	American Robin (BCF_{TP-OB})	Canvas Back (BCF_{TP-HB})	Deer Mouse (BCF_{TP-HM})	Least Shrew (BCF_{TP-OM})	Mallard Duck (BCF_{TP-OB})	Marsh Rice Rat (BCF_{TP-OM})	Marsh Wren (BCF_{TP-OB})	Mourning Dove (BCF_{TP-HB})	Muskrat (BCF_{TP-OM})	Northern Bobwhite (BCF_{TP-OB})	Salt-marsh Harvest Mouse (BCF_{TP-HM})	Short-tailed Shrew (BCF_{TP-OM})	Western Meadow Lark (BCF_{TP-OM})	White-footed Mouse (BCF_{TP-OM})
Copper	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	NA	NA	1.80e-04	1.86e-04	NA	1.32e-04	NA	NA	8.02e-05	NA	2.22e-04	1.86e-04	NA	1.84e-04
Mercuric chloride	1.06e-02	4.76e-03	3.13e-03	3.24e-03	4.28e-03	2.30e-03	2.21e-02	8.34e-03	1.39e-03	8.34e-03	3.87e-03	3.24e-03	1.01e-02	3.21e-03
Methylmercury	1.59e-03	7.13e-04	4.68e-04	4.84e-04	6.41e-04	3.44e-04	3.32e-03	1.25e-03	2.08e-04	1.25e-03	5.78e-04	4.84e-04	1.51e-03	4.79e-04
Nickel	NA	NA	3.60e-03	3.72e-03	NA	2.64e-03	NA	NA	1.60e-03	NA	4.45e-03	3.72e-03	NA	3.68e-03
Selenium	5.02e-01	2.25e-01	1.36e-03	1.41e-03	2.02e-01	1.00e-03	1.05e+00	3.95e-01	6.07e-04	3.95e-01	1.68e-03	1.41e-03	4.76e-01	1.39e-03
Silver	NA	NA	1.80e-03	1.86e-03	NA	1.32e-03	NA	NA	8.02e-04	NA	2.22e-03	1.86e-03	NA	1.84e-03
Thallium	NA	NA	2.40e-02	2.48e-02	NA	1.76e-02	NA	NA	1.07e-02	NA	2.96e-02	2.48e-02	NA	2.46e-02
Zinc	3.89e-03	1.74e-03	5.39e-05	5.58e-05	1.57e-03	3.96e-05	8.11e-03	3.05e-03	2.40e-05	3.05e-03	6.67e-05	5.58e-05	3.68e-03	5.53e-05

Notes:

NA - Indicates insufficient data to determine value

HB - Herbivorous bird
HM - Herbivorous mammal
OB - Omnivorous bird
OM - Omnivorous mammal
TP - Terrestrial plant

– Values provided were determined as specified in the text of Appendix D. *BCF* values for omnivores were determined based on an equal diet. *BCF* values for dioxin and furan congeners determined using BEF values specified in Chapter 2.

Table D-2

Bioconcentration Factors for Water to Wildlife Measurement Receptors

(Page 1 of 6)

Compound	Measurement Receptors										
	American Kestrel (BCF_{W-CN})	American Robin (BCF_{W-OM})	Canvas Back (BCF_{W-HM})	Deer Mouse (BCF_{W-HM})	Least Shrew (BCF_{W-OM})	Long-tailed Weasel (BCF_{W-OM})	Mallard Duck (BCF_{W-OM})	Marsh Rice Rat (BCF_{W-OM})	Marsh Wren (BCF_{W-OM})	Mink (BCF_{W-CM})	Mourning Dove (BCF_{W-OM})
Dioxins and Furans											
2,3,7,8-TCDD	4.30e+01	4.71e+01	2.21e+01	8.19e-03	9.34e-03	6.88e-03	2.00e+01	1.03e-02	9.46e+01	5.39e-03	3.75e+01
1,2,3,7,8-PcCDD	3.96c+01	4.34c+01	2.04c+01	7.54c-03	8.59c-03	6.33c-03	1.84c+01	9.44c-03	8.70c+01	4.96c-03	3.45c+01
1,2,3,4,7,8-HxCDD	1.33c+01	1.46c+01	6.86c+00	2.54c-03	2.89c-03	2.13c-03	6.21c+00	3.18c-03	2.93c+01	1.67c-03	1.16c+01
1,2,3,6,7,8-HxCDD	5.16e+00	5.66e+00	2.65e+00	9.83e-04	1.12e-03	8.25e-04	2.40e+00	1.23e-03	1.14e+01	6.47e-04	4.50e-01
1,2,3,7,8,9-HxCDD	6.02e+00	6.60e+00	3.10e+00	1.15e-03	1.31e-03	9.63e-04	2.80e+00	1.44e-03	1.32e+01	7.55e-04	5.25e+00
1,2,3,4,6,7,8-HpCDD	2.19e+00	2.40e+00	1.13e+00	4.18e-04	4.76e-04	3.51e-04	1.02e+00	5.23e-04	4.82e+00	2.75e-04	1.91e+00
OCDD	5.16e-01	5.66e-01	2.65e-01	9.83c-05	1.12e-04	8.25e-05	2.40e-01	1.23e-04	1.14e+00	6.47e-05	4.50e-01
2,3,7,8-TCDF	3.44e+01	3.77e+01	1.77e+01	6.55e-03	7.47e-03	5.50e-03	1.60e+01	8.21e-03	7.57e+01	4.31e-03	3.00e+01
1,2,3,7,8-PeCDF	9.46e+00	1.04e+01	4.87e+00	1.80e-03	2.05e-03	1.51e-03	4.40e+00	2.26e-03	2.08e+01	1.19e-03	8.25e+00
2,3,4,7,8-PeCDF	6.88e+01	7.54e+01	3.54e+01	1.31e-02	1.49e-02	1.10e-02	3.20e+01	1.64e-02	1.51e+02	8.62e-03	6.00e+01
1,2,3,4,7,8-HxCDF	3.27c+00	3.58c+00	1.68c+00	6.23c-04	7.10c-04	5.23c-04	1.52c+00	7.80c-04	7.19c+00	4.10c-04	2.85c+00
1,2,3,6,7,8-HxCDF	8.17e+00	8.95e+00	4.20e+00	1.56e-03	1.77e-03	1.31e-03	3.80e+00	1.95e-03	1.80e+01	1.02e-03	7.12e+00
2,3,4,6,7,8-HxCDF	2.88e+01	3.16e+01	1.48e+01	5.49e-03	6.26e-03	4.61e-03	1.34e+01	6.88e-03	6.34e+01	3.61e-03	2.51e+01
1,2,3,7,8,9-HxCDF	2.71e+01	2.97e+01	1.39e+01	5.16e-03	5.88e-03	4.33e-03	1.26e+01	6.47e-03	5.96e+01	3.40e-03	2.36e+01
1,2,3,4,6,7,8-HpCDF	4.73e-01	5.18e-01	2.43e-01	9.01e-05	1.03e-04	7.57e-05	2.20e-01	1.13e-04	1.04e+00	5.93e-05	4.12e-01
1,2,3,4,7,8,9-HpCDF	1.68e+01	1.84e+01	8.63e+00	3.20e-03	3.64e-03	2.68e-03	7.81e+00	4.00e-03	3.69e+01	2.10e-03	1.46e+01
OCDF	6.88e-01	7.54e-01	3.54e-01	1.31e-04	1.49e-04	1.10e-04	3.20e-01	1.64e-04	1.51e+00	8.62e-05	6.00e-01
Polynuclear Aromatic Hydrocarbons (PAHs)											
Benzo(a)pyrene	3.34c-03	3.67c-03	1.72c-03	5.10c-03	5.81c-03	4.28c-03	1.55c-03	3.75c-03	7.35c-03	3.36c-03	2.92c-03
Benzo(a)anthracene	1.18e-03	1.30e-03	6.08e-04	1.81e-03	2.06e-03	1.52e-03	5.50e-04	1.33e-03	2.60e-03	1.19e-03	1.03e-03
Benzo(b)fluoranthene	3.95e-03	4.34e-03	2.03e-03	6.03e-03	6.88e-03	5.07e-03	1.84e-03	4.44e-03	8.70e-03	3.97e-03	3.46e-03
Benzo(k)fluoranthene	3.92e-03	4.31e-03	2.02e-03	6.00e-03	6.84e-03	5.04e-03	1.83e-03	4.41e-03	8.64e-03	3.95e-03	3.43e-03
Chrysene	1.36e-03	1.50e-03	7.01e-04	2.08e-03	2.37e-03	1.75e-03	6.34e-04	1.53e-03	3.00e-03	1.37e-03	1.19e-03
Dibenz(a,h)anthracene	8.74e-03	9.61e-03	4.50e-03	1.34e-02	1.52e-02	1.12e-02	4.07e-03	9.84e-03	1.93e-02	8.79e-03	7.66e-03
Indeno(1,2,3-cd)pyrene	2.04e-02	2.24e-02	1.05e-02	3.12e-02	3.56e-02	2.62e-02	9.48e-03	2.29e-02	4.49e-02	2.05e-02	1.78e-02
Polychlorinated Biphenyls (PCBs)											
Aroclor 1016	6.28e-04	6.91e-04	3.24e-04	9.61e-04	1.10e-03	8.07e-04	2.93e-04	7.07e-04	1.38e-03	6.32e-04	5.50e-04
Aroclor 1254	3.98c-03	4.38c-03	2.05c-03	6.11c-03	6.96c-03	5.13c-03	1.86c-03	4.48c-03	8.78c-03	4.02c-03	3.49c-03
Nitroaromatics											
1,3-Dinitrobenzene	7.68e-08	8.45e-08	3.96e-08	1.18e-07	1.34e-07	9.87e-08	3.58e-08	8.65e-08	1.69e-07	7.73e-08	6.73e-08
2,4-Dinitrotoluene	2.45e-07	2.69e-07	1.26e-07	3.76e-07	4.28e-07	3.15e-07	1.14e-07	2.76e-07	5.39e-07	2.47e-07	2.14e-07

Table D-2

Bioconcentration Factors for Water to Wildlife Measurement Receptors

(Page 2 of 6)

Compound	Measurement Receptors										
	American Kestrel (BCF_{W-CB})	American Robin (BCF_{W-OB})	Canvas Back (BCF_{W-HB})	Deer Mouse (BCF_{W-HM})	Least Shrew (BCF_{W-OM})	Long-tailed Weasel (BCF_{W-OM})	Mallard Duck (BCF_{W-OB})	Marsh Rice Rat (BCF_{W-OM})	Marsh Wren (BCF_{W-OB})	Mink (BCF_{W-CM})	Mourning Dove (BCF_{W-OM})
2,6-Dinitrotoluene	1.91e-07	2.10e-07	9.84e-08	2.91e-07	3.32e-07	2.44e-07	8.90e-08	2.15e-07	4.21e-07	1.92e-07	1.67e-07
Nitrobenzene	1.69e-07	1.85e-07	8.68e-08	2.58e-07	2.94e-07	2.17e-07	7.86e-08	1.90e-07	3.72e-07	1.70e-07	1.48e-07
Pentachloronitrobenzene	1.08e-04	1.19e-04	5.57e-05	1.66e-04	1.89e-04	1.39e-04	5.04e-05	1.22e-04	2.38e-04	1.09e-04	9.47e-05
Phthalate Esters											
Bis(2-ethylhexyl)phthalate	3.97e-04	4.37e-04	2.05e-04	6.08e-04	6.93e-04	5.11e-04	1.85e-04	4.47e-04	8.75e-04	4.00e-04	3.48e-04
Di(n)octyl phthalate	5.30e+00	5.82e+00	2.73e+00	8.10e+00	9.23e+00	6.80e+00	2.47e+00	5.96e+00	1.17e+01	5.33e+00	4.64e+00
Volatile Organic Compounds											
Acetone	1.49e-09	1.63e-09	7.65e-10	2.28e-09	2.60e-09	1.91e-09	6.92e-10	1.67e-09	3.28e-09	1.50e-09	1.30e-09
Acrylonitrile	4.41e-09	4.84e-09	2.27e-09	6.74e-09	7.69e-09	5.66e-09	2.05e-09	1.27e-09	9.71e-09	4.44e-09	3.85e-09
Chloroform	2.20e-07	2.42e-07	1.13e-07	3.38e-07	3.85e-07	2.84e-07	1.02e-07	2.47e-07	4.84e-07	2.22e-07	1.93e-07
Crotonaldehyde	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dioxane	1.34e-09	1.47e-09	6.88e-10	2.05e-09	2.34e-09	1.72e-09	6.23e-10	1.50e-09	2.95e-09	1.35e-09	1.17e-09
Formaldehyde	5.45e-09	5.99e-09	2.80e-09	8.34e-09	9.51e-09	7.01e-09	2.54e-09	6.13e-09	1.20e-08	5.49e-09	4.77e-09
Vinyl chloride	3.47e-08	3.82e-08	1.79e-08	5.31e-08	6.05e-08	4.46e-08	1.62e-08	3.91e-08	7.65e-08	3.49e-08	3.04e-08
Other Chlorinated Organics											
Hexachlorobenzene	7.88e-04	8.67e-04	4.06e-04	1.21e-03	1.37e-03	1.01e-03	3.67e-04	8.87e-04	1.74e-03	7.93e-04	6.90e-04
Hexachlorobutadiene	1.34e-04	1.47e-04	6.88e-05	2.04e-04	2.32e-04	1.71e-04	6.23e-05	1.51e-04	2.94e-04	1.34e-04	1.17e-04
Hexachlorocyclopentadiene	2.00e-04	2.20e-04	1.03e-04	3.06e-04	3.49e-04	2.57e-04	9.31e-05	2.25e-04	4.40e-04	2.02e-04	1.75e-04
Pentachlorobenzene	3.04e-04	3.34e-04	1.56e-04	4.63e-04	5.28e-04	3.89e-04	1.41e-04	3.42e-04	6.69e-04	3.05e-04	2.66e-04
Pentachlorophenol	2.99e-04	3.28e-04	1.54e-04	4.56e-04	5.19e-04	3.83e-04	1.39e-04	3.36e-04	6.58e-04	3.00e-04	2.61e-04
Pesticides											
4,4-DDE	4.47e-03	4.92e-03	2.30e-03	6.83e-03	7.79e-03	5.74e-03	2.08e-03	5.03e-03	9.85e-03	4.50e-03	3.92e-03
Heptachlor	2.56e-04	2.82e-04	1.32e-04	3.92e-04	4.47e-04	3.29e-04	1.19e-04	2.88e-04	5.64e-04	2.58e-04	2.24e-04
Hexachlorophene	8.59e-02	9.45e-02	4.42e-02	1.31e-01	1.50e-01	1.10e-01	4.00e-02	9.67e-02	1.89e-01	8.65e-02	7.53e-02
Inorganics											
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony	NA	NA	NA	1.51e-04	1.72e-04	1.27e-04	NA	NA	NA	9.93e-05	NA
Arsenic	NA	NA	NA	3.02e-04	3.44e-04	2.53e-04	NA	NA	NA	1.99e-04	NA
Barium	NA	NA	NA	2.26e-05	2.58e-05	1.90e-05	NA	NA	NA	1.49e-05	NA
Beryllium	NA	NA	NA	1.51e-04	1.72e-04	1.27e-04	NA	NA	NA	9.93e-05	NA
Cadmium	1.32e-02	1.46e-02	6.82e-03	1.81e-05	2.06e-05	1.52e-05	6.17e-03	1.49e-02	2.92e-02	1.19e-05	1.16e-02
Chromium (hexavalent)	NA	NA	NA	8.30e-04	9.46e-04	6.97e-04	NA	NA	NA	5.46e-04	NA

Compound	Measurement Receptors										
	American Kestrel (BCF_{W-CN})	American Robin (BCF_{W-OB})	Canvas Back (BCF_{W-HM})	Deer Mouse (BCF_{W-HM})	Least Shrew (BCF_{W-OM})	Long-tailed Weasel (BCF_{W-OM})	Mallard Duck (BCF_{W-OB})	Marsh Rice Rat (BCF_{W-OM})	Marsh Wren (BCF_{W-OB})	Mink (BCF_{W-OM})	Mourning Dove (BCF_{W-OM})
Copper	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	4.53e-05	5.16e-05	3.80e-05	NA	NA	NA	2.98e-05	NA
Mercuric Chloride	2.99e-03	3.27e-03	1.54e-03	7.88e-04	8.98e-04	6.63e-04	1.39e-03	2.99e-03	6.57e-03	5.18e-04	2.61e-03
Methylmercury	4.48e-04	4.90e-04	2.30e-04	1.18e-04	1.34e-04	9.91e-05	2.08e-04	5.05e-04	9.85e-04	7.74e-05	3.90e-04
Nickel	NA	NA	NA	9.05e-04	1.03e-03	7.60e-04	NA	NA	NA	5.96e-04	NA
Selenium	1.41e-01	1.55e-01	7.27e-02	3.42e-04	3.90e-04	2.88e-04	6.58e-02	1.59e-01	3.11e-01	2.25e-04	1.24e-01
Silver	NA	NA	NA	4.53e-04	5.16e-04	3.80e-04	NA	NA	NA	2.98e-04	NA
Thallium	NA	NA	NA	6.03e-03	6.88e-03	5.07e-03	NA	NA	NA	3.97e-03	NA
Zinc	1.09e-03	1.20e-03	5.63e-04	1.36e-05	1.55e-05	1.14e-05	5.09e-04	1.23e-03	2.41e-03	8.93e-06	9.57e-04

Notes:

NA - Indicates insufficient data to determine value

HB - Herbivorous bird
HM - Herbivorous mammal
OB - Omnivorous bird
OM - Omnivorous mammal
TP - Terrestrial plant

Values provided were determined as specified in the text of Appendix D. *BCF* values for omnivores were determined based on an equal diet. *BCF* values for dioxin and furan congeners determined using BEF values specified in Chapter 2.

Table D-2

Bioconcentration Factors for Water to Wildlife Measurement Receptors

(Page 4 of 6)

Compound	Muskrat (BCF_{W-OM})	Northern Bobwhite (BCF_{W-OB})	Northern Harrier (BCF_{W-CM})	Red Fox (BCF_{W-CM})	Red-tailed Hawk (BCF_{W-HM})	Salt-marsh Harvest Mouse (BCF_{W-HM})	Short-tailed Shrew (BCF_{W-OM})	Spotted Sandpiper (BCF_{W-CSB})	Swift Fox (BCF_{W-OM})	Western Meadow Lark (BCF_{W-OM})	White-footed Mouse (BCF_{W-OM})
	Measurement Receptors										
Dioxins and Furans											
2,3,7,8-TCDD	5.33e-03	3.75e+01	2.06e+01	4.69e-03	2.06e+01	8.60e-03	8.18e-03	5.99e+01	5.07e-03	4.51e+01	8.24e-03
1,2,3,7,8-PeCDD	4.90e-03	3.45e+01	1.90e+01	4.31e-03	1.90e+01	7.91e-03	7.53e-03	5.51e+01	4.66e-03	4.15e+01	7.58e-03
1,2,3,4,7,8-HxCDD	1.65e-03	1.16e+01	6.39e+00	1.45e-03	6.39e+00	2.67e-03	2.54e-03	1.86e+01	1.57e-03	1.40e+01	2.55e-03
1,2,3,6,7,8-HxCDD	6.40e-05	4.50e+00	2.47e+00	5.62e-04	2.47e+00	1.03e-03	9.82e-04	7.18e+00	6.08e-04	5.41e+00	9.89e-04
1,2,3,7,8,9-HxCDD	7.46e-04	5.25e+00	2.88e+00	6.56e-04	2.88e+00	1.20e-03	1.15e-03	8.38e+00	7.10e-04	6.31e+00	1.15e-03
1,2,3,4,6,7,8-HpCDD	2.72e-04	1.91e+00	1.05e+00	2.39e-04	1.05e+00	4.39e-04	4.17e-04	3.05e+00	2.59e-04	2.30e+00	4.20e-04
OCDD	6.40e-05	4.50e-01	2.47e-01	5.62e-05	2.47e-01	1.03e-04	9.82e-05	7.18e-01	6.08e-05	5.41e-01	9.89e-05
2,3,7,8-TCDF	4.26e-03	3.00e+01	1.65e+01	3.75e-03	1.65e+01	6.88e-03	6.55e-03	4.79e+01	4.06e-03	3.61e+01	6.59e-03
1,2,3,7,8-PeCDF	1.17e-03	8.25e+00	4.53e+00	1.03e-03	4.53e+00	1.89e-03	1.80e-03	1.32e+01	1.12e-03	9.91e+00	1.81e-03
2,3,4,7,8-PeCDF	8.53e-03	6.00e+01	3.30e+01	7.50e-03	3.30e+01	1.38e-02	1.31e-02	9.58e+01	8.11e-03	7.21e+01	1.32e-02
1,2,3,4,7,8-HxCDF	4.05e-04	2.85e+00	1.57e+00	3.56e-04	1.57e+00	6.54e-04	6.22e-04	4.55e+00	3.85e-04	3.42e+00	6.26e-04
1,2,3,6,7,8-HxCDF	1.01e-03	7.12e+00	3.92e+00	8.91e-04	3.92e+00	1.63e-03	1.55e-03	1.14e+01	9.63e-04	8.56e+00	1.57e-03
2,3,4,6,7,8-HxCDF	3.57e-03	2.51e+01	1.38e+01	3.14e-03	1.38e+01	5.76e-03	5.48e-03	4.01e+01	3.40e-03	3.02e+01	5.52e-03
1,2,3,7,8,9-HxCDF	3.36e-03	2.36e+01	1.30e+01	2.95e-03	1.30e+01	5.42e-03	5.15e-03	3.77e+01	3.19e-03	2.84e+01	5.19e-03
1,2,3,4,6,7,8-HpCDF	5.86e-05	4.12e-01	2.27e-01	5.16e-05	2.27e-01	9.46e-05	9.00e-05	6.58e-01	5.58e-05	4.96e-01	9.06e-05
1,2,3,4,7,8,9-HpCDF	2.08e-03	1.46e+01	8.04e+00	1.83e-03	8.04e+00	0.00e+00	3.19e-03	2.33e+01	1.98e-03	1.76e+01	3.21e-03
OCDF	8.53e-05	6.00e-01	3.30e-01	7.50e-05	3.30e-01	1.38e-04	1.31e-04	9.58e-01	8.11e-05	7.21e-01	1.32e-04
Polynuclear aromatic hydrocarbons (PAHs)											
Benzo(a)pyrene	3.32e-03	2.92e-03	1.60e-03	2.92e-03	1.60e-03	5.35e-03	5.09e-03	4.64e-03	3.16e-03	3.49e-03	5.13e-03
Benzo(a)anthracene	1.18e-03	1.03e-03	5.66e-04	1.04e-03	5.66e-04	1.90e-03	1.81e-03	1.64e-03	1.12e-03	1.24e-03	1.82e-03
Benzo(b)fluoranthene	3.93e-03	3.46e-03	1.89e-03	3.45e-03	1.89e-03	6.34e-03	6.03e-03	5.49e-03	3.73e-03	4.13e-03	6.07e-03
Benzo(k)fluoranthene	3.91e-03	3.43e-03	1.88e-03	3.44e-03	1.88e-03	6.30e-03	6.00e-03	5.46e-03	3.72e-03	4.10e-03	6.04e-03
Chrysene	1.35e-03	1.19e-03	6.53e-04	1.19e-03	6.53e-04	2.19e-03	2.08e-03	1.89e-03	1.29e-03	1.42e-03	2.09e-03
Dibenz(a,h)anthracene	8.70e-03	7.66e-03	4.19e-03	7.65e-03	4.19e-03	1.40e-02	1.33e-02	1.22e-02	8.27e-03	9.14e-03	1.34e-02
Indeno(1,2,3-cd)pyrene	2.03e-02	1.78e-02	9.76e-03	1.79e-02	9.76e-03	3.28e-02	3.12e-02	2.83e-02	1.93e-02	2.13e-02	3.14e-02
Polychlorinated biphenyls (PCBs)											
Aroclor 1016	6.25e-04	5.50e-04	3.01e-04	5.50e-04	3.01e-04	1.01e-03	9.60e-04	8.74e-04	5.95e-04	6.57e-04	9.66e-04
Aroclor 1254	3.98e-03	3.49e-03	1.91e-03	3.50e-03	1.91e-03	6.41e-03	6.10e-03	5.54e-03	3.78e-03	4.16e-03	6.14e-03
Nitroaromatics											
1,3-Dinitrobenzene	7.65e-08	6.73e-08	3.68e-08	6.72e-08	3.68e-08	1.23e-07	1.17e-07	1.07e-07	7.27e-08	8.03e-08	1.18e-07
2,4-Dinitrotoluene	2.44e-07	2.14e-07	1.17e-07	2.15e-07	1.17e-07	3.94e-07	3.75e-07	3.41e-07	2.32e-07	2.56e-07	3.78e-07

Table D-2

Bioconcentration Factors for Water to Wildlife Measurement Receptors

(Page 5 of 6)

Compound	Measurement Receptors										
	Muskrat (BCF_{W-OM})	Northern Bobwhite (BCF_{W-OB})	Northern Harrier (BCF_{W-CM})	Red Fox (BCF_{W-CM})	Red-tailed Hawk (BCF_{W-BM})	Salt-marsh Harvest Mouse (BCF_{W-BM})	Short-tailed Shrew (BCF_{W-OM})	Spotted Sandpiper (BCF_{W-CSB})	Swift Fox (BCF_{W-OM})	Western Meadow Lark (BCF_{W-OM})	White-footed Mouse (BCF_{W-OM})
2,6-Dinitrotoluene	1.89e-07	1.67e-07	9.16e-08	1.67e-07	9.16e-08	3.06e-07	2.91e-07	2.66e-07	1.80e-07	2.00e-07	2.93e-07
Nitrobenzene	1.68e-07	1.48e-07	8.08e-08	1.48e-07	8.08e-08	2.71e-07	2.58e-07	2.35e-07	1.60e-07	1.76e-07	2.59e-07
Pentachloronitrobenzene	1.08e-04	9.47e-05	5.18e-05	9.49e-05	5.18e-05	1.74e-04	1.66e-04	1.50e-04	1.03e-04	1.13e-04	1.67e-04
Phthalate Esters											
Bis(2-ethylhexyl)phthalate	3.96e-04	3.48e-04	1.90e-04	3.48e-04	1.90e-04	6.38e-04	6.07e-04	5.52e-04	3.76e-04	4.15e-04	6.11e-04
Di(n)octyl phthalate	5.27e+00	4.64e+00	2.54e+00	4.64e+00	2.54e+00	8.51e+00	8.09e+00	7.37e+00	5.01e+00	5.54e+00	8.15e+00
Volatile Organic Compounds											
Acetone	1.48e-09	1.30e-09	7.12e-10	1.30e-09	7.12e-10	2.39e-09	2.28e-09	2.07e-09	1.41e-09	1.55e-09	2.29e-09
Acrylonitrile	4.39e-09	3.85e-09	2.11e-09	3.86e-09	2.11e-09	7.08e-09	6.73e-09	6.14e-09	4.17e-09	4.62e-09	6.78e-09
Chloroform	2.20e-07	1.93e-07	1.05e-07	1.93e-07	1.05e-07	3.55e-07	3.38e-07	3.06e-07	2.09e-07	2.30e-07	3.40e-07
Crotonaldehyde	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dioxane	1.33e-09	1.17e-09	6.41e-10	1.17e-09	6.41e-10	2.15e-09	2.05e-09	1.86e-09	1.27e-09	1.40e-09	2.06e-09
Formaldehyde	5.43e-09	4.77e-09	2.61e-09	4.77e-09	2.61e-09	8.76e-09	8.33e-09	7.58e-09	5.16e-09	5.69e-09	8.39e-09
Vinyl chloride	3.45e-08	3.04e-08	1.66e-08	3.04e-08	1.66e-08	5.58e-08	5.30e-08	4.83e-08	3.29e-08	3.63e-08	5.34e-08
Other Chlorinated Organics											
Hexachlorobenzene	7.84e-04	6.90e-04	3.78e-04	6.90e-04	3.78e-04	1.27e-03	1.20e-03	1.10e-03	7.46e-04	8.24e-04	1.21e-03
Hexachlorobutadiene	1.33e-04	1.17e-04	6.41e-05	1.17e-04	6.41e-05	2.13e-04	2.04e-04	1.86e-04	1.26e-04	1.40e-04	2.05e-04
Hexachlorocyclopentadiene	1.99e-04	1.75e-04	9.58e-05	1.75e-04	9.58e-05	3.22e-04	3.06e-04	2.78e-04	1.90e-04	2.09e-04	3.08e-04
Pentachlorobenzene	3.01e-04	2.66e-04	1.45e-04	2.65e-04	1.45e-04	4.86e-04	4.63e-04	4.22e-04	2.87e-04	3.17e-04	4.66e-04
Pentachlorophenol	2.96e-04	2.61e-04	1.43e-04	2.61e-04	1.43e-04	4.78e-04	4.55e-04	4.15e-04	2.82e-04	3.12e-04	4.58e-04
Pesticides											
4,4-DDE	4.45e-03	3.92e-03	2.14e-03	3.91e-03	2.14e-03	7.18e-03	6.83e-03	6.22e-03	4.23e-03	4.67e-03	6.87e-03
Heptachlor	2.55e-04	2.24e-04	1.23e-04	2.24e-04	1.23e-04	4.12e-04	3.92e-04	3.56e-04	2.43e-04	2.68e-04	3.94e-04
Hexachlorophene	8.55e-02	7.53e-02	4.12e-02	7.52e-02	4.12e-02	1.38e-01	1.31e-01	1.20e-01	8.13e-02	8.98e-02	1.32e-01
Inorganics											
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony	9.82e-05	NA	NA	8.63e-05	NA	1.58e-04	1.51e-04	NA	9.33e-05	NA	1.52e-04
Arsenic	1.96e-04	NA	NA	1.73e-04	NA	3.17e-04	3.01e-04	NA	1.87e-04	NA	3.03e-04
Barium	1.47e-05	NA	NA	1.29e-05	NA	2.38e-05	2.26e-05	NA	1.40e-05	NA	2.28e-05
Beryllium	9.82e-05	NA	NA	8.63e-05	NA	1.58e-04	1.51e-04	NA	9.33e-05	NA	1.52e-04
Cadmium	1.18e-05	1.16e-02	6.35e-03	1.04e-05	6.35e-03	1.90e-05	1.81e-05	1.84e-02	1.12e-05	1.38e-02	1.82e-05
Chromium (hexavalent)	5.40e-04	NA	NA	4.75e-04	NA	8.71e-04	8.29e-04	NA	5.13e-04	NA	8.34e-04

Table D-2

Bioconcentration Factors for Water to Wildlife Measurement Receptors

(Page 6 of 6)

Compound	Measurement Receptors										
	Muskrat (BCF_{W-OM})	Northern Bobwhite (BCF_{W-OB})	Northern Harrier (BCF_{W-CM})	Red Fox (BCF_{W-CM})	Red-tailed Hawk (BCF_{W-HM})	Salt-marsh Harvest Mouse (BCF_{W-HM})	Short-tailed Shrew (BCF_{W-OM})	Spotted Sandpiper (BCF_{W-CSB})	Swift Fox (BCF_{W-OM})	Western Meadow Lark (BCF_{W-OM})	White-footed Mouse (BCF_{W-OM})
Copper	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	2.94e-05	NA	NA	2.59e-05	NA	4.75e-05	4.52e-05	NA	2.80e-05	NA	4.55e-05
Mercuric chloride	5.13e-04	2.61e-03	1.43e-03	4.50e-04	1.43e-03	8.25e-04	7.88e-04	4.16e-03	4.88e-04	3.13e-03	2.99e-03
Methylmercury	7.66e-05	3.90e-04	2.14e-04	6.73e-05	2.14e-04	1.24e-04	1.18e-04	6.23e-04	7.28e-05	4.69e-04	1.18e-04
Nickel	5.89e-04	NA	NA	5.18e-04	NA	9.50e-04	9.04e-04	NA	5.60e-04	NA	9.10e-04
Selenium	2.23e-04	1.24e-01	6.76e-02	1.96e-04	6.76e-02	3.60e-04	3.42e-04	1.96e-01	2.12e-04	1.48e-01	3.44e-04
Silver	2.94e-04	NA	NA	2.59e-04	NA	4.75e-04	4.52e-04	NA	2.80e-04	NA	4.55e-04
Thallium	3.93e-03	NA	NA	3.45e-03	NA	6.34e-03	6.03e-03	NA	3.73e-03	NA	6.07e-03
Zinc	8.83e-06	9.57e-04	5.24e-04	7.77e-06	5.24e-04	1.43e-05	1.36e-05	1.52e-03	8.40e-06	1.14e-03	1.37e-05

Notes:

NA - Indicates insufficient data to determine value

HB - Herbivorous bird
HM - Herbivorous mammal
OB - Omnivorous bird
OM - Omnivorous mammal
TP - Terrestrial plant

– Values provided were determined as specified in the text of Appendix D. *BCF* values for omnivores were determined based on an equal diet. *BCF* values for dioxin and furan congeners determined using BEF values specified in Chapter 2.

TABLE D-3

BIOCONCENTRATION FACTORS FOR SOIL/SEDIMENT TO WILDLIFE MEASUREMENT RECEPTORS

Compound	Measurement Receptors										
	American Kestrel (BCF_{S-CB})	American Robin (BCF_{S-OB})	Canvas Back (BCF_{S-HB})	Deer Mouse (BCF_{S-HM})	Least Shrew (BCF_{S-OM})	Long-tailed Weasel (BCF_{S-OM})	Mallard Duck (BCF_{S-OB})	Marsh Rice Rat (BCF_{S-OM})	Marsh Wren (BCF_{S-OB})	Mink (BCF_{S-CM})	Mourning Dove (BCF_{S-OM})
Dioxins and Furans											
2,3,7,8-TCDD	4.78e-01	4.92e+00	6.26e-01	7.81e-05	7.41e-04	1.62e-04	1.09e+00	1.70e-04	6.74e+00	1.05e-04	2.41e+00
1,2,3,7,8-PeCDD	4.40e-01	4.53e+00	5.76e-01	7.19e-05	6.81e-04	1.49e-04	1.01e+00	1.56e-04	6.20e+00	9.66e-05	2.22e+00
1,2,3,4,7,8-HxCDD	1.48e-01	1.53e+00	1.94e-01	2.42e-05	2.30e-04	5.02e-05	3.39e-01	5.26e-05	2.09e+00	3.25e-05	7.48e-01
1,2,3,6,7,8-HxCDD	5.74e-02	5.90e-01	7.51e-02	9.37e-06	8.89e-05	1.94e-05	1.31e-01	2.04e-05	8.09e-01	1.26e-05	2.89e-02
1,2,3,7,8,9-HxCDD	6.69e-02	6.89e-01	8.77e-02	1.09e-05	1.04e-04	2.27e-05	1.53e-01	2.38e-05	9.44e-01	1.47e-05	3.38e-01
1,2,3,4,6,7,8-HpCDD	2.44e-02	2.51e-01	3.19e-02	3.98e-06	3.78e-05	8.26e-06	5.58e-02	8.66e-06	3.44e-01	5.35e-06	1.23e-01
OCDD	5.74e-03	5.90e-02	7.51e-03	9.37e-07	8.89e-06	1.94e-06	1.31e-02	2.04e-06	8.09e-02	1.26e-06	2.89e-02
2,3,7,8-TCDF	3.83e-01	3.94e+00	5.01e-01	6.25e-05	5.93e-04	1.30e-04	8.75e-01	1.36e-04	5.39e+00	8.40e-05	1.93e+00
1,2,3,7,8-PeCDF	1.05e-01	1.08e+00	1.38e-01	1.72e-05	1.63e-04	3.56e-05	2.41e-01	3.74e-05	1.48e+00	2.31e-05	5.31e-01
2,3,4,7,8-PeCDF	7.65e-01	7.87e+00	1.00e+00	1.25e-04	1.19e-03	2.59e-04	1.75e+00	2.72e-04	1.08e+01	1.68e-04	3.86e+00
1,2,3,4,7,8-HxCDF	3.63e-02	3.74e-01	4.76e-02	5.94e-06	5.63e-05	1.23e-05	8.31e-02	1.29e-05	5.12e-01	7.98e-06	1.83e-01
1,2,3,6,7,8-HxCDF	9.09e-02	9.35e-01	1.19e-01	1.48e-05	1.41e-04	3.08e-05	2.08e-01	3.23e-05	1.28e+00	1.99e-05	4.58e-01
2,3,4,6,7,8-HxCDF	3.20e-01	3.30e+00	4.19e-01	5.23e-05	4.96e-04	1.09e-04	7.33e-01	1.14e-04	4.52e+00	7.03e-05	1.62e+00
1,2,3,7,8,9-HxCDF	3.01e-01	3.10e+00	3.94e-01	4.92e-05	4.67e-04	1.02e-04	6.89e-01	1.07e-04	4.25e+00	6.61e-05	1.52e+00
1,2,3,4,6,7,8-HpCDF	5.26e-03	5.41e-02	6.89e-03	8.59e-07	8.15e-06	1.78e-06	1.20e-02	1.87e-06	7.42e-02	1.15e-06	2.65e-02
1,2,3,4,7,8,9-HpCDF	1.86e-01	1.92e+00	2.44e-01	3.05e-05	2.89e-04	6.32e-05	4.27e-01	6.62e-05	2.63e+00	4.09e-05	9.40e-01
OCDF	7.65e-03	7.87e-02	1.00e-02	1.25e-06	1.19e-05	2.59e-06	1.75e-02	2.72e-06	1.08e-01	1.68e-06	3.86e-02
Polynuclear Aromatic Hydrocarbons (PAHs)											
Benzo(a)pyrene	3.71e-05	3.81e-04	4.85e-05	4.86e-05	4.61e-04	1.01e-04	8.50e-05	6.21e-05	5.22e-04	6.53e-05	1.87e-04
Benzo(a)anthracene	1.32e-05	1.35e-04	1.72e-05	1.73e-05	1.64e-04	3.58e-05	3.01e-05	2.20e-05	1.85e-04	2.32e-05	6.63e-05
Benzo(b)fluoranthene	4.39e-05	4.50e-04	5.74e-05	5.75e-05	5.46e-04	1.19e-04	1.01e-04	7.35e-05	6.18e-04	7.73e-05	2.22e-04
Benzo(k)fluoranthene	4.36e-05	4.48e-04	5.71e-05	5.73e-05	5.43e-04	1.19e-04	1.00e-04	7.30e-05	6.14e-04	7.69e-05	2.20e-04
Chrysene	1.52e-05	1.55e-04	1.98e-05	1.99e-05	1.88e-04	4.12e-05	3.47e-05	2.54e-05	2.13e-04	2.67e-05	7.64e-05
Dibenz(a,h)anthracene	9.73e-05	9.98e-04	1.27e-04	1.27e-04	1.21e-03	2.64e-04	2.23e-04	1.63e-04	1.37e-03	1.71e-04	4.91e-04
Indeno(1,2,3-cd)pyrene	2.27e-04	2.32e-03	2.96e-04	2.98e-04	2.82e-03	6.18e-04	5.19e-04	3.79e-04	3.19e-03	4.00e-04	1.14e-03
Polychlorinated Biphenyls (PCBs)											
Aroclor 1016	6.99e-06	7.17e-05	9.14e-06	9.16e-06	8.69e-05	1.90e-05	1.60e-05	1.17e-05	9.83e-05	1.23e-05	3.53e-05
Aroclor 1254	4.43e-05	4.55e-04	5.80e-05	5.83e-05	5.52e-04	1.21e-04	1.02e-04	7.42e-05	6.24e-04	7.83e-05	2.24e-04
Nitroaromatics											
1,3-Dinitrobenzene	8.55e-10	8.77e-09	1.12e-09	1.12e-09	1.06e-08	2.32e-09	1.96e-09	1.43e-09	1.20e-08	1.51e-09	4.31e-09
2,4-Dinitrotoluene	2.72e-09	2.79e-08	3.56e-09	3.58e-09	3.40e-08	7.43e-09	6.24e-09	4.56e-09	3.83e-08	4.81e-09	1.37e-08
2,6-Dinitrotoluene	2.13e-09	2.18e-08	2.78e-09	2.78e-09	2.63e-08	5.76e-09	4.87e-09	3.56e-09	2.99e-08	3.73e-09	1.07e-08

TABLE D-3

BIOCONCENTRATION FACTORS FOR SOIL/SEDIMENT TO WILDLIFE MEASUREMENT RECEPTORS

(Page 2 of 6)

Compound	Measurement Receptors										
	American Kestrel (BCF_{S-CR})	American Robin (BCF_{S-OR})	Canvas Back (BCF_{S-HB})	Deer Mouse (BCF_{S-HM})	Least Shrew (BCF_{S-OM})	Long-tailed Weasel (BCF_{S-OM})	Mallard Duck (BCF_{S-OB})	Marsh Rice Rat (BCF_{S-OM})	Marsh Wren (BCF_{S-OB})	Mink (BCF_{S-CM})	Mourning Dove (BCF_{S-OM})
Nitrobenzene	1.88e-09	1.92e-08	2.45e-09	2.46e-09	2.33e-08	5.10e-09	4.30e-09	3.14e-09	2.64e-08	3.31e-09	9.47e-09
Pentachloronitrobenzene	1.20e-06	1.23e-05	1.57e-06	1.58e-06	1.50e-05	3.28e-06	2.76e-06	2.01e-06	1.69e-05	2.13e-06	6.07e-06
Phthalate Esters											
Bis(2-ethylhexyl)phthalate	4.42e-06	4.53e-05	5.78e-06	5.80e-06	5.50e-05	1.20e-05	1.01e-05	7.40e-06	6.22e-05	7.79e-06	2.23e-05
Di(n)octyl phthalate	5.89e-02	6.04e-01	7.71e-02	7.72e-02	7.32e-01	1.60e-01	1.35e-01	9.86e-02	8.29e-01	1.04e-01	2.97e-01
Volatile Organic Compounds											
Acetone	1.65e-11	1.70e-10	2.16e-11	2.17e-11	2.06e-10	4.51e-11	3.79e-11	2.77e-11	2.33e-10	2.92e-11	8.34e-11
Acrylonitrile	4.91e-11	5.05e-10	6.42e-11	6.43e-11	6.10e-10	1.33e-10	1.12e-10	2.11e-11	6.92e-10	8.64e-11	2.47e-10
Chloroform	2.45e-09	2.51e-08	3.20e-09	3.22e-09	3.06e-08	6.68e-09	5.60e-09	4.09e-09	3.44e-08	4.33e-09	1.23e-08
Crotonaldehyde	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dioxane	1.49e-11	1.53e-10	1.94e-11	1.96e-11	1.86e-10	4.06e-11	3.41e-11	2.49e-11	2.09e-10	2.63e-11	7.50e-11
Formaldehyde	6.06e-11	6.21e-10	7.92e-11	7.95e-11	7.54e-10	1.65e-10	1.39e-10	1.01e-10	8.52e-10	1.07e-10	3.06e-10
Vinyl chloride	3.86e-10	3.96e-09	5.05e-10	5.06e-10	4.80e-09	1.05e-09	8.85e-10	6.47e-10	5.44e-09	6.80e-10	1.95e-09
Other Chlorinated Organics											
Hexachlorobenzene	8.77e-06	8.99e-05	1.15e-05	1.15e-05	1.09e-04	2.38e-05	2.01e-05	1.47e-05	1.23e-04	1.54e-05	4.42e-05
Hexachlorobutadiene	1.49e-06	1.53e-05	1.95e-06	1.94e-06	1.84e-05	4.02e-06	3.40e-06	2.49e-06	2.10e-05	2.61e-06	7.50e-06
Hexachlorocyclopentadiene	2.22e-06	2.28e-05	2.91e-06	2.92e-06	2.77e-05	6.06e-06	5.09e-06	3.72e-06	3.13e-05	3.92e-06	1.12e-05
Pentachlorobenzene	3.38e-06	3.46e-05	4.42e-06	4.42e-06	4.19e-05	9.16e-06	7.74e-06	5.65e-06	4.75e-05	5.93e-06	1.70e-05
Pentachlorophenol	3.32e-06	3.41e-05	4.34e-06	4.34e-06	4.12e-05	9.01e-06	7.61e-06	5.56e-06	4.67e-05	5.84e-06	1.68e-05
Pesticides											
4,4-DDE	4.98e-05	5.10e-04	6.51e-05	6.52e-05	6.18e-04	1.35e-04	1.14e-04	8.33e-05	7.00e-04	8.76e-05	2.51e-04
Heptachlor	2.85e-06	2.92e-05	3.73e-06	3.74e-06	3.55e-05	7.76e-06	6.53e-06	4.77e-06	4.01e-05	5.03e-06	1.44e-05
Hexachlorophene	9.56e-04	9.81e-03	1.25e-03	1.25e-03	1.19e-02	2.60e-03	2.19e-03	1.60e-03	1.35e-02	1.68e-03	4.82e-03
Inorganics											
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony	NA	NA	NA	1.44e-06	1.36e-05	2.98e-06	NA	NA	NA	1.93e-06	NA
Arsenic	NA	NA	NA	2.88e-06	2.73e-05	5.97e-06	NA	NA	NA	3.87e-06	NA
Barium	NA	NA	NA	2.16e-07	2.05e-06	4.48e-07	NA	NA	NA	2.90e-07	NA
Beryllium	NA	NA	NA	1.44e-06	1.36e-05	2.98e-06	NA	NA	NA	1.93e-06	NA
Cadmium	1.47e-04	1.51e-03	1.93e-04	1.73e-07	1.64e-06	3.58e-07	3.37e-04	2.47e-04	2.07e-03	2.32e-07	7.43e-04
Chromium (hexavalent)	NA	NA	NA	7.91e-06	7.50e-05	1.64e-05	NA	NA	NA	1.06e-05	NA
Copper	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE D-3

BIOCONCENTRATION FACTORS FOR SOIL/SEDIMENT TO WILDLIFE MEASUREMENT RECEPTORS

(Page 3 of 6)

Compound	Measurement Receptors										
	American Kestrel (BCF_{S-CB})	American Robin (BCF_{S-OB})	Canvas Back (BCF_{S-HB})	Deer Mouse (BCF_{S-HM})	Least Shrew (BCF_{S-OM})	Long-tailed Weasel (BCF_{S-OM})	Mallard Duck (BCF_{S-OB})	Marsh Rice Rat (BCF_{S-OM})	Marsh Wren (BCF_{S-OB})	Mink (BCF_{S-CM})	Mourning Dove (BCF_{S-OB})
Lead	NA	NA	NA	4.32e-07	4.09e-06	8.95e-07	NA	NA	NA	5.80e-07	NA
Mercuric chloride	3.32e-05	3.42e-04	4.35e-05	7.52e-06	7.10e-05	1.56e-05	7.60e-05	5.57e-05	4.68e-04	1.01e-05	1.68e-04
Methylmercury	4.98e-06	5.12e-05	6.52e-06	1.12e-06	1.06e-05	2.33e-06	1.14e-05	8.34e-06	7.02e-05	1.51e-06	2.51e-05
Nickel	NA	NA	NA	8.63e-06	8.18e-05	1.79e-05	NA	NA	NA	1.16e-05	NA
Selenium	1.57e-03	1.61e-02	2.05e-03	3.27e-06	3.10e-05	6.77e-06	3.60e-03	2.63e-03	2.21e-02	4.39e-06	7.92e-03
Silver	NA	NA	NA	4.32e-06	4.09e-05	8.95e-06	NA	NA	NA	5.80e-06	NA
Thallium	NA	NA	NA	5.75e-05	5.46e-04	1.19e-04	NA	NA	NA	7.73e-05	NA
Zinc	1.22e-05	1.25e-04	1.59e-05	1.29e-07	1.23e-06	2.69e-07	2.79e-05	2.04e-05	1.71e-04	1.74e-07	6.13e-05

Notes:

NA - Indicates insufficient data to determine value

HB - Herbivorous bird
HM - Herbivorous mammal
OB - Omnivorous bird
OM - Omnivorous mammal
S - Soil/Sediment

– Values provided were determined as specified in the text of Appendix D. *BCF* values for omnivores were determined based on an equal diet. *BCF* values for dioxin and furan congeners determined using BEF values specified in Chapter 2.

TABLE D-3

BIOCONCENTRATION FACTORS FOR SOIL/SEDIMENT TO WILDLIFE MEASUREMENT RECEPTORS

(Page 4 of 6)

Compound	Measurement Receptors										
	Muskrat (BCF_{S-OM})	Northern Bobwhite (BCF_{S-OB})	Northern Harrier (BCF_{S-CM})	Red Fox (BCF_{S-CM})	Red-tailed Hawk (BCF_{S-BM})	Salt-marsh Harvest Mouse (BCF_{S-HM})	Short-tailed Shrew (BCF_{S-OM})	Spotted Sandpiper (BCF_{S-CSB})	Swift Fox (BCF_{S-OM})	Western Meadow Lark (BCF_{S-OM})	White-footed Mouse (BCF_{S-OM})
Dioxins and Furans											
2,3,7,8-TCDD	3.48e-05	4.13e+00	3.42e+00	8.19e-05	3.42e+00	9.66e-05	7.41e-04	1.43e+01	9.41e-05	4.78e+00	1.47e-04
1,2,3,7,8-PeCDD	3.20e-05	3.80e+00	3.15e+00	7.53e-05	3.15e+00	8.88e-05	6.81e-04	1.31e+01	8.66e-05	4.40e+00	1.35e-04
1,2,3,4,7,8-HxCDD	1.08e-05	1.28e+00	1.06e+00	2.54e-05	1.06e+00	2.99e-05	2.30e-04	4.43e+00	2.92e-05	1.48e+00	4.55e-05
1,2,3,6,7,8-HxCDD	4.18e-07	4.95e-01	4.11e-01	9.82e-06	4.11e-01	1.16e-05	8.89e-05	1.71e+00	1.13e-05	5.74e-01	1.76e-05
1,2,3,7,8,9-HxCDD	4.87e-06	5.78e-01	4.79e-01	1.15e-05	4.79e-01	1.35e-05	1.04e-04	2.00e+00	1.32e-05	6.69e-01	2.05e-05
1,2,3,4,6,7,8-HpCDD	1.78e-06	2.11e-01	1.75e-01	4.17e-06	1.75e-01	4.92e-06	3.78e-05	7.28e-01	4.80e-06	2.44e-01	7.48e-06
OCDD	4.18e-07	4.95e-02	4.11e-02	9.82e-07	4.11e-02	1.16e-06	8.89e-06	1.71e-01	1.13e-06	5.74e-02	1.76e-06
2,3,7,8-TCDF	2.79e-05	3.30e+00	2.74e+00	6.55e-05	2.74e+00	7.72e-05	5.93e-04	1.14e+01	7.53e-05	3.83e+00	1.17e-04
1,2,3,7,8-PeCDF	7.66e-06	9.08e-01	7.53e-01	1.80e-05	7.53e-01	2.12e-05	1.63e-04	3.14e+00	2.07e-05	1.05e+00	3.23e-05
2,3,4,7,8-PeCDF	5.57e-05	6.60e+00	5.48e+00	1.31e-04	5.48e+00	1.55e-04	1.19e-03	2.28e+01	1.51e-04	7.65e+00	2.35e-04
1,2,3,4,7,8-HxCDF	2.65e-06	3.14e-01	2.60e-01	6.22e-06	2.60e-01	7.34e-06	5.63e-05	1.09e+00	7.15e-06	3.63e-01	1.12e-05
1,2,3,6,7,8-HxCDF	6.62e-06	7.84e-01	6.50e-01	1.56e-05	6.50e-01	1.83e-05	1.41e-04	2.71e+00	1.79e-05	9.09e-01	2.79e-05
2,3,4,6,7,8-HxCDF	2.33e-05	2.77e+00	2.29e+00	5.48e-05	2.29e+00	6.47e-05	4.96e-04	9.56e+00	6.30e-05	3.20e+00	9.83e-05
1,2,3,7,8,9-HxCDF	2.19e-05	2.60e+00	2.16e+00	5.16e-05	2.16e+00	6.08e-05	4.67e-04	8.99e+00	5.93e-05	3.01e+00	9.24e-05
1,2,3,4,6,7,8-HpCDF	3.83e-07	4.54e-02	3.77e-02	9.00e-07	3.77e-02	1.06e-06	8.15e-06	1.57e-01	1.04e-06	5.26e-02	1.61e-06
1,2,3,4,7,8,9-HpCDF	1.36e-05	1.61e+00	1.33e+00	3.19e-05	1.33e+00	0.00e+00	2.89e-04	5.57e+00	3.67e-05	1.86e+00	5.72e-05
OCDF	5.57e-07	6.60e-02	5.48e-02	1.31e-06	5.48e-02	1.55e-06	1.19e-05	2.28e-01	1.51e-06	7.65e-02	2.35e-06
Polynuclear aromatic hydrocarbons (PAHs)											
Benzo(a)pyrene	2.17e-05	3.19e-04	2.66e-04	5.10e-05	2.66e-04	6.01e-05	4.61e-04	1.11e-03	5.86e-05	3.72e-04	9.13e-05
Benzo(a)anthracene	7.69e-06	1.13e-04	9.41e-05	1.81e-05	9.41e-05	2.13e-05	1.64e-04	3.93e-04	2.08e-05	1.32e-04	3.24e-05
Benzo(b)fluoranthene	2.57e-05	3.78e-04	3.14e-04	6.03e-05	3.14e-04	7.11e-05	5.46e-04	1.31e-03	6.93e-05	4.40e-04	1.08e-04
Benzo(k)fluoranthene	2.55e-05	3.75e-04	3.12e-04	6.00e-05	3.12e-04	7.08e-05	5.43e-04	1.30e-03	6.90e-05	4.37e-04	1.08e-04
Chrysene	8.85e-06	1.30e-04	1.08e-04	2.08e-05	1.08e-04	2.45e-05	1.88e-04	4.53e-04	2.39e-05	1.52e-04	3.73e-05
Dibenz(a,h)anthracene	5.68e-05	8.37e-04	6.97e-04	1.34e-04	6.97e-04	1.58e-04	1.21e-03	2.91e-03	1.54e-04	9.75e-04	2.39e-04
Indeno(1,2,3-cd)pyrene	1.33e-04	1.95e-03	1.62e-03	3.12e-04	1.62e-03	3.68e-04	2.82e-03	6.77e-03	3.59e-04	2.27e-03	5.59e-04
Polychlorinated biphenyls (PCBs)											
Aroclor 1016	4.08e-06	6.01e-05	5.01e-05	9.60e-06	5.01e-05	1.13e-05	8.69e-05	2.09e-04	1.10e-05	7.01e-05	1.72e-05
Aroclor 1254	2.60e-05	3.81e-04	3.17e-04	6.11e-05	3.17e-04	7.20e-05	5.52e-04	1.32e-03	7.02e-05	4.44e-04	1.09e-04
Nitroaromatics											
1,3-Dinitrobenzene	5.00e-10	7.35e-09	6.12e-09	1.17e-09	6.12e-09	1.39e-09	1.06e-08	2.55e-08	1.35e-09	8.57e-09	2.10e-09
2,4-Dinitrotoluene	1.60e-09	2.34e-08	1.95e-08	3.75e-09	1.95e-08	4.43e-09	3.40e-08	8.14e-08	4.32e-09	2.73e-08	6.73e-09

TABLE D-3

BIOCONCENTRATION FACTORS FOR SOIL/SEDIMENT TO WILDLIFE MEASUREMENT RECEPTORS

(Page 5 of 6)

	Measurement Receptors										
Compound	Muskrat (BCF_{S-OM})	Northern Bobwhite (BCF_{S-OB})	Northern Harrier (BCF_{S-CM})	Red Fox (BCF_{S-CM})	Red-tailed Hawk (BCF_{S-BM})	Salt-marsh Harvest Mouse (BCF_{S-BM})	Short-tailed Shrew (BCF_{S-OM})	Spotted Sandpiper (BCF_{S-CSB})	Swift Fox (BCF_{S-OM})	Western Meadow Lark (BCF_{S-OM})	White-footed Mouse (BCF_{S-OM})
2,6-Dinitrotoluene	1.24e-09	1.83e-08	1.52e-08	2.91e-09	1.52e-08	3.43e-09	2.63e-08	6.35e-08	3.34e-09	2.13e-08	5.21e-09
Nitrobenzene	1.10e-09	1.61e-08	1.34e-08	2.58e-09	1.34e-08	3.04e-09	2.33e-08	5.61e-08	2.96e-09	1.88e-08	4.62e-09
Pentachloronitrobenzene	7.05e-07	1.04e-05	8.62e-06	1.66e-06	8.62e-06	1.96e-06	1.50e-05	3.60e-05	1.91e-06	1.21e-05	2.97e-06
Phthalate esters											
Bis(2-ethylhexyl)phthalate	2.58e-06	3.80e-05	3.16e-05	6.07e-06	3.16e-05	7.17e-06	5.50e-05	1.32e-04	6.98e-06	4.43e-05	1.09e-05
Di(n)octyl phthalate	3.44e-02	5.07e-01	4.22e-01	8.09e-02	4.22e-01	9.55e-02	7.32e-01	1.76e+00	9.31e-02	5.91e-01	1.45e-01
Volatile organic compounds											
Acetone	9.68e-12	1.42e-10	1.18e-10	2.28e-11	1.18e-10	2.69e-11	2.06e-10	4.94e-10	2.62e-11	1.66e-10	4.08e-11
Acrylonitrile	2.87e-11	4.42e-10	3.51e-11	6.74e-11	3.51e-10	7.95e-11	6.10e-10	1.46e-09	7.75e-11	4.91e-10	1.21e-10
Chloroform	1.44e-09	2.10e-08	1.75e-08	3.38e-09	1.75e-08	3.98e-09	3.06e-08	7.31e-08	3.88e-09	2.45e-08	6.05e-09
Crotonaldehyde	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dioxane	8.72e-12	1.28e-10	1.06e-10	2.05e-11	1.06e-10	2.42e-11	1.86e-10	4.44e-10	2.36e-11	1.49e-10	3.67e-11
Formaldehyde	3.55e-11	5.21e-10	4.34e-10	8.34e-11	4.34e-10	9.83e-11	7.54e-10	1.81e-09	9.58e-11	6.07e-10	1.49e-10
Vinyl chloride	2.26e-10	3.32e-09	2.77e-09	5.31e-10	2.77e-09	6.26e-10	4.80e-09	1.15e-08	6.10e-10	3.87e-09	9.51e-10
Other chlorinated organics											
Hexachlorobenzene	5.12e-06	7.54e-05	6.28e-05	1.20e-05	6.28e-05	1.42e-05	1.09e-04	2.62e-04	1.38e-05	8.79e-05	2.16e-05
Hexachlorobutadiene	8.65e-07	1.28e-05	1.06e-05	2.04e-06	1.06e-05	2.40e-06	1.84e-05	4.44e-05	2.34e-06	1.49e-05	3.65e-06
Hexachlorocyclopentadiene	1.30e-06	1.91e-05	1.59e-05	3.06e-06	1.59e-05	3.61e-06	2.77e-05	6.64e-05	3.52e-06	2.23e-05	5.49e-06
Pentachlorobenzene	1.97e-06	2.90e-05	2.42e-05	4.63e-06	2.42e-05	5.46e-06	4.19e-05	1.01e-04	5.32e-06	3.39e-05	8.30e-06
Pentachlorophenol	1.94e-06	2.86e-05	2.38e-05	4.55e-06	2.38e-05	5.37e-06	4.12e-05	9.93e-05	5.23e-06	3.33e-05	8.16e-06
Pesticides											
4,4-DDE	2.90e-05	4.28e-04	3.56e-04	6.83e-05	3.56e-04	8.06e-05	6.18e-04	1.49e-03	7.85e-05	4.99e-04	1.22e-04
Heptachlor	1.67e-06	2.45e-05	2.04e-05	3.92e-06	2.04e-05	4.62e-06	3.55e-05	8.51e-05	4.51e-06	2.86e-05	7.03e-06
Hexachlorophene	5.59e-04	8.22e-03	6.85e-03	1.31e-03	6.85e-03	1.55e-03	1.19e-02	2.86e-02	1.51e-03	9.58e-03	2.35e-03
Inorganics											
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony	6.41e-07	NA	NA	1.51e-06	NA	1.78e-06	1.36e-05	NA	1.73e-06	NA	2.70e-06
Arsenic	1.28e-06	NA	NA	3.01e-06	NA	3.56e-06	2.73e-05	NA	3.47e-06	NA	5.40e-06
Barium	9.62e-08	NA	NA	2.26e-07	NA	2.67e-07	2.05e-06	NA	2.60e-07	NA	4.05e-07
Beryllium	6.41e-07	NA	NA	1.51e-06	NA	1.78e-06	1.36e-05	NA	1.73e-06	NA	2.70e-06
Cadmium	7.69e-08	1.27e-03	1.05e-03	1.81e-07	1.05e-03	2.13e-07	1.64e-06	4.40e-03	2.08e-07	1.48e-03	3.24e-07
Chromium (hexavalent)	3.53e-06	NA	NA	8.29e-06	NA	9.78e-06	7.50e-05	NA	9.53e-06	NA	1.49e-05

TABLE D-3

BIOCONCENTRATION FACTORS FOR SOIL/SEDIMENT TO WILDLIFE MEASUREMENT RECEPTORS

(Page 6 of 6)

	Measurement Receptors										
Compound	Muskrat (BCF_{S-OM})	Northern Bobwhite (BCF_{S-OB})	Northern Harrier (BCF_{S-CM})	Red Fox (BCF_{S-CM})	Red-tailed Hawk (BCF_{S-HM})	Salt-marsh Harvest Mouse (BCF_{S-HM})	Short-tailed Shrew (BCF_{S-OM})	Spotted Sandpiper (BCF_{S-CSB})	Swift Fox (BCF_{S-OM})	Western Meadow Lark (BCF_{S-OM})	White-footed Mouse (BCF_{S-OM})
Copper	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Cyanide	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	1.92e-07	NA	NA	4.52e-07	NA	5.33e-07	4.09e-06	NA	5.20e-07	NA	8.11e-07
Mercuric chloride	3.35e-06	2.87e-04	2.38e-04	7.88e-06	2.38e-04	9.29e-06	7.10e-05	9.92e-04	9.03e-06	3.32e-04	1.41e-05
Methylmercury	5.00e-07	4.30e-05	3.56e-05	1.18e-06	3.56e-05	1.39e-06	1.06e-05	1.49e-04	1.35e-06	4.98e-05	2.11e-06
Nickel	3.85e-06	NA	NA	9.04e-06	NA	1.07e-05	8.18e-05	NA	1.04e-05	NA	1.62e-05
Selenium	1.46e-06	1.35e-02	1.12e-02	3.42e-06	1.12e-02	4.04e-06	3.10e-05	4.69e-02	3.93e-06	1.57e-02	6.13e-06
Silver	1.92e-06	NA	NA	4.52e-06	NA	5.33e-06	4.09e-05	NA	5.20e-06	NA	8.11e-06
Thallium	2.57e-05	NA	NA	6.03e-05	NA	7.11e-05	5.46e-04	NA	6.93e-05	NA	1.08e-04
Zinc	5.77e-08	1.05e-04	8.71e-05	1.36e-07	8.71e-05	1.60e-07	1.23e-06	3.63e-04	1.56e-07	1.22e-04	2.43e-07

Notes:

NA - Indicates insufficient data to determine value

HB - Herbivorous bird
HM - Herbivorous mammal
OB - Omnivorous bird
OM - Omnivorous mammal
S - Soil/Sediment

– Values provided were determined as specified in the text of Appendix D. *BCF* values for omnivores were determined based on an equal diet. *BCF* values for dioxin and furan congeners determined using BEF values specified in Chapter 2.

FOOD-CHAIN MULTIPLIERS

Log K_{ow}	Trophic Level of Consumer		
	2	3	4
2.0	1.0	1.0	1.0
2.5	1.0	1.0	1.0
3.0	1.0	1.0	1.0
3.1	1.0	1.0	1.0
3.2	1.0	1.0	1.0
3.3	1.0	1.1	1.0
3.4	1.0	1.1	1.0
3.5	1.0	1.1	1.0
3.6	1.0	1.1	1.0
3.7	1.0	1.1	1.0
3.8	1.0	1.2	1.0
3.9	1.0	1.2	1.1
4.0	1.0	1.3	1.1
4.1	1.0	1.3	1.1
4.2	1.0	1.4	1.1
4.3	1.0	1.5	12
4.4	1.0	1.6	1.2
4.5	1.0	1.8	1.3
4.6	1.0	2.0	1.5
4.7	1.0	2.2	1.6
4.8	1.0	2.5	1.9
4.9	1.0	2.8	2.2
5.0	1.0	3.2	2.6
5.1	1.0	3.6	3.2
5.2	1.0	4.2	3.9
5.3	1.0	4.8	4.7
5.4	1.0	5.5	5.8
5.5	1.0	6.3	7.1
5.6	1.0	7.1	8.6

FOOD-CHAIN MULTIPLIERS

Log K_{ow}	Trophic Level of Consumer		
	2	3	4
5.7	1.0	8.0	10
5.8	1.0	8.8	12
5.9	1.0	9.7	14
6.0	1.0	11	16
6.1	1.0	11	18
6.2	1.0	12	20
6.3	1.0	13	22
6.4	1.0	13	23
6.5	1.0	14	25
6.6	1.0	14	26
6.7	1.0	14	26
6.8	1.0	14	27
6.9	1.0	14	27
7.0	1.0	14	26
7.1	1.0	14	25
7.2	1.0	14	24
7.3	1.0	13	23
7.4	1.0	13	21
7.5	1.0	13	19
7.6	1.0	12	17
7.7	1.0	11	14
7.8	1.0	10	12
7.9	1.0	9.2	9.8
8.0	1.0	8.2	7.8
8.1	1.0	7.3	6.0
8.2	1.0	6.4	4.5
8.3	1.0	5.5	3.3
8.4	1.0	4.7	2.4
8.5	1.0	3.9	1.7
8.6	1.0	3.3	1.1

FOOD-CHAIN MULTIPLIERS

Log K_{ow}	Trophic Level of Consumer		
	2	3	4
8.7	1.0	2.7	0.78
8.8	1.0	2.2	0.52
8.9	1.0	1.8	0.35
9.0	1.0	1.5	0.23

Source: U.S. EPA. 1995k. "Great Lakes Water Quality Initiative Technical Support Document for the Procedure to Determine Bioaccumulation factors." EPA-820-B-95-005. Office of Water. Washington, D.C. March.

APPENDIX G

Toxicity Reference Values (TRVs)
from Appendix E EPA, 1999b

APPENDIX E

TOXICITY REFERENCE VALUES

Appendix E presents implementation of the recommended approach (described in Chapter 5) for identifying toxicity reference values (*TRV*s) for measurement receptors. Discussion is provided for determining compound-specific *TRV* values for community and wildlife measurement receptors.

Following the guidance in Sections E-1.0 through E-1.2, U.S. EPA OSW has identified default *TRV* values for the measurement receptors of the seven example food webs (listed in Chapter 4) and the compounds commonly identified in ecological risk assessments for combustion facilities (identified in Chapter 2). Section E-1.0 describes the determination of *TRV* values for surface water, sediment, and soil community measurement receptors in the example food webs. Section E-2.0 describes determination of *TRV* values for wildlife measurement receptors in the example food webs. Tables E-1 through E-8 present the default *TRV* values selected, the basis for selection of each value, and the references evaluated in determination of each value.

TRV values for a limited number of compounds are included in this appendix (see Tables E-1 through E-3) to facilitate the completion of screening ecological risk assessments. However, it is expected that *TRV* values for additional compounds and receptors may be required for evaluation on a site specific basis. In such cases, *TRV* values for these additional compounds could be determined following the same guidance used in determination of the *TRV* values reported in this appendix. For the determination of *TRV* values for measurement receptors not specifically represented in Sections E-1.0 through E-2.0 (e.g., amphibians and reptiles), an approach consistent to that presented in this appendix could be utilized by applying data applicable to those measurement receptors being evaluated.

The default *TRV*s provided in Tables E-1 through E-8 are based on values reported in available scientific literature. Toxicity values identified in secondary reference sources were verified, where possible, by reviewing the primary reference source. As noted in Chapter 5, *TRV* values may change as additional toxicity research is conducted and the availability of toxicity data in the scientific literature increases. As a result, U.S. EPA OSW recommends evaluating the latest toxicity data before completing a risk assessment to ensure that the toxicity data used in the risk assessment is the most current. If more appropriate *TRV* values can be documented, they should be used presented to the respective permitting authority for approval.

*TRV*s were not identified for amphibians and reptiles because of the paucity of toxicological information on these receptors. Additional guidance on determination and use of *TRV* values in the screening level ecological risk assessment is provided in Chapter 5.

E-1.0 *TRVs* FOR COMMUNITY MEASUREMENT RECEPTORS IN SURFACE WATER, SEDIMENT, AND SOIL

TRV values provided in this appendix for community measurement receptors in surface water, sediment, and soil were identified from screening toxicity values developed and/or adopted by federal and/or state regulatory agencies. As discussed in Chapter 5, these screening toxicity values are generally provided in the form of standards, criteria, guidance, or benchmarks. For compounds with no available screening toxicity value, *TRV*s were determined using toxicity values from available scientific literature. The

equilibrium partitioning (EqP) approach was used to compute several sediment *TRV*s. Uncertainty factors (UFs) were applied to toxicity values, as necessary, to meet the *TRV* criteria discussed in Chapter 5. The following sections discuss determination of *TRV* values for community receptors in surface water, sediment, and soil.

Freshwater TRVs Freshwater *TRV*s should be used for freshwater and estuarine ecosystems with a salinity less than 5 parts per thousand. Freshwater *TRV*s, based on the dissolved concentration of the compound in surface water, are listed in Table E-1. *TRV*s were identified using the following hierarchy:

1. Federal chronic ambient water quality criteria (AWQC) calculated for with no final residue value (U.S. EPA 1999; 1996b). Federal AWQC for cadmium, copper, lead, nickel, and zinc were multiplied by a chemical-specific conversion factor to determine a *TRV* based on dissolved concentration (U.S. EPA 1999; 1996b).

2. Final chronic values (FCV) for COPCs for which their AWQC included a final residue value (U.S. EPA 1996b).

3. If inadequate data (insufficient number of families of aquatic life with toxicity data) were available to compute an AWQC or FCV, U.S. EPA (1999; 1996b) also reported secondary chronic values (SCV) calculated using the Tier II method in the Great Lakes Water Quality Initiative (GLWQI) (reported in 40 CFR Part 122). This method is similar to the procedures for calculating an FCV. It uses statistically-derived "adjustment factors" to address deficiencies in available data. The adjustment factor decreases as the number of representative families increases.

4. If an AWQC, FCV, or GLWQI Tier II SCV value were not available, toxicity values cited by U.S. EPA (1987) were identified. These toxicity values represent the lowest available values. Further, additional toxicity values available from the AQUIRE database in U.S. EPA's *ECOTOXicology Database System* (U.S. EPA 1996a) were identified. If collected from a secondary source (such as AQUIRE), original studies were obtained and reviewed for accuracy. The toxicity values reported in Table E-1 represent the lowest (most conservative), ecologically relevant, available value.

5. If toxicity data were unavailable, a surrogate *TRV* from a COPC with a similar structure was identified.

6. If no surrogate was available, a *TRV* was not listed. The potential toxicity of a COPC with no *TRV* should be addressed as an uncertainty (see Chapter 6)

Standard AQUIRE report summaries on tests were screened for duration, endpoint, effect, and concentration. Studies were also screened for ecologically relevant effects by focusing on studies that evaluated effects on survival, reproduction, and growth. Aspects of endpoint, duration, and test organism in each toxicity study were evaluated to identify the most appropriate study. Several compounds, most notably metals, had a large number of toxicity values based on various endpoints, organisms, and exposure durations. In these instances, best scientific judgment was used to identify the most appropriate toxicity value (see Chapter 5).

Chronic NOAEL-based values were not adjusted, but rather were carried through unchanged to become the *TRV*. Toxicity values identified as "less than" a particular concentration were divided by 2 to represent an average value because the true value is unknown, and it occurs between 0 and the noted concentration. *UF*s discussed in Chapter 5 were applied to toxicity values not meeting *TRV* criteria.

Saltwater TRVs Saltwater *TRV*s are applicable to marine water bodies and estuarine systems with a salinity greater than 5 ppt. Saltwater *TRV*s are listed in Table E-2. Saltwater water *TRV* development followed the same procedure as described above for freshwater receptors, except no GLWQI Tier II SCVs were available. In addition, if no saltwater *TRV* for a surrogate compound was available, the corresponding freshwater *TRV* was adopted.

Freshwater Sediment TRVs Freshwater sediment *TRV*s are listed in Table E-3. They are applicable to water bodies with a salinity less than 5 ppt. Freshwater sediment *TRV*s were identified from various sets of screening values and ecotoxicity review documents. The lowest available screening values among the following sources were identified:

1. No effect level (NEL) and lowest effect level (LEL) values from "Ontario's Approach to Sediment Assessment and Remediation" (Persaud et al. 1993)

2. Apparent effects threshold (AET) values for the amphipod, *Hyallela azteca*, reported in "Creation of Freshwater Sediment Quality Database and Preliminary Analysis of Freshwater Apparent Effects Thresholds" (Washington State Department of Ecology 1994)

3. Sediment effect concentrations jointly published by the National Biological Service and the U.S. EPA (Ingersoll et al. 1996).

If a screening value was not available in the sources listed above, toxicity studies and other values compiled and reported by Jones, Hull, and Suter (1997) were reviewed to identify possible *TRV*s. Relevant studies were prioritized based on the criteria listed in Chapter 5, and uncertainty factors were applied, as applicable, based on criteria presented (see Chapter 5).

If a screening or sediment toxicity value was not available for an organic COPC, a freshwater sediment *TRV* was computed, using the EqP approach (see Chapter 5), from the compounds corresponding freshwater *TRV* and K_{oc} value. The U.S. EPA Office of Water utilizes the EqP approach to develop sediment quality criteria for nonionic (neutral) organic chemicals (U.S. EPA 1993). The EqP approach assumes that the toxicity of a compound in sediment is a function of the concentration in pore water and that to be nontoxic, the pore water must meet the surface water final chronic value. The EqP approach also assumes that the concentration of a compound in sediment pore water depends on the carbon content of the sediment and the compound's organic carbon partitioning coefficient (U.S. EPA 1993). A *TRV* may be calculated using the following equation (U.S. EPA 1993):

$$TRV_{sed} = K_{oc} \cdot f_{oc} \cdot TRV_{sw} \qquad \text{Equation E-1}$$

where

TRV_{sed} = Sediment *TRV* (µg/kg)

K_{oc}	=	Organic carbon partition coefficient (L/kg)
f_{oc}	=	Fraction of organic carbon in sediment (unitless)—default value = 4% (0.04)
TRV_{sw}	=	Corresponding surface water *TRV* (µg/L)

Marine Sediment TRVs Marine sediment *TRV*s are listed in Table E-4. They are applicable to sediments of marine water bodies and estuarine systems with a salinity greater than 5 ppt. Marine sediment *TRV*s were developed following the procedures used to identify the freshwater sediment *TRV*s. Screening values were compiled from the following sources:

1. No observed effect level (NOEL) sediment quality assessment guidelines for State of Florida coastal waters (MacDonald 1993).

2. Marine and estuarine effects range low (ERL) values from "Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments" (Long et al. 1995)

3. ERL values from "The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program" (Long and Morgan 1991)

4. Marine sediment quality criteria from "Sediment Management Standards" (Washington State Department of Ecology 1991)

Screening values were adopted directly as *TRV*s. If a screening value was not available in the sources listed above, toxicity values from a search of the scientific literature and those compiled and reported by Hull and Suter (1994) were reviewed to identify possible *TRV*s. Original studies were obtained, where possible, and toxicity values were verified. Relevant studies were prioritized based on the criteria listed in Chapter 5, and uncertainty factors were applied, as appropriate, based on criteria (see Chapter 5). If a screening or ecologically relevant sediment toxicity value from the scientific literature were not available for an organic COPC, a marine sediment *TRV* was computed, using the EqP approach, from the COPC's corresponding saltwater *TRV* and K_{oc} value (see Equation E-1).

Terrestrial Plant TRVs The terrestrial plant *TRV*s listed in Table E-5 are based on bulk soil exposures. Available terrestrial plant toxicity values from the scientific literature were used to develop presented *TRV* values. Toxicity values were first identified from the following secondary sources:

1. Studies cited in *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Terrestrial Plants: 1997 Revision* (Efroymson, Will, Suter, and Wooten 1997). Available studies were obtained and reviewed for accuracy of toxicity values. UFs were applied depending on study endpoint and available information.

2. Toxicity values in the Phytotox database in U.S. EPA's *ECOTOXicology Database* System. Available studies were obtained and toxicity values were verified. UFs were applied depending on study endpoint and available information.

3. Toxicity values in U.S. EPA Region 5 *Ecological Data Quality Levels (EDQL) Database* (PRC 1995). The database contains media-specific EDQLs for the RCRA Appendix IX constituents (40 CFR Part 264). The EDQLs represent conservative media concentrations

protective of media receptors and wildlife that might be exposed through food chains based in these media. Available studies were obtained and toxicity values were verified. UFs were applied depending on study endpoint and available information.

Original studies were obtained, where possible, and prioritized based on criteria listed in Chapter 5. Uncertainty factors were applied, as appropriate, based on criteria (discussed in Chapter 5) to develop *TRV* values. For COPCs without toxicity data, the *TRV* for a surrogate COPC was adopted. If an appropriate surrogate *TRV* was not available, no *TRV* value was identified. Generally, review of toxicity data available in the scientific literature indicates that limited *TRV*s are available for organic compounds; while *TRV*s for metals are available.

Soil Invertebrate TRVs The soil invertebrate *TRV*s listed in Table E-6 are based on bulk soil exposures. Available soil invertebrate toxicity values from the scientific literature were used to develop *TRV*s for these receptors. Soil invertebrate toxicity values were first identified from the following secondary sources:

1. Studies cited in *Toxicological Benchmarks for Potential Contaminants of Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process* (Will and Suter II 1995a). Available studies were obtained and toxicity values were verified. UFs were applied depending on study endpoint and available information.

2. Scientific literature was searched for toxicity values for outstanding compounds. Relevant studies were obtained, toxicity values were verified, and UFs were applied as described.

Original studies were obtained, where possible, and prioritized based on criteria listed in Chapter 5. Uncertainty factors were applied, as appropriate, based on criteria to develop *TRV*s. If no toxicity value was available for a COPC, the *TRV* for a surrogate COPC was adopted.

E-2.0 *TRVs* FOR WILDLIFE MEASUREMENT RECEPTORS

TRV values for wildlife measurement receptors are listed in Tables E-7 (mammals) and E-8 (birds). *TRVs* were not developed for each avian and mammalian measurement receptor in the seven example food webs because of the paucity of species-specific data. Rather, U.S. EPA OSW focused on identifying a set of avian *TRV*s and a set of mammalian *TRV*s for the classes of compounds listed in Section 2.3. U.S. EPA OSW assumed that, among the literature reviewed for a particular guild, the lowest available toxicity value across orders in class Aves and across orders in class Mammalia would provide a conservative estimate of toxicity. Available mammalian and avian toxicity values from the scientific literature were used to develop *TRVs* for these receptors. Also, as previously noted, *TRV* values were not identified for amphibians and reptiles because of the paucity of toxicological information on these receptors. Wildlife measurement receptors *TRV* values were first identified from the following secondary sources:

1. Toxicity values compiled in *Toxicological Benchmarks for Wildlife: 1996 Revision* (Sample, Opresko, and Suter 1996).

2. Toxicity values listed in the Terretox database of U.S. EPA's *ECOTOXicology Database System* (U.S. EPA 1996b) were screened to identify studies potentially meeting the criteria listed in Chapter 5.

Original studies were compiled, where possible, and reviewed to verify their accuracy based on criteria listed in Chapter 5. In many cases, best scientific judgement was used to screen out studies with poor experimental design (see Chapter 5). Uncertainty factors were applied, as appropriate, to develop *TRVs* based on criteria presented in Chapter 5.

Conversions Some avian and mammalian toxicity data are expressed in terms of compound concentration in the food of the test organism. To convert to daily dose, it is necessary to determine the exposure duration and organism body weight. If the study does not report this information, the results should not be used to compute a *TRV*. If information on exposure duration and organism body weight is available, dietary concentration can be computed to dose using the following generic equation:

$$DD = \frac{C \cdot IR}{BW} \qquad \text{Equation E-2}$$

where

DD	=	COPC dose (mg COPC/kg BW/day)
C	=	Concentration of COPC in diet (mg COPC/kg food)
IR	=	Food ingestion rate (kg/day)
BW	=	Test organism body weight (kg)

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U.S. EPA. 1999. *National Recommended Water Quality Criteria-Correction.* EPA 822-Z-99-001. Office of Water. April.

Washington State Department of Ecology. 1991. *Sediment Management Standards.* Washington Administrative Code 173-204.

Washington State Department of Ecology. 1994. *Creation and Analysis of Freshwater Sediment Quality Values in Washington State.* Publication No. 97-32-a. July.

TABLE E-1

FRESHWATER TOXICITY REFERENCE VALUES

(Page 1 of 8)

Compound	Toxicity Value		Uncertainty Factor[b]	TRV[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Polychlorinateddibenzo-p-dioxins (μg/L)					
2,3,7,8-TCDD	Chronic LOEL	0.000038	0.1	0.0000038	Mehrle et al. (1988). 2,3,7,8-TCDD toxicity value for rainbow trout (*Oncorhynchus mykiss*).
Polynuclear aromatic hydrocarbons (PAH) (μg/L)					
Total high molecular weight (HMW) PAHs	--	--	--	0.014	Benzo(a)pyrene toxicity used as surrogate measure of toxicity. This TRV should be used if assessing the risk of total HMW PAHs.
Benzo(a)pyrene	Tier II value	0.014	Not applicable	0.014	U.S. EPA (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Benzo(a)anthracene	Tier II SCV	0.027	Not applicable	0.027	Suter and Tsao (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Benzo(b)fluoranthene	--	--	--	0.027	Toxicity value not available. Benzo(a)anthracene used as surrogate.
Benzo(k)fluoranthene	--	--	--	0.027	Toxicity value not available. Benzo(a)anthracene used as surrogate.
Chrysene	--	--	--	0.027	Toxicity value not available. Benzo(a)anthracene used as surrogate.
Dibenz(a,h)anthracene	--	--	--	0.027	Toxicity value not available. Benzo(a)anthracene used as surrogate.
Indeno(1,2,3-cd)pyrene	--	--	--	0.027	Toxicity value not available. Benzo(a)anthracene used as surrogate.
Polychlorinated biphenyls (PCB) (μg/L)					
Aroclor 1016	--	0.19	Not applicable	0.19	Adopted from U.S. EPA (1996) value for Total PCB. Calculated using Great Lakes Water Quality Initiative Tier II methodology.

TABLE E-1

FRESHWATER TOXICITY REFERENCE VALUES

(Page 2 of 8)

Compound	Toxicity Value		Uncertainty Factor[b]	TRV[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Aroclor 1254	--	0.19	Not applicable	0.19	Adopted from U.S. EPA (1996) value for Total PCB. Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Nitroaromatics (μg/L)					
1,3-Dinitrobenzene	Subchronic NOEC	260	0.1	26	van der Schalie (1983). Algal growth test with *Selenastrum capricornutum*.
2,4-Dinitrotoluene	Chronic LOEL	230	0.1	23	U.S. EPA (1987)
2,6-Dinitrotoluene	Chronic NOEC	60	Not applicable	60	Kuhn et al. (1989). Toxicity value for water flea (*Daphnia magna*).
Nitrobenzene	Acute LOEL	27,000	0.01[e]	270	U.S. EPA (1987)
Pentachloronitrobenzene	LC50	1,000	0.01	10	Hashimoto and Nishiuchi (1981). Toxicity value for common carp (*Cyprinus carpio*).
Phthalate esters (μg/L)					
Bis(2-ethylhexyl)phthalate	Tier II SCV	3.0	Not applicable	3.0	Suter and Tsao (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Di(n)octyl phthalate	Chronic NOEL	320	Not applicable	320	McCarthy and Whitmore (1985). Toxicity value for water flea (*D. magna*).
Volatile organic compounds (μg/L)					
Acetone	Tier II SCV	1,500	Not applicable	1,500	Suter and Tsao (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Acrylonitrile	Chronic LOEL	2,600	0.1	260	U.S. EPA (1987)
Chloroform	Tier II SCV	28	Not applicable	28	Suter and Tsao (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.

TABLE E-1

FRESHWATER TOXICITY REFERENCE VALUES

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Compound	Toxicity Value		Uncertainty Factor[b]	TRV[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Crotonaldehyde	Acute LC50	3,500	0.01	35	Dawson et al. (1977). Toxicity value for bluegill sunfish (*Lepomis macrochirus*).
1,4-Dioxane	Acute EC0	6,210,000	0.01	62,100	Bringmann and Kühn (1982). Toxicity value for water flea (*D. magna*).
Formaldehyde	Acute LC50	4,960	0.01	49.6	Reardon and Harrell (1990). No data available for formalehyde. Formalin containing 37 percent formaldehyde used as a surrogate. Endpoint based on formaldehyde concentration.
Vinyl chloride	Subchronic LC100	388,000	0.01[e]	3,880	Brown et al. (1977)
Other chlorinated organics (μg/L)					
Hexachlorobenzene	Proposed chronic criterion	3.68	Not applicable	3.68	U.S. EPA (1987)
Hexachlorobutadiene	Chronic LOEL	9.3	0.1	0.93	U.S. EPA (1987)
Hexachlorocyclopentadiene	Chronic LOEL	5.2	0.1	0.52	U.S. EPA (1987)
Pentachlorobenzene	Tier II value	0.47	Not applicable	0.47	U.S. EPA (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Pentachlorophenol	Chronic criterion	15	Not applicable	15	U.S. EPA (1999). Value expressed as a function of pH and calculated as follows: TRV = exp(1.005(pH)-5.134). A pH of 7.8 is assumed to calculate the displayed value.
Pesticides (μg/L)					
4,4'-DDE	Acute LOEL	1,050	0.01[e]	10.5	U.S. EPA (1987)
Heptachlor	Chronic criterion	0.0038	Not applicable	0.0038	U.S. EPA (1987)

TABLE E-1

FRESHWATER TOXICITY REFERENCE VALUES

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Compound	Toxicity Value		Uncertainty Factor[b]	TRV[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Hexachlorophene	Subchronic NOEC	8.8	0.1	0.88	Call et al. (1989). Toxicity value for fathead minnow (*P. promelas*).
Inorganics (mg/L) [f]					
Aluminum	FCV	0.087	Not applicable	0.087	U.S. EPA (1988)
Antimony	Proposed chronic criterion	0.03	Not applicable	0.03	U.S. EPA (1987)
Arsenic (trivalent)	Chronic criterion	0.15	Not applicable	0.15	U.S. EPA (1999)
Barium	Tier II SCV	0.004	Not applicable	0.004	Suter and Tsao (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Beryllium	Tier II SCV	0.00066	Not applicable	0.00066	Suter and Tsao (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Cadmium	Chronic criterion	0.0022 (dissolved)	Not applicable	0.0022	U.S. EPA (1999). Value expressed as a function of water hardness and calculated as follows: TRV = exp(m_c[ln(hardness)]+b_c) where m_c = 0.7852 and b_c = -2.715. Criterion was converted to dissolved concentration using the following conversion factor: 1.101672-[(ln hardness)(0.041838]. A assumed hardness of 100 mg/L and a conversion from mg/L to μg/L were used to calculate the displayed value.
Chromium (hexavalent)	Chronic criterion	0.011	Not applicable	0.011	U.S. EPA (1999).
Copper	Chronic criterion	0.009 (dissolved)	Not applicable	0.009	U.S. EPA (1999). Value expressed as a function of water hardness and calculated as follows: TRV = exp(m_c[ln(hardness)]+b_c) where m_c = 0.8545 and b_c = -1.702. Criterion was converted to dissolved concentration using a conversion factor of 0.960. A assumed hardness of 100 mg/L and a conversion from mg/L to μg/L were used to calculate the displayed value.

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FRESHWATER TOXICITY REFERENCE VALUES

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Compound	Toxicity Value		Uncertainty Factor[b]	TRV[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Total Cyanide	Chronic criterion	0.0052	Not applicable	0.0052	U.S. EPA (1999). This value is expressed as mg free cyanide (as CN)/L.
Lead	Chronic criterion	0.0025 (dissolved)	Not applicable	0.0025	U.S. EPA (1999). Value expressed as a function of water hardness and calculated as follows: TRV = $\exp(m_c[\ln(\text{hardness})]+b_c)$ where $m_c = 1.273$ and $b_c = -4.705$. Criterion was converted to dissolved concentration using the following conversion factor: 1.46203-[(ln hardness)(0.145712]. A assumed hardness of 100 mg/L and a conversion from mg/L to μg/L were used to calculate the displayed value.
Mercuric chloride	Chronic criterion	0.00077	Not applicable	0.00077	U.S. EPA (1999). This value was from data for inorganic mercury (II).
Methyl mercury	Tier II SCV	0.0000028	Not applicable	0.0000028	Suter and Tsao (1996). Calculated using Great Lakes Water Quality Initiative Tier II methodology.
Nickel	Chronic criterion	0.052 (dissolved)	Not applicable	0.052	U.S. EPA (1999). Value expressed as a function of water hardness and calculated as follows: TRV = $\exp(m_c[\ln(\text{hardness})]+b_c)$ where $m_c = 0.8460$ and $b_c = 0.0584$. Criterion was converted to dissolved concentration using a conversion factor of 0.997. A assumed hardness of 100 mg/L and a conversion from mg/L to μg/L were used to calculate the displayed value.
Selenium	Chronic criterion	0.005	Not applicable	0.005	U.S. EPA (1999)
Silver	Proposed chronic criterion	0.00012	Not applicable	0.00012	U.S. EPA (1987)
Thallium	Chronic LOEL	0.04	0.1	0.004	U.S. EPA (1987)

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Compound	Toxicity Value		Uncertainty Factor[b]	TRV[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Zinc	Chronic criterion	0.118 (dissolved)	Not applicable	0.118	U.S. EPA (1999). Value expressed as a function of water hardness and calculated as follows: TRV = $\exp(m_c[\ln(\text{hardness})]+b_c)$ where $m_c = 0.8473$ and $b_c = 0.884$. Criterion was converted to dissolved concentration using a conversion factor of 0.986. A assumed hardness of 100 mg/L and a conversion from mg/L to μg/L were used to calculate the displayed value.

Notes:

a The duration of exposure is defined as chronic if it represents about 10 percent or more of the test animals lifetime expectancy. Acute exposures represent single exposures or multiple exposures occurring within a short time. For evaluating exposure duration, the following general guidelines were used. For invertebrates and other lower trophic level aquatic biota: (1) chronic duration lasted for 7 or more days, (2) subchronic duration lasted from 3 to 6 days, and (3) acute duration lasted 2 days or less. For fish: (1) chronic duration lasted for more than 90 days, (2) subchronic duration lasted from 14 to 90 days, and (3) acute duration lasted less than 2 weeks.

b Uncertainty factors are used to extrapolate a toxicity value to a chronic NOAEL TRV. See Chapter 5 (Section 5.4) of the SLERAP for a discussion of the use of uncertainty factors.

c TRV was calculated by multiplying the toxicity value with the uncertainty factor.

d The references refer to the source of the toxicity value. Complete reference citations are provided below.

e Best scientific judgment used to identify uncertainty factor. See Chapter 5 (Section 5.4.1.2) for a discussion the use of best scientific judgement. Factors evaluated include test duration, ecological relevance of endpoint, experimental design, and availability of toxicity data.

f TRVs for metals are based on the dissolved metal concentration. According to U.S. EPA (1993) policy, concentrations of dissolved metal more closely approximate the bioavailable fraction of metal in the water column.

EC0 = Effective concentration for zero percent of the test organisms.
FCV = Final Chronic Value
HMW = High molecular weight
LC50 = Lethal concentration for 50 percent of the test organisms.
LC100 = Lethal concentration for 100 percent of the test organisms.
LOEL = Lowest Observed Effect Level
NOEC = No Observed Effect Concentration
NOEL = No Observed Effect Level
SCV = Secondary Chronic Value
TRV = Toxicity Reference Value

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FRESHWATER TOXICITY REFERENCE VALUES

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TABLE E-2

MARINE/ESTUARINE SURFACE WATER TOXICITY REFERENCE VALUES

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Compound	Toxicity Value		Uncertainty Factor[b]	Toxicity Reference Value[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Polychlorinateddibnzo-p-dioxins (μg/L)					
2,3,7,8-TCDD	LOEC	0.000038	0.1	0.0000038	No saltwater data were available, therefore, corresponding freshwater toxicity value was used (rainbow trout, *Oncorhynchus mykiss*) from Mehrle et al. (1988). 2,3,4,5-TCDD toxicity value used.
Polynuclear aromatic hydrocarbons (PAH) (μg/L)					
Total high molecular weight (HMW) PAHs	Acute LC50	>50	0.01[e]	0.5	Rossi and Neff (1978) evaluated toxicity of three HMW (three or more aromatic rings) PAHs to the polychaete, *Neanthes arenaceodentata*. LC50 of each HMW PAH exceeded 50 μg/L. This TRV should be used if assessing the risk of total HMW PAHs.
Benzo(a)pyrene	Acute LC50	>50	0.01[e]	0.5	Rossi and Neff (1978). Toxicity value for polychaete (*N. arenaceodentata*).
Benzo(a)anthracene	Acute LC50	>50	0.01[e]	0.5	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Benzo(b)fluoranthene	Acute LC50	>50	0.01[e]	0.5	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Benzo(k)fluoranthene	Acute LC50	>50	0.01[e]	0.5	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Chrysene	Acute LC50	>50	0.01[e]	0.5	Rossi and Neff (1978). Toxicity of several PAHs was evaluted. LC50 of each individual HMW PAH exceeded 50 μg/L.
Dibenz(a,h)anthracene	Acute LC50	>50	0.01[e]	0.5	Rossi and Neff (1978). Toxicity of several PAHs was evaluted. LC50 of individual HMW PAHs exceeded 50 μg/L.
Indeno(1,2,3-cd)pyrene	Acute LC50	>50	0.01[e]	0.5	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Polychlorinated biphenyls (PCB) (μg/L)					
Aroclor 1016	--	0.03	Not applicable	0.03	U.S. EPA (1987) chronic criterion for ambient water quality.

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MARINE/ESTUARINE SURFACE WATER TOXICITY REFERENCE VALUES

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Compound	Toxicity Value		Uncertainty Factor[b]	Toxicity Reference Value[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Aroclor 1254	--	0.03	Not applicable	0.03	U.S. EPA (1987) chronic criterion for ambient water quality.
Nitroaromatics (μg/L)					
1,3-Dinitrobenzene	--	--	--	66.8	Toxicity data not available. TRV for nitrobenzene used as surrogate.
2,4-Dinitrotoluene	Chronic criterion	370	Not applicable	370	U.S. EPA (1987)
2,6-Dinitrotoluene	--	--	--	370	Toxicity data not available. TRV for 2,4-dinitrotoluene used as surrogate.
Nitrobenzene	Acute criterion	6,680	0.01	66.8	U.S. EPA (1987)
Pentachloronitrobenzene	Acute LC50	1,000	0.01	10	No toxicity value or surrogate TRV available, therefore, corresponding freshwater toxicity value (common carp, *Cyprinus carpio*) from Hashimoto and Nishiuchi (1981) adopted.
Phthalate esters (μg/L)					
Bis(2-ethylhexyl)phthalate	Acute LC50	>170	0.01	1.7	Adams et al. (1995). Toxicity value for sheepshead minnow (*Cyprinodon variegatus*).
Di(n)octyl phthalate	NOEL	320	Not applicable	320	No toxicity value or surrogate TRV available, therefore, corresponding freshwater toxicity value used (water flea, *D. magna*) from McCarthy and Whitmore (1985).
Volatile organic compounds (μg/L)					
Acetone	Acute LC50	2,100,000	0.01	21,000	Price et al. (1974). Toxicity value for brine shrimp (*Artemia* sp.).
Acrylonitrile	Acute LC50	10,000	0.01	100	Portmann and Wilson (1971). Toxicity value for common shrimp (*Crangon crangon*).

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MARINE/ESTUARINE SURFACE WATER TOXICITY REFERENCE VALUES

(Page 3 of 8)

Compound	Toxicity Value		Uncertainty Factor[b]	Toxicity Reference Value[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Chloroform	Acute LC 50	18,000	0.01	180	Anderson and Luster (1980). Toxicity value for Rainbow trout (*Salmo gairdnari*).
Crotonaldehyde	Acute LC50	1,300	0.01	13	Dawson et al. (1977). Toxicity value for inland silverside (*Menidia beryllina*).
1,4-Dioxane	Acute LC50	6,700,000	0.01	67,000	Dawson et al. (1977). Toxicity value for inland silverside (*M. beryllina*).
Formaldehyde	Acute LC50	4,960	0.01	49.6	No toxicity value or surrogate TRV available for this constituent, therefore, corresponding freshwater toxicity value used (Striped bass, *Morone saxatilis*) from Reardon and Harell (1990). No data available for formadehyde. Formalin containing 37 percent formaldehyde used as surrogate. TRV expressed on formaldehyde basis.
Vinyl chloride	Subchronic LC100	388,000	0.01[e]	3,880	No toxicity value of surrogate TRV available, therefore, corresponding freshwater toxicity value used (Northern pike, *Esox lucius*) from Brown et al. (1977).
Other chlorinated organics (μg/L)					
Hexachlorobenzene	Acute EC50	>1,000	0.01	10	Zaroogian (1981). Toxicity value for American oyster (*Crassostrea virginica*).
Hexachlorobutadiene	Acute LOEL	32	0.01[e]	0.32	U.S. EPA (1987)
Hexachlorocyclopentadiene	Acute LOEL	7.0	0.01[e]	0.07	U.S. EPA (1987)
Pentachlorobenzene	Subchronic NOEC	18	0.1	1.8	Hansen and Cripe (1991). Toxicity value for sheepshead minnow (*Cyprinodon variegatus*).
Pentachlorophenol	Chronic criterion	7.9	Not applicable	7.9	U.S. EPA (1987)
Pesticides (μg/L)					

TABLE E-2

MARINE/ESTUARINE SURFACE WATER TOXICITY REFERENCE VALUES

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Compound	Toxicity Value		Uncertainty Factor[b]	Toxicity Reference Value[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
4,4'-DDE	Acute LOEL	14	0.01[e]	0.14	U.S. EPA (1987)
Heptachlor	Chronic criterion	0.0036	Not applicable	0.0036	U.S. EPA (1987)
Hexachlorophene	Acute LC50	3.3	0.01	0.033	Calleja et al. (1994). Toxicity value for brine shrimp (*Artemia salina*).
Inorganics (mg/L)					
Aluminum	Acute LT50	0.271	0.01	0.00271	Study examined influence of pH and temperature on acute (48-hour) toxicity (as time to mortality) of aluminum to smoltifying Atlantic salmon (*Salmo salar*). Endpoint concentration based on sum of inorganic and organic aluminum for exposure at pH 6.5 (Poleo and Muniz 1993).
Antimony	Proposed chronic criterion	0.5	Not applicable	0.5	U.S. EPA (1987)
Arsenic (trivalent)	Chronic criterion	0.036	Not applicable	0.036	U.S. EPA (1987)
Barium	Subchronic LC50	>500.	0.01[e]	5.0	U.S. EPA (1978)
Beryllium	Tier II SCV	0.00066	Not applicable	0.00066	No toxicity value or surrogate TRV available, therefore, corresponding freshwater TRV adopted. Suter and Tsao (1996); value calculated using Great Lakes Water Quality Initiative Tier II methodology.
Cadmium	Chronic criterion	0.0093	Not applicable	0.0093	U.S. EPA (1987)
Chromium (hexavalent)	Chronic criterion	0.05	Not applicable	0.05	U.S. EPA (1987)
Copper	Chronic criterion	0.0031	Not applicable	0.0031	U.S. EPA 1999. When the concentration of dissolved organic carbon is elevated, copper is substantially less toxic and use of a water effects ratio may be appropriate.

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MARINE/ESTUARINE SURFACE WATER TOXICITY REFERENCE VALUES

(Page 5 of 8)

Compound	Toxicity Value		Uncertainty Factor[b]	Toxicity Reference Value[c]	Reference and Notes [d]
	Duration and Endpoint[a]	Concentration			
Total Cyanide	Chronic criterion	0.001	Not applicable	0.001	U.S. EPA (1987)
Lead	Chronic criterion	0.0081	Not applicable	0.0081	U.S. EPA (1999)
Mercuric chloride	Chronic criterion	0.00094	Not applicable	0.00094	U.S. EPA (1999). This value was from data for inorganic mercury (II).
Methyl mercury	Subchronic NOAEL	0.030	0.1	0.003	Sharp and Neff (1982). Toxicity value for mummichog (*Fundulus heteroclitus*).
Nickel	Chronic criterion	0.0082	Not applicable	0.0082	U.S. EPA (1999)
Selenium	Chronic criterion	0.071	Not applicable	0.071	U.S. EPA (1987)
Silver	Chronic criterion/ proposed criterion	0.0023	Not applicable	0.0023	U.S. EPA (1987)
Thallium	Acute LOEL	2.13	0.01[e]	0.02	U.S. EPA (1987)
Zinc	Chronic criterion	0.081	1.0	0.081	U.S. EPA (1999)

TABLE E-2

MARINE/ESTUARINE SURFACE WATER TOXICITY REFERENCE VALUES

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Notes:

a The duration of exposure is defined as chronic if it represents about 10 percent or more of the test animals lifetime expectancy. Acute exposures represent single exposures or multiple exposures occurring within a short time. For evaluating exposure duration, the following general guidelines were used. For invertebrates and other lower trophic level aquatic biota: (1) chronic duration lasted for 7 or more days, (2) subchronic duration lasted from 3 to 6 days, and (3) acute duration lasted 2 days or less. For fish: (1) chronic duration lasted for more than 90 days, (2) subchronic duration lasted from 14 to 90 days, and (3) acute duration lasted less than 2 weeks.

b Uncertainty factors are used to extrapolate a toxicity value to a chronic NOAEL TRV. See Chapter 5 (Section 5.4) of the SLERAP for a discussion of the use of uncertainty factors.

c TRV was calculated by multiplying the toxicity value with the uncertainty factor.

d The references refer to the source of the toxicity value. Complete reference citations are provided at the end of this appendix.

e Best scientific judgment used to identify uncertainty factor. See Chapter 5 (Section 5.4.1.2) for a discussion of the use of best scientific judgement. Factors evaluated include test duration, ecological relevance of endpoint, experimental design, and availability of toxicity data.

EC50 = Effective concentration for 50 percent of the test organisms.
FCV = Final Chronic Values
HMV = High molecular weight
LC50 = Lethal concentration for 50 percent of the test organisms.
LC100 = Lethal concentration for 100 percent of the test organisms.
LOEC = Lowest Observed Effect Concentration
LOEL = Lowest Observed Effect Level
LT50 = Lethal threshold concentration for 50 percent of the test organisms.
NOAEL = No Observed Adverse Effect Level
NOEL = No Observed Effect Level
SCV = Secondary Chronic Value
TRV = Toxicity Reference Value

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MARINE/ESTUARINE SURFACE WATER TOXICITY REFERENCE VALUES

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TABLE E-2

MARINE/ESTUARINE SURFACE WATER TOXICITY REFERENCE VALUES

(Page 8 of 8)

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TABLE E-3

FRESHWATER SEDIMENT TOXICITY REFERENCE VALUES

(Page 1 of 7)

Compound	Freshwater TRV [a]	K_{oc} Value [b]	Bed Sediment TRV (dry weight)	Reference and Notes [c]
Polychlorinateddibenzo-p-dioxins (μg/kg)				
2,3,7,8-TCDD	0.0000038	2,691,535	0.41	TRV was calculated using equilibrium partitioning (EqP) approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Polynuclear aromatic hydrocarbons (PAH) (μg/kg)				
Total high molecular weight (HMW) PAH	Not applicable	Not applicable	170	TRV is ERL value computed by Ingersoll et al. (1996) based on 28-day amphipod (*Hyalella azteca*) toxicity tests. This TRV may be used if risk of total HMW PAHs is assessed.
Benzo(a)pyrene	Not applicable	Not applicable	84	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Benzo(a)anthracene	Not applicable	Not applicable	19	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Benzo(b)fluoranthene	Not applicable	Not applicable	37	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Benzo(k)fluoranthene	Not applicable	Not applicable	37	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Chrysene	Not applicable	Not applicable	30	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Dibenz(a,h)anthracene	Not applicable	Not applicable	10	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Indeno(1,2,3-cd)pyrene	Not applicable	Not applicable	30	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.

TABLE E-3

FRESHWATER SEDIMENT TOXICITY REFERENCE VALUES

(Page 2 of 7)

Compound	Freshwater TRV [a]	K_{oc} Value [b]	Bed Sediment TRV (dry weight)	Reference and Notes [c]
Polychlorinated biphenyls (PCB) (μg/kg)				
Aroclor 1016	Not applicable	Not applicable	50	TRV is an ERL value for Total PCB calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Aroclor 1254	Not applicable	Not applicable	50	TRV is an ERL value for Total PCB calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Nitroaromatics (μg/kg)				
1,3-Dinitrobenzene	26	20.6	21.4	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
2,4-Dinitrotoluene	23	51	46.9	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
2,6-Dinitrotoluene	60	41.9	100.6	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Nitrobenzene	270	119	1285.2	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Pentachloronitrobenzene	10	5,890	2356	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Phthalate esters (μg/kg)				
Bis(2-ethylhexyl)phthalate	3	111,000	1.33×10^{4}	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Di(n)octyl phthalate	320	9.03×10^{8}	1.16×10^{10}	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]

TABLE E-3

FRESHWATER SEDIMENT TOXICITY REFERENCE VALUES

(Page 3 of 7)

Compound	Freshwater TRV [a]	K_{oc} Value [b]	Bed Sediment TRV (dry weight)	Reference and Notes [c]
Volatile organic compounds (μg/kg)				
Acetone	1,500	0.951	57.1	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Acrylonitrile	260	2.22	23.1	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Chloroform	28	53.0	59.4	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Crotonaldehyde	35	Not available	Not calculated	No TRV was calculated because no K_{oc} or K_{ow} values were identified for this constituent.
1,4-Dioxane	62,100	0.876	2176.0	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Formaldehyde	49.6	2.62	5.2	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Vinyl chloride	3,880	11.1	1722.7	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Other chlorinated organics (μg/kg)				
Hexachlorobenzene	Not applicable	Not applicable	20	TRV is an LEL value (Persaud et al. 1993).
Hexachlorobutadiene	0.93	6,940	258.2	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Hexachlorocyclopentadiene	0.52	9,510	197.8	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]

TABLE E-3

FRESHWATER SEDIMENT TOXICITY REFERENCE VALUES

(Page 4 of 7)

Compound	Freshwater TRV [a]	K_{oc} Value [b]	Bed Sediment TRV (dry weight)	Reference and Notes [c]
Pentachlorobenzene	0.47	32,148	604.4	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Pentachlorophenol	Not applicable	Not applicable	7,000	TRV is an AET value for *H. azteca* (Washington State Department of Ecology 1994).
Pesticides (μg/kg)				
4,4'-DDE	Not applicable	Not applicable	5	TRV is an LEL value (Persaud et al. 1993). p,p'-DDE used as a surrogate.
Heptachlor	Not applicable	Not applicable	0.3	TRV is an NEL value (Persaud et al. 1993). The NEL was selected because no LEL was available.
Hexachlorophene	0.88	1,800,000	63,360	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Inorganics (mg/kg)				
Aluminum	Not applicable	Not applicable	14,000	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.
Antimony	Not applicable	Not applicable	64.0	TRV is an AET for *H. azteca* (Washington State Department of Ecology 1994).
Arsenic	Not applicable	Not applicable	6.0	TRV is an LEL value (Persaud et al. 1993).
Barium	Not applicable	Not applicable	20	TRV is a U.S. EPA Region 5 guideline value for classification of sediments for determining the suitability of dredged sediments for open water disposal, as cited in Hull and Suter II (1994).
Beryllium	Not applicable	Not applicable	Not available	Regulatory or toxicity value not available.
Cadmium	Not applicable	Not applicable	0.6	TRV is an LEL value (Persaud et al. 1993).

TABLE E-3

FRESHWATER SEDIMENT TOXICITY REFERENCE VALUES

(Page 5 of 7)

Compound	Freshwater TRV [a]	K_{oc} Value [b]	Bed Sediment TRV (dry weight)	Reference and Notes [c]
Chromium (total)	Not applicable	Not applicable	26	TRV is an LEL value (Persaud et al. 1993).
Copper	Not applicable	Not applicable	16	TRV is an LEL value (Persaud et al. 1993).
Total Cyanide	Not applicable	Not applicable	0.1	TRV is a U.S. EPA Region 5 guideline value for classification of sediments for determining the suitability of dredged sediments for open water disposal, as cited in Hull and Suter II (1994).
Lead	Not applicable	Not applicable	31	TRV is an LEL value (Persaud et al. 1993).
Mercuric chloride	Not applicable	Not applicable	0.2	No toxicity data available for divalent inorganic mercury. Total mercury used as surrogate for divalent inorganic mercury. TRV is an LEL value (Persaud et al. 1993).
Methyl mercury	Not applicable	Not applicable	0.2	No toxicity data available for methyl mercury. Total mercury used as surrogate for methylmercury. TRV is an LEL value (Persaud et al. 1993).
Nickel	Not applicable	Not applicable	16	TRV is an LEL value (Persaud et al. 1993).
Selenium	Not applicable	Not applicable	0.1	TRV is an AET for *H. azteca* (Washington State Department of Ecology 1994).
Silver	Not applicable	Not applicable	4.5	TRV is an AET for *H. azteca* (Washington State Department of Ecology 1994).
Thallium	Not applicable	Not applicable	Not available	Regulatory value or toxicity value not available.
Zinc	Not applicable	Not applicable	110	TRV is an ERL value calculated by Ingersoll et al. (1996) based on 28-day *H. azteca* toxicity tests.

TABLE E-3

FRESHWATER SEDIMENT TOXICITY REFERENCE VALUES

(Page 6 of 7)

Notes:

a Toxicity reference values are in units of micrograms per kilogram (μg/kg) and milligrams per kilograms (mg/kg) for organic and inorganic constituents, respectively.

b Values are in units of liters per kilogram (L/kg). K_{oc} = Organic carbon normalized sorption coefficient. References and equations used to calculate K_{oc} values are provided in Appendix A.

c The references refer to the study from which the TRV was identified. Complete reference citations are provided below.

d Freshwater sediment TRV calculated with the following equation:

$$\text{Freshwater sediment TRV} = \text{Freshwater TRV (Table E-1)} * K_{oc} * f_{oc,bs}$$

where,

K_{oc} = organic carbon partition coefficient, and

$f_{oc,bs}$= fraction of organic carbon in bed sediment, assumed to be 4 percent = 0.04.

K_{oc} values discussed in Appendix A.

AET = Apparent Effects Threshold
ERL = Effects Range-Low
EqP = Equilibrium Partitioning
HMV = High molecular weight
LEL = Lowest Effect Level
NEL = No Effect Level
TRV = Toxicity Reference Value

TABLE E-3

FRESHWATER SEDIMENT TOXICITY REFERENCE VALUES

(Page 7 of 7)

REFERENCES

Default TRVs for sediments in freshwater habitats were identified from the three sets of freshwater toxicity values presented below. While some compound-specific freshwater sediment toxicity information is available in the scientific literature, available toxicity values were not used because of the compexity in understanding the role of naturally-occurring sediment features (such as grain size, ammonia, sulfide, soil type, and organic carbon content) in toxicity to benthic invertebrates. Among these sets of value, the lowest available toxicity value for a particular compound was adopted as the TRV. In many cases, a default TRV was calculated from the corresponding freshwater TRV using EPA's equilibrium partitioning approach, assuming a 4 percent organic carbon content.

Hull, R.N. and G.W. Suter II. 1994. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1994 Revision.* ES/ER/TM-95/R1. Environmental Sciences Division, Oak Ridge National Laboratory. Oak Ridge, Tennessee. June.

Ingersoll, C.G., P.S. Haverland, E.L. Brunson, T.J. Canfield, F.J. Dwyer, C.E. Henke, N.E. Kemble, D.R. Mount, and R.G. Fox. 1996. "Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod *Hyallela azteca* and the Midge *Chironomous riparius*." *International Association of Great Lakes Research.* Volume 22. Pages 602-623.

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TABLE E-4

MARINE/ESTUARINE SEDIMENT TOXICITY REFERENCE VALUES

(Page 1 of 8)

Compound	Marine/Estuarine Surface Water TRV[a]	K_{oc} Value[b]	Bed Sediment TRV (dry weight)	Reference and Notes[c]
Ploychlorinateddibenzo-p-dioxins (μg/kg)				
2,3,7,8-TCDD	0.0000038	2,691,535	0.41	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04.[d]
Polynuclear aromatic hydrocarbons (PAH) (μg/kg)				
Total high molecular weight (HMW) PAH	Not applicable	Not applicable	870	Recommended NOEL for Florida Department of Environmental Regulation (DER) (MacDonald 1993). This TRV may be used in risk of total HMW PAHs is assessed.
Benzo(a)pyrene	Not applicable	Not applicable	230	Recommended NOEL for Florida DER (MacDonald 1993).
Benzo(a)anthracene	Not applicable	Not applicable	160	Recommended NOEL for Florida DER (MacDonald 1993).
Benzo(b)fluoranthene	0.5	836,000	418,000	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04.[d]
Benzo(k)fluoranthene	Not applicable	Not applicable	240	TRV is a LEL value from Persaud et al. (1993).
Chrysene	Not applicable	Not applicable	220	Recommended NOEL for Florida DER (MacDonald 1993).
Dibenz(a,h)anthracene	Not applicable	Not applicable	31	Recommended NOEL for Florida DER (MacDonald 1993).
Indeno(1,2,3-cd)pyrene	Not applicable	Not applicable	1,360	TRV was computed from OC-based marine sediment quality criterion from Washington State Department of Ecology (1991) and fractional organic carbon content of 0.04, as follows: TRV = 34 mg/kg * 0.04 * 1000 μg/mg.

TABLE E-4

MARINE/ESTUARINE SEDIMENT TOXICITY REFERENCE VALUES

(Page 2 of 8)

Compound	Marine/Estuarine Surface Water TRV[a]	K_{oc} Value[b]	Bed Sediment TRV (dry weight)	Reference and Notes[c]
Polychlorinated biphenyls (PCB) (μg/kg)				
Aroclor 1016	Not applicable	Not applicable	22.7	TRV is an ERL value for Total PCB from Long et al. (1995).
Aroclor 1254	Not applicable	Not applicable	22.7	TRV is an ERL value for Total PCB from Long et al. (1995).
Nitroaromatics (μg/kg)				
1,3-Dinitrobenzene	66.8	20.6	55.0	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04.[d]
2,4-Dinitrotoluene	370	51	754.8	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04.[d]
2,6-Dinitrotoluene	370	41.9	620.1	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04.[d]
Nitrobenzene	66.8	119	318.0	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04.[d]
Pentachloronitrobenzene	10	5,890	2356	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04.[d]

TABLE E-4

MARINE/ESTUARINE SEDIMENT TOXICITY REFERENCE VALUES

(Page 3 of 8)

Compound	Marine/Estuarine Surface Water TRV[a]	K_{oc} Value[b]	Bed Sediment TRV (dry weight)	Reference and Notes[c]
Phthalate esters (μg/kg)				
Bis(2-ethylhexyl)phthalate	Not applicable	Not applicable	470	TRV was calculated using OC-based marine sediment quality criterion from Washington State Department of Ecology (1991) and fractional organic carbon content of 0.04, as follows: TRV = 47 mg/kg * 0.04 * 1000 μg/mg.
Di(n)octyl phthalate	Not applicable	Not applicable	580	TRV was calculated using OC-based marine sediment quality criterion from Washington State Department of Ecology (1991) and fractional organic carbon content of 0.04, as follows: TRV = 58 mg/kg * 0.04 * 1000 μg/mg.
Volatile organic compounds (μg/kg)				
Acetone	21,000	0.951	798.8	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Acrylonitrile	100	2.22	8.88	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Chloroform	180	53.0	381.6	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Crotonaldehyde	13	Not available	Not computed	No TRV was calculated because no K_{oc} or K_{ow} value was identified.
1,4-Dioxane	67,000	0.876	2348	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Formaldehyde	49.6	2.62	5.2	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]

TABLE E-4

MARINE/ESTUARINE SEDIMENT TOXICITY REFERENCE VALUES

(Page 4 of 8)

Compound	Marine/Estuarine Surface Water TRV[a]	K_{oc} Value[b]	Bed Sediment TRV (dry weight)	Reference and Notes[c]
Vinyl chloride	3,880	11.1	1722.7	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Other chlorinated organics (μg/kg)				
Hexachlorobenzene	Not applicable	Not applicable	15.2	TRV was calculated using OC-based marine sediment quality criterion from Washington State Department of Ecology (1991) and a fractional OC content of 0.04, as follows: TRV = 0.38 mg/kg * 0.04 * 1000 μg/mg.
Hexachlorobutadiene	Not applicable	Not applicable	156	TRV was calculated using OC-based marine sediment quality criterion from Washington State Department of Ecology (1991) and a fractional OC content of 0.04, as follows: TRV = 3.9 mg/kg * 0.04 * 1000 μg/mg.
Hexachlorocyclopentadiene	0.07	9,510	26.6	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Pentachlorobenzene	1.8	32,148	2315	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Pentachlorophenol	Not applicable	Not applicable	360	TRV is marine sediment quality criterion from Washington State Department of Ecology (1991).
Pesticides (μg/kg)				
4,4'-DDE	Not applicable	Not applicable	1.7	Recommended NOEL for p,p'-DDE for Florida DER (MacDonald 1993).
Heptachlor	0.0036	9,530	1.37	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]
Hexachlorophene	0.033	1,800,000	2376	TRV was calculated using EqP approach (EPA 1993), assuming a fractional organic content of 0.04. [d]

TABLE E-4

MARINE/ESTUARINE SEDIMENT TOXICITY REFERENCE VALUES

(Page 5 of 8)

Compound	Marine/Estuarine Surface Water TRV[a]	K_{oc} Value[b]	Bed Sediment TRV (dry weight)	Reference and Notes[c]
Inorganics (mg/kg)				
Aluminum	Not applicable	Not applicable	Not available	Screening or toxicity value not available.
Antimony	Not applicable	Not applicable	2	TRV is an ERL value (Long and Morgan 1991).
Arsenic	Not applicable	Not applicable	6	TRV is an LEL value for Province of Ontario (Persaud et al. 1993).
Barium	Not applicable	Not applicable	20	TRV is a U.S. EPA Region 5 guideline value for classification of sediments for determining the suitability of dredged material for open water disposal, as cited in Hull and Suter II (1994).
Beryllium	Not applicable	Not applicable	Not available	Screening or toxicity value not available.
Cadmium	Not applicable	Not applicable	1.0	Recommended NOEL for Florida DER (MacDonald 1993).
Chromium (hexavalent)	Not applicable	Not applicable	8.1	TRV is an ERL value for total chromium (Long et al. 1995).
Copper	Not applicable	Not applicable	28	Recommended NOEL for Florida DER (MacDonald 1993).
Total Cyanide	Not applicable	Not applicable	0. 1	TRV is a U.S. EPA Region V guideline value for classification of sediments for determining the suitability of dredged material for open water disposal, as cited in Hull and Suter II (1994).

TABLE E-4

MARINE/ESTUARINE SEDIMENT TOXICITY REFERENCE VALUES

(Page 6 of 8)

Compound	Marine/Estuarine Surface Water TRV[a]	K_{oc} Value[b]	Bed Sediment TRV (dry weight)	Reference and Notes[c]
Lead	Not applicable	Not applicable	21.0	Recommended NOEL for Florida DER (MacDonald 1993).
Mercuric chloride	Not applicable	Not applicable	0.1	No toxicity data available for divalent inorganic mercury. Total mercury is used as surrogate. Recommended NOEL for Florida DER (MacDonald 1993).
Methyl mercury	Not applicable	Not applicable	0.1	No toxicity data available for methyl mercury. Total mercury is used as surrogate. Recommended NOEL for Florida DER (MacDonald 1993).
Nickel	Not applicable	Not applicable	20.9	TRV is an ERL value (Long et al. 1995).
Selenium	Not applicable	Not applicable	Not Available	Screening or toxicity value not available.
Silver	Not applicable	Not applicable	0.5	Recommended NOEL for Florida DER (MacDonald 1993).
Thallium	Not appliable	Not applicable	Not available	Screening or toxicity value not available.
Zinc	Not applicable	Not applicable	68	Recommended NOEL for Florida DER (MacDonald 1993).

TABLE E-4

MARINE/ESTUARINE SEDIMENT TOXICITY REFERENCE VALUES

(Page 7 of 8)

Notes:

a Sediment TRVs are in units of micrograms per kilogram (μg/kg) and milligrams per kilograms (mg/kg) for organic and inorganic constituents, respectively.
b Values are in units of liters per kilogram (L/kg). K_{oc} = Organic carbon normalized sorption coefficient. References and equations used to calculate values are provided in Appendix A.
c The references refer to the study or studies from which the endpoint and concentrations were identified. Complete reference citations are provided below.
d Sediment TRV calculated with the following equation:

Sediment TRV = Marine/estuarine surface water TRV (Table E-2) * K_{oc} * $f_{oc,bs}$

where,

K_{oc} = organic carbon partition coefficient, and
$f_{oc,bs}$= fraction of organic carbon in bed sediment, assumed to be 1 percent = 0.01.

K_{oc} values are discussed in Appendix A.

EqP = Equilibrium Partitioning
ERL = Effects Range-Low
HMW = High molecular weight
LEL = Lowest Effect Level
NOEL = No Observed Effect Level
TRV = Toxicity Reference Value

TABLE E-4

MARINE/ESTUARINE SEDIMENT TOXICITY REFERENCE VALUES

(Page 8 of 8)

REFERENCES

Default TRVs for sediments in marine and estuarine habitats were identified from several sets of toxicity values (standards, benchmarks, and guidelines) presented below. While some compound-specific marine/estuarine sediment toxicity information is available in the scientific literature, available toxicity values were not used because of the compexity in understanding the role of naturally-occurring sediment features (such as grain size, ammonia, sulfide, soil type, and organic carbon content) in toxicity to benthic invertebrates. Among these sets of value, the lowest available toxicity value for a particular compound was adopted as the TRV. In many cases, a default TRV was calculated from the corresponding freshwater TRV using EPA's equilibrium partitioning approach, assuming a 4 percent organic carbon content.

Hull, R.N. and G.W. Suter II. 1994. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1994 Revision.* ES/ER/TM-95/R1. Environmental Sciences Division, Oak Ridge National Laboratory. Oak Ridge, Tennessee. June.

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TABLE E-5

TERRESTRIAL PLANT TOXICITY REFERENCE VALUES

(Page 1 of 15)

Compound	Basis for TRV				TRV [c]	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Concentration	Uncertainty Factor [b]		
Polychlorinateddibenzo-p-dioxins (μg/kg)						
2,3,7,8-TCDD	--	--	--	--	--	Toxicity value not identified.
Polynuclear aromatic hydrocarbons (PAH) (μg/kg)						
Total high molecular weight (HMW) PAH	Chronic NOAEL	Wheat	1,200	Not applicable	1,200	Benzo(a)pyrene toxicity used as representative toxicity of all HMW PAHs. This TRV may be used to characterize risk of total HMW PAHs to terrestrial plants.
Benzo(a)pyrene	Chronic NOAEL	Wheat	1,200	Not applicable	1,200	Sims and Overcash (1983)
Benzo(a)anthracene	Not available	--	--	--	1,200	Toxicity value not available. Benzo(a)pyrene used as surrogate.
Benzo(b)fluoranthene	Chronic NOAEL	Wheat	1,200	Not applicable	1,200	Sims and Overcash (1983).
Benzo(k)fluoranthene	Not available	--	--	--	1,200	Toxicity value not available. Benzo(a)pyrene used as surrogate.
Chrysene	Not available	--	--	--	1,200	Toxicity value not available. Benzo(a)pyrene used as surrogate.
Dibenz(a,h)anthracene	Not available	--	--	--	1,200	Toxicity value not available. Benzo(a)pyrene used as surrogate.

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TERRESTRIAL PLANT TOXICITY REFERENCE VALUES

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Compound	Basis for TRV				TRV [c]	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Concentration	Uncertainty Factor [b]		
Indeno(1,2,3-cd)pyrene	Not available	--	--	--	1,200	Toxicity value not available. Benzo(a)pyrene used as surrogate.
Polychlorinated biphenyls (PCB) (μg/kg)						
Aroclor 1016	--	--	--	--	10,000	No toxicity value available. Aroclor 1254 TRV adopted as surrogate.
Aroclor 1254	Chronic NOAEL	Soybean shoot weight	10,000	Not applicable	10,000	Value for toxicity of Aroclor 1254 (Weber and Mrozek 1979).
Nitroaromatics (μg/kg)						
1,3-Dinitrobenzene	--	--	--	--	--	Toxicity value not available.
2,4-Dinitrotoluene	--	--	--	--	--	Toxicity value not available.
2,6-Dinitrotoluene	--	--	--	--	--	Toxicity value not available.
Nitrobenzene	--	--	--	--	--	Toxicity value not available.
Pentachloronitrobenzene	--	--	--	--	--	Toxicity value not available.
Phthalate esters (μg/kg)						
Bis(2-ethylhexyl)phthalate	--	--	--	--	--	Toxicity value not available.
Di(n)octyl phthalate	--	--	--	--	--	Toxicity value not available.
Volatile organic compounds (μg/kg)						

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Compound	Basis for TRV				TRV [c]	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Concentration	Uncertainty Factor [b]		
Acetone	--	--	--	--	--	Toxicity value not available.
Acrylonitrile	--	--	--	--	--	Toxicity value not available.
Chloroform	--	--	--	--	--	Toxicity value not available.
Crotonaldehyde	--	--	--	--	--	Toxicity value not available.
1,4-Dioxane	--	--	--	--	--	Toxicity value not available.
Formaldehyde	--	--	--	--	--	Toxicity value not available.
Vinyl chloride	--	--	--	--	--	Toxicity value not available.
Other chlorinated organics (μg/kg)						
Hexachlorobenzene	--	--	--	--	--	Toxicity value not available.
Hexachlorobutadiene	--	--	--	--	--	Toxicity value not available.
Hexachlorocyclopentadiene	Acute EC50	Lettuce growth	10,000	0.01	100	Hulzebos et al. (1993)
Pentachlorobenzene	--	--	--	--	--	Toxicity value not available.
Pentachlorophenol	Chronic LOAEL	Rice	17,300	0.1	1,730	Nagasawa et al. (1981)
Pesticides (μg/kg)						
4,4'-DDE	--	--	--	--	--	Toxicity value not available.

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Compound	Basis for TRV				TRV [c]	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Concentration	Uncertainty Factor [b]		
Heptachlor	Chronic NOAEL	Carrot	1,000	Not applicable	1,000	Ahrens and Kring (1968)
Hexachlorophene	--	--	--	--	--	Toxicity value not available.
Inorganics (mg/kg)						
Aluminum	Subchronic NOAEL	White clover seedling establishmen t	50	0.1[e]	5	Mackay et al. (1990)
Antimony	Not specified	Not specified	5	0.1[e]	0.5	Kabata-Pendias and Pendias (1992)
Arsenic	Chronic LOAEL	Corn yield (weight)	10	0.1	1	Woolson et al. (1971)
Barium	Chronic LOAEL	Barley shoot growth	500	0.01[e]	5	Chaudry et al. (1977)
Beryllium	Not specified	Not specified	10	0.01[e]	0.1	Kabata-Pendias and Pendias (1992)
Cadmium	Chronic LOAEL	Spruce seedling growth	2	0.1[e]	0.2	Burton et al. (1984)
Chromium (hexavalent)	Subchronic EC50	Lettuce growth	1.8	0.01	0.018	Adema and Hazen (1989)
Copper	Chronic LOAEL	Barley	10	0.1	1.0	Toivonem and Hofstra (1979)

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TERRESTRIAL PLANT TOXICITY REFERENCE VALUES

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Compound	Basis for TRV				TRV [c]	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Concentration	Uncertainty Factor [b]		
Cyanide, total	--	--	--	--	--	Toxicity value not available.
Lead	Chronic LOAEL	Senna	46	0.1	4.6	Krishnayya and Bedi (1986)
Mercuric chloride	Acute NOEC	Barley	34.9	0.01[e]	0.349	Panda et al. (1992)
Methyl mercury	--	--	--	--	--	Toxicity value not available.
Nickel	Chronic NOAEL	Bush bean shoot growth	25	Not applicable	25	Wallace et al. (1977)
Selenium	Subchronic NOAEL	Alfalfa shoot weight	0.5	0.1	0.05	Wan et al. (1988)
Silver	Not specified	Not specified	2	0.01[e]	0.02	Kabata-Pendias and Pendias (1992)
Thallium	Not specified	Not specified	1	0.01[e]	0.01	Kabata-Pendias and Pendias (1992)
Zinc	Chronic LOAEL	Spring barley	9	0.1	0.9	Davis, Beckett, and Wollan (1978)

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Notes:

a To evaluate exposure duration, the following general guidelines were used: Chronic duration represents exposures occurring about 10 or more days, including exposure during a critical life stage, such as germination and shoot development. Subchronic duration generally lasts 2 days through several days, however a sensitive life stage is not exposed. Acute duration generally includes exposures occurring 0 to 2 days.

b Uncertainty factors are used to extrapolate a toxicity value to a chronic NOAEL TRV. See Chapter 5 (Section 5.4) of the SLERAP for a discussion on the use of uncertainty factors.

c TRV was calculated by multiplying the toxicity value with the uncertainty factor.

d The references refer to the source of the toxicity value. Complete reference citations are provided below.

e Best scientific judgment was used to identify uncertainty factor. See Chapter 5 (Section 5.4.1.2) for a discussion on the use of best scientific judgement. Factors evaluated include test duration, ecological relevance of endpoint, and experimental design.

EC50 = Effective concentration for 50 percent of the test organisms.
HWC = High molecular weight
LOAEL = Lowest Observed Adverse Effects Level
NOAEL = No Observed Adverse Effects Level
NOEC = No Observed Effects Concentration
TRV = Toxicity Reference Value

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TERRESTRIAL PLANT TOXICITY REFERENCE VALUES

REFERENCES

Efroymson, Will, Suter II, and Wooten (1997) provides a comprehensive review of ecologically-relevant terrestrial plant toxicity information. This source was reviewed to identify studies to develop TRVs for terrestrial plant. Based on the information presented, one or more references were obtained and reviewed to identify compound-specific toxicity values. For some compounds, the available information identified a single study meeting the requirements for a TRV, as discussed in Chapter 5 (Section 5.4) of the SLERAP. In most cases, each reference was obtained and reviewed to identify a single toxicity value to develop a TRV for each compound. In a few cases where a primary study could not be obtained, a toxicity value is based on a secondary source. As noted below, additional compendia were reviewed to identify toxicity studies to review. For compounds not discussed in Efroymson, Will, Suter II, and Wooten (1997), the scientific literature was searched, and relevant studies were obtained and reviewed. The references reviewed are listed below. The study selected for the TRV is highlighted in bold.

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Benzo(k)fluoranthene

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TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 1 of 12)

Compound	TRV				TRV[c]	Reference and Notes[d]
	Duration and Endpoint[a]	Test Species	Concentration	Uncertainty Factor[b]		
Polychlorinateddibenzo-p-dioxins (μg/kg)						
2,3,7,8-TCDD	Chronic (85-day); no mortality reported at 5,000 μg/kg	Earthworm (*Allolobophora caliginosa*)	5,000	0.1[e]	500	Toxicity value for 2,3,7,8-TCDD (Reinecke and Nash 1984). UF applied to concentration because mortality only endpoint available and data not subjected to statistical analysis.
Polynuclear aromatic hydrocarbons (PAH) (μg/kg)						
Total HMW PAH	Not available	--	--	--	25,000	Benzo(a) pyrene used as surrogate for HMW PAH compounds.
Benzo(a)pyrene	Chronic (28-day) NOAEL for growth	Woodlouse (*Porcellio scaber*)	25,000	Not applicable	25,000	van Straalen and Verweij (1991)
Benzo(a)anthracene	Not available	--	--	--	25,000	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Benzo(b)fluoranthene	Not available	--	--	--	25,000	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Benzo(k)fluoranthene	Not available	--	--	--	25,000	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Chrysene	Not available	--	--	--	25,000	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Dibenz(a,h)anthracene	Not available	--	--	--	25,000	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.
Indeno(1,2,3-cd)pyrene	Not available	--	--	--	25,000	Toxicity value not available. TRV for benzo(a)pyrene used as surrogate.

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 2 of 12)

Compound	TRV				TRV[c]	Reference and Notes[d]
	Duration and Endpoint[a]	Test Species	Concentration	Uncertainty Factor[b]		
Polychlorinated biphenyls (PCB) (μg/kg)						
Aroclor 1016	Acute median LC50	Earthworm (*Eisenia foetida*)	251,000	0.01	2,510	Rhett et al. (1989).
Aroclor 1254	Acute median LC50	Earthworm (*Eisenia foetida*)	251,000	0.01	2,510	Rhett et al. (1989).
Nitroaromatics (μg/kg)						
1,3-Dinitrobenzene	--	--	--	--	2,260	Toxicity value not available. Nitrobenzene used as surrogate.
2,4-Dinitrotoluene	--	--	--	--	--	Toxicity value not available.
2,6-Dinitrotoluene	--	--	--	--	--	Toxicity value not available.
Nitrobenzene	Subchronic (14-day) LC50	Earthworm (species uncertain)	226,000	0.01[e]	2,260	Neuhauser et al. (1986).
Pentachloronitrobenzene	--	--	--	--		Toxicity value not available.
Phthalate esters (μg/kg)						
Bis(2-ethylhexyl)phthalate	--	--	--	--	--	Toxicity value not available.
Di(n)octyl phthalate	--	--	--	--	--	Toxicity value not available.
Volatile organic compounds (μg/kg)						
Acetone	--	--	--	--	--	Toxicity value not available.
Acrylonitrile	--	--	--	--	--	Toxicity value not available.

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 3 of 12)

Compound	TRV				TRV[c]	Reference and Notes[d]
	Duration and Endpoint[a]	Test Species	Concentration	Uncertainty Factor[b]		
Chloroform	--	--	--	--	--	Toxicity value not available.
Crotonaldehyde	--	--	--	--	--	Toxicity value not available.
1,4-Dioxane	--	--	--	--	--	Toxicity value not available.
Formaldehyde	--	--	--	--	--	Toxicity value not available.
Vinyl chloride	--	--	--	--	--	Toxicity value not available.
Other chlorinated organics (μg/kg)						
Hexachlorobenzene	--	--	--	--	--	Toxicity value not available.
Hexachlorobutadiene	--	--	--	--	--	Toxicity value not available.
Hexachlorocyclopentadiene	--	--	--	--	--	Toxicity value not available.
Pentachlorobenzene	LC50 of unspecified duration	Earthworm (species uncertain)	115,000	0.01[e]	1,150	van Gestel et al. (1991)
Pentachlorophenol	Chronic (21-day) NOAEL for hatching success	Earthworm (*Eisenia andrei*)	10,000	Not applicable	10,000	van Gestel et al. (1988)
Pesticides (μg/kg)						
4,4'-DDE	--	--	--	--	--	Toxicity value not available.
Heptachlor	--	--	--	--	--	Toxicity value not available.
Hexachlorophene	--	--	--	--	--	Toxicity value not available.
Inorganics (mg/kg)						

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 4 of 12)

Compound	TRV				TRV[c]	Reference and Notes[d]
	Duration and Endpoint[a]	Test Species	Concentration	Uncertainty Factor[b]		
Aluminum	--	--	--	--	--	Toxicity value not available.
Antimony	--	--	--	--	--	Toxicity value not available.
Arsenic	Chronic (56-day); reduced cocoon production reported at single concentration tested	Earthworm (*Eisenia fetida*)	25	0.01[e]	0.25	Fischer and Koszorus (1992)
Barium	--	--	--	--	--	Toxicity value not available.
Beryllium	--	--	--	--	--	Toxicity value not available.
Cadmium	Chronic (4-month) NOAEL for cocoon production	Earthworm (*Dendrobaena rubida*)	10	Not applicable	10	Bengtsson and et al. (1986)
Chromium (hexavalent)	Chronic (60-day); survival reduced 25 percent at lowest tested concentration	Earthworm (*Octochaetus pattoni*)	2	0.1[e]	0.2	Abbasi and Soni (1983)
Copper	Chronic (56-day) NOAEL for cocoon production	Earthworm (*Eisenia fetida*)	32.0	Not applicable	32.0	Spurgeon et al. (1994)
Cyanide, total	--	--	--	--	--	Toxicity value not available.
Lead	Chronic (4-month) NOAEL for cocoon production	Earthworm (*Dendrobaena rubida*)	100	Not applicable	100	Bengtsson et al. 1986

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 5 of 12)

Compound	TRV				TRV [c]	Reference and Notes [d]
	Duration and Endpoint [a]	Test Species	Concentration	Uncertainty Factor [b]		
Mercuric chloride	Not available	--	--	--	2.5	Toxicity value not available. TRV for methyl mercury used as a surrogate.
Methyl mercury	Chronic (12-week) NOAEL for segment regeneration and survival	Earthworm (*Eisenia foetida*)	2.5	Not applicable	2.5	Beyer et al. (1985). Wet weight NOAEL of 1 mg/kg converted to corresponding dry weight NOAEL based on 60 percent moisture content. Uncertainty factor of 0.1 used because segment regeneration may not be a sensitive endpoint.
Nickel	Chronic (20-week) NOAEL for cocoon production	Earthworm (*Eisenia foetida*)	100	Not applicable	100	Malecki et al. (1982)
Selenium	Chronic; reduced cocoon production at single tested concentration	Earthworm (*Eisenia foetida*)	77	0.1[e]	7.7	Fischer and Koszorus (1992)
Silver	--	--	--	--	--	Toxicity value not available.
Thallium	--	--	--	--	--	Toxicity value not available.
Zinc	Chronic (56-day) NOEC for cocoon production	Earthworm (*Eisenia fetida*)	199	Not applicable	199	Spurgeon et al. (1994)

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

Notes:

a - duration, the following general guidelines were used: Chronic duration represents exposures occurring about 10 or more days, including exposure during a critical life stage encompassing a sensitive endpoint. Subchronic duration generally lasts 2 days through several days, however a sensitive life stage is not exposed. Acute duration generally includes exposures from 0 to 2 days.

b Uncertainty factors are used to extrapolate a toxicity value to a chronic NOAEL TRV. See Chapter 5 (Section 5.4) of the SLERAP for a discussion on the use of uncertainty factors.

c TRV was calculated by multiplying the toxicity value with the uncertainty factor.

d The references refer to the source of the toxicity value. Complete reference citations are provided below.

e Best scientific judgment used to identify uncertainty factor. See Chapter 5 (Section 5.4.1.2) for a discussion on the use of best scientific judgement. Factors evaluated include test duration, ecological relevance of measured effect, experimental design, and availability of toxicity data.

HMW = High molecular weight
LC50 = Concentration lethal to 50 percent of the test organisms.
NOAEL = No Observed Adverse Effects Level
NOEC = No Observed Effects Level
UF = Uncertainty Factor
TRV = Toxicity Reference Value

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

REFERENCES

Efroymson, Will, and Suter II (1997) provides a comprehensive review of ecologically-relevant soil invertebrate toxicity information. This source was reviewed to identify studies to develop TRVs for invertebrates. Effects of compounds on microbial communities were not considered. Based on the information presented, one or more references were obtained and reviewed to identify compound-specific toxicity values. For some compounds, the available information identified a single study meeting the requirements for a TRV, as discussed in Section 5.4. In most cases, each reference was obtained and reviewed to identify a single toxicity value to develop a TRV for each compound. In a few cases where a primary study could not be obtained, a toxicity value is based on a secondary source. As noted below, additional compendia were reviewed to identify toxicity studies to review. For compounds not discussed in Efroymson, Will, and Suter II (1997), the scientific literature was searched, and relevant studies were obtained and reviewed. The references reviewed are listed below. The study selected for the TRV is highlighted in bold.

Polychlorinated dibenzo(p)dioxins

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van Brummelen, T.C., and S.C. Stuijfzand. 1993. "Effects of benzo(a)pyrene on survival, growth and energy reserves in terrestrial isopods *Oniscus asellus* and *Porcellio scaber*." *Science of the Total Environment. Supplement.* Pages 921-930.

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Nitrobenzene

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 8 of 12)

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Pentachlorobenzene

van Gestel, C.A.M., W.-C. Ma, and C.E. Smit. 1991. "Development of QSARs in Terrestrial Ecotoxicology: Earthworm Toxicity and Soil Sorption of Chlorophenols, Chlorobenzenes, and Dichloroaniline." *The Science of the Total Environment*. Volume 109/110. Pages 589-604.

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Heimbach, F. 1992. "Effects of Pesticides on Earthworm Populations: Comparison of Results from Laboratory and Field Tests." In *Ecotoxicology of Earthworms*. P.W. Greig-Smith et al. (eds). Intercept Ltd., U.K. Pages 100-106.

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Arsenic

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Cadmium

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 9 of 12)

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van Gestel, C.A.M., W.A. van Dis, E.M. Dirven-van Breemen, P.M. Sparenburg, and R. Baerselman. 1991. "Influence of Cadmium, Copper, and Pentachlorophenol on Growth and Sexual development of *Eisenia andrei* (Oligochaeta; Annelida)." *Biology and Fertility of Soils.* Volume 12. Pages 117-121.

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Chromium (Hexavalent)

Abbasi, S.A. and R. Soni. 1983. "Stress-Induced Enhancement of Reproduction in Earthworm, *Octochaetus pattoni*, Exposed to Chromium (VI) and Mercury (II)—Implications in Environmental Management." *International Journal of Environmental Studies.* Volume 22. Pages 43-47.

Molnar, L., E. Fischer, and M. Kallay. 1989. "Laboratory Studies on the Effect, Uptake and Distribution of Chromium in *Eisenia foetida* (Annelida, Oligochaeta)." *Zool. Anz.* Volume 223(1/2). Pages 57-66.

Soni, R., and S.A. Abbasi. 1981. "Mortality and Reproduction inEearthworms *Pheretima posthuma* Exposed to Chromium (VI)." *International Journal of Environmental Studies.* Volume 17. Pages 147-149.

Copper

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SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 10 of 12)

Korthals, G. W., A. D. Alexiev, T. M. Lexmond, J. E. Kammenga, and T. Bongers. 1996. "Long-term Effects of Copper and pH on the Nematode Community in an Agroecosystem." *Environmental Toxicology and Chemistry.* Volume 15. Pages 979–985.

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Lead

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Spurgeon, D.J., S.P. Hopkin, and D.T. Jones. 1994. "Effects of Cadmium, Copper, Lead, and Zinc on Growth, Reproduction, and Survival of the Earthworm *Eisenia fetida* (Savigny): Assessing the Environmental Impact of Point-source Metal Contamination in Terrestrial Ecosystems." *Environmental Pollution.* Volume 84. Pages 123-130.

Mercuric chloride

TABLE E-6

SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

(Page 11 of 12)

Abbasi, S.A., and R. Soni. 1983. "Stress-induced Enhancement of Reproduction in Earthworm *Octochaetus pattoni* Exposed to Chromium (VI) and Mercury (II) - Implications in Environmental Management." *International Journal of Environmental Studies.* Volume 22. Pages 43-47.

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Methyl mercury

Beyer, W.N., E. Cromartie, and G.B. Moment. 1985. "Accumulation of Methyl Mercury in the Earthworm, *Eisenia foetida*, and its Effects on Regeneration." *Bulletin of Environmental Contamination and Toxicology.* Volume 35. Pages 157-162.

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Nickel

Malecki, M.R., E.F. Neuhauser, and R.C. Loehr. 1982. "The Effect of Metals on the Growth and Reproduction of *Eisenia foetida* (Oligochaeta, Lumbricidae)." *Pedobiologia.* Volume 24. Pages 129-137.

Selenium

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Zinc

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SOIL INVERTEBRATE TOXICITY REFERENCE VALUES

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TABLE E-7

MAMMAL TOXICITY REFERENCE VALUES

(Page 1 of 15)

Compound	Basis for Toxicity Reference Value (TRV)				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose [b]	Uncertainty Factor [c]		
Polychlorinateddibenzo-p-dioxins (μg/kg BW-day)						
2,3,7,8-TCDD	Chronic (multigenerational) NOAEL for reproduction	Rat	0.001	Not applicable	0.001	Murray et al. (1979). TRV based on toxicity of 2,3,7,8-TCDD.
Polynuclear aromatic hydrocarbons (PAH) (μg/kg BW-day)						
Total high molecular weight (HMW) PAH	--	--	--	--	100	TRV based on benzo(a)pyrene toxicity. This TRV should be assessing the risk of Total HMW PAH.
Benzo(a)pyrene	Acute (10 days) LOAEL (reproductive effects)	Mouse	10,000	0.01	100	Mackenzie and Angevine (1981)
Benzo(a)anthracene	Single dose LOAEL (gastrointestinal effects)	Mouse	16,666	0.01	167	Bock and King (1959)
Benzo(b)fluoranthene	--	--	--	--	--	Toxicity value not available.
Benzo(k)fluoranthene	--	--	--	--	--	Toxicity value not available.
Chrysene	--	--	--	--	--	Toxicity value not available.
Dibenz(a,h)anthracene	Subchronic (15 days) LOAEL (reduced growth rate)	Rat	200	0.01[e]	2	Haddow et al. (1937)
Indeno(1,2,3-cd)pyrene	--	--	--	--	--	Toxicity value not available.

TABLE E-7

MAMMAL TOXICITY REFERENCE VALUES

(Page 2 of 15)

Compound	Basis for Toxicity Reference Value (TRV)				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose [b]	Uncertainty Factor [c]		
Polychlorinated biphenyls (PCB) (μg/kg BW-day)						
Aroclor 1016	Subchronic (14.5 weeks) LOAEL (mortality)	Mink	20.6	0.01	0.206	Aulerich et al. (1985). TRV based on toxicity of 3,4,5-hexachlorobiphenyl.
Aroclor 1254	Subchronic (14.5 weeks) LOAEL (mortality)	Mink	20.6	0.01	0.206	Aulerich et al. (1985). TRV based on toxicity of 3,4,5-hexachlorobiphenyl.
Nitroaromatics (μg/kg BW-day)						
1,3-Dinitrobenzene	Chronic (16 weeks) NOAEL	Rat	1,051	1.0	1,051	Cody et al. (1981)
2,4-Dinitrotoluene	Chronic (24 months) NOAEL	Dog	700	1.0	700	Ellis et al. (1979)
2,6-Dinitrotoluene	Single dose LOAEL (mortality)	Dog	4,000	0.01	400	Lee et al. (1976)
Nitrobenzene	--	--	--	--	--	Toxicity value not available.
Pentachloronitrobenzene	Chronic (2 years) NOAEL	Mouse	458,333	1.0	458,333	National Toxicology Program (1987)
Phthalate esters (μg/kg BW-day)						
Bis(2-ethylhexyl)phthalate	Chronic (2 years) NOAEL	Rat	60,000	1.0	60,000	Carpenter et al. (1953)
Di(n)octyl phthalate	Chronic (105 days) NOAEL	Mouse	7,500,000	1.0	7,500,000	Heindel et al. (1989)
Volatile organic compounds (μg/kg BW-day)						
Acetone	Subchronic (90 days) NOAEL	Albino Rat, male	100,000	0.1	10,000	U.S. EPA (1986)
Acrylonitrile	Chronic (2 years) LOAEL (lesions and other organ effects)	Rat	4,600	0.1	460	Quast et al. (1980)
Chloroform	Chronic (80 weeks) NOAEL	Mouse	60,000	1.0	60,000	Roe et al. (1979)

TABLE E-7

MAMMAL TOXICITY REFERENCE VALUES

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Compound	Basis for Toxicity Reference Value (TRV)				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose [b]	Uncertainty Factor [c]		
Crotonaldehyde	Acute (4-hour) LD50	Rat	8,000	0.01	80	Rinehart (1967)
1,4-Dioxane	Chronic (23 months) LOAEL (lung tumors)	Guinea Pig	1,069,767	0.1	106,777	Hoch-Ligeti and Argus (1970)
Formaldehyde	Acute (single dose) LOAEL (mortality)	Rat	230,000	0.01	2,300	Tsuchiya et al. (1975)
Vinyl chloride	Chronic (2 years) NOAEL	Rat	1,700	0.1	170	Feron et al. (1981)
Other chlorinated organics (μg/kg BW-day)						
Hexachlorobenzene	Chronic (>247 days) NOAEL	Rat	1,600	1.0	1,600	Grant et al. (1977)
Hexachlorobutadiene	Chronic (2 years) NOAEL	Rat	200	1.0	200	Kociba et al. (1977)
Hexachlorocyclopentadiene	Subchronic (13 weeks) NOAEL	Rat	38,000	0.1	3,800	Abdo et al. (1984)
Pentachlorobenzene	Chronic (180 days) NOAEL	Rat	7,250	1.0	7,250	Linder et al. (1980)
Pentachlorophenol	Subchronic (62 days) NOAEL	Rat	3,000	0.1	300	Schwetz et al. (1978)
Pesticides (μg/kg BW-day)						
4,4'-DDE	Subchronic (5 weeks) NOAEL	Rat	10,000	0.1	1,000	Kornburst et al. (1986)
Heptachlor	Subchronic (60 days) LOAEL (mortality)	Rat	250	0.01	2.5	Green (1970)
Hexachlorophene	Acute LD50	Rat	560,000	0.01	5600	Meister (1994)
Inorganics (mg/kg BW-day)						
Aluminum	Chronic (>1 year) LOAEL (growth)	Rat	19.3	0.1	1.93	Ondreicka et al. (1966)

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MAMMAL TOXICITY REFERENCE VALUES

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Compound	Basis for Toxicity Reference Value (TRV)				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose [b]	Uncertainty Factor [c]		
Antimony	Chronic (4 years) LOAEL (mortality)	Rat	0.66	0.1	0.066	Schroeder et al. (1970)
Arsenic	Chronic (2 years) NOAEL	Dog	1.25	1.0	1.25	Byron et al. (1967)
Barium	Chronic (16 months) NOAEL	Rat	0.51	1.0	0.51	Perry et al. (1983)
Beryllium	Chronic (>1 year) NOAEL	Rat	0.66	1.0	0.66	Schroeder and Mitchner (1975)
Cadmium	Chronic (>150 days) LOAEL (reproduction)	Mouse	2.52	0.01	0.0252	Schroeder and Mitchner (1971)
Chromium (hexavalent)	Chronic (1 year) NOAEL	Rat	3.5	1.0	3.5	MacKenzie et al. (1958)
Copper	Chronic (357 days) NOAEL	Mink	12.0	1.0	12.0	Aulerich et al. (1982)
Total Cyanide	Chronic (2 years) NOAEL	Rat	24	1.0	24	Howard and Hanzal (1955)
Lead	Chronic (>150 days) LOAEL (mortality)	Mouse	3.75	0.01	0.0375	Schroeder and Mitchner (1971)
Mercuric chloride	Chronic (6 months) NOAEL (reproduction)	Mink	1.01	1.0	1.01	Aulerich et al. (1974)
Methyl mercury	Subchronic (93 days) NOAEL	Rat	0.032	1.0	0.032	Verschuuren et al. (1976)
Nickel	Chronic (2 years) NOAEL	Rat	50	1.0	50	Ambrose et al. (1976)
Selenium	Chronic (>150 days) LOAEL (mortality)	Mouse	0.76	0.1	0.076	Schroeder and Mitchner (1971)
Silver	Chronic (125 days) LOAEL (hypoactivity)	Mouse	3.75	0.1	0.375	Rungby and Danscher (1984)

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MAMMAL TOXICITY REFERENCE VALUES

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Compound	Basis for Toxicity Reference Value (TRV)				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose [b]	Uncertainty Factor [c]		
Thallium	Subchronic (60 days) LOAEL (testicular function)	Rat	1.31	0.01[h]	0.0131	Formigli et al. (1986)
Zinc	Subchronic (13 weeks) NOAEL	Mouse	104	0.1	10.4	Maita et al. (1981)

Notes:

a The duration of exposure is defined as chronic if it represents about 10 percent or more of the test animal's lifetime expectancy. Acute exposures represent single exposure or multiple exposures occurring within about two weeks or less. Subchronic exposures are defined as multiple exposures occurring for less than 10 percent of the test animal's lifetime expectancy but more that 2 weeks.

b Reported values, which were dose in food or diet, were converted to dose based on body weight and intake rate using Opresko, Sample, and Suter 1996.

c Uncertainty factors are used to extrapolate a toxicity value to a chronic NOAEL TRV. See Chapter 5 (Section 5.4) for a discussion on the use of uncertainty factors. The TRV was calculated by multiplying the toxicity value by the uncertainty factor.

d The references refer to the study or studies from which the endpoint and doses were identified. Complete reference citations are provided at the end of this table.

e Best scientific judgement used to identify uncertainty factor. See Chapter 5 (Section 5.4.1.2) for a discussion of the use of best scientific judgement. Factors evaluated include test duration, ecological relevance of endpoint, experimental design, and availability of toxicity data.

HMW = High molecular weight
LD50 = Lethal dose to 50 percent of the test organisms.
LOAEL = Lowest Observed Adverse Effect Level
NOAEL = No Observed Adverse Effect Level
TRV = Toxicity Reference Value

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REFERENCES

Sample, Opresko, and Suter II (1996) provides a comprehensive review of ecologically-relevant mammal toxicity information. This source was reviewed to identify studies to develop TRVs for mammals. Based on the information presented, one or more references were obtained and reviewed to identify compound-specific toxicity values. For some compounds, the available information identified a single study meeting the requirements for a TRV, as discussed in Section 5.4. In most cases, each reference was obtained and reviewed to identify a single toxicity value to develop a TRV for each compound. In a few cases where a primary study could not be obtained, a toxicity value is based on a secondary source. As noted below, additional compendia were reviewed to identify toxicity studies to review. For compounds not discussed in Sample, Opresko, and Suter II (1996), the scientific literature was searched, and relevant studies were obtained and reviewed. The references reviewed are listed below. The study selected for the TRV is highlighted in bold.

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Zinc

TABLE E-8

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Compound	Basis for TRV				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose[b]	Uncertainty Factor [c]		
Polychlorinateddibenzo(p)dioxins (μg/kg BW-day)						
2,3,7,8-TCDD	Subchronic (10 weeks) NOAEL	Ring-necked pheasant hen	0.01	Not applicable	0.01	Nosek et al. (1992). TRV based on toxicity of 2,3,7,8-TCDD.
Polynuclear aromatic hydrocarbons (PAH) (μg/kg BW-day)						
Total high molecular weight (HMW) PAH	--	--	--	--	0.14	TRV based on toxicity of benzo(k)fluoranthene. If TRVs are not available for all individual HMW PAHs, this TRV should be used to assess potential risk of Total HMW PAH.
Benzo(a)pyrene	Acute NOAEL	Chicken embryo	100	0.01	1.0	Brunström et al. (1991).
Benzo(a)anthracene	Acute LD50	Chicken embryo	79	0.01	0.79	Brunström et al. (1991).
Benzo(b)fluoranthene	--	--	--	--	0.14	No toxicity data available for benzo(b) fluoranthene. Benzo(k)fluoranthene used as surrogate.
Benzo(k)fluoranthene	Acute LD50	Chicken embryo	14	0.01	0.14	Brunström et al. (1991).
Chrysene	Acute LOAEL	Chicken embryo	100	0.01	1.0	Brunström et al. (1991).
Dibenz(a,h)anthracene	Acute LD50	Chicken embryo	39	0.01	0.39	Brunström et al. (1991).

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Compound	Basis for TRV				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose [b]	Uncertainty Factor [c]		
Indeno(1,2,3-cd)pyrene	Acute LOAEL	Chicken embryo	100	0.01	1.0	Brunström et al. (1991).
Polychlorinated biphenyls (PCB) (μg/kg BW-day)						
Aroclor 1016	--	--	--	--	--	No toxicity data available. Aroclor 1254 TRV used as surrogate.
Aroclor 1254	Chronic (3 months) LOAEL (embryonic mortality)	Ring dove	720	0.1	72	Peakall et al. (1972). TRV based on toxicity of Aroclor 1254.
Nitroaromatics (μg/kg BW-day)						
1,3-Dinitrobenzene	Acute LD50	Redwing blackbird	42.2	0.01	0.422	Schafer (1972)
2,4-Dinitrotoluene	--	--	--	--	--	Toxicity value not available.
2,6-Dinitrotoluene	--	--	--	--	--	Toxicity value not available.
Nitrobenzene	--	--	--	--	--	Toxicity value not available.
Pentachloronitrobenzene	Chronic (35 weeks) NOAEL	Chicken	68,750	Not applicable	68,750	Dunn et al. (1979)
Phthalate esters (μg/kg BW-day)						
Bis(2-ethylhexyl)phthalate	Subchronic (4 weeks) NOAEL	Ring dove	1,110	0.1	111	Peakall (1974)
Di(n)octyl phthalate	--	--	--	--	--	Toxicity value not available.
Volatile organic compounds (μg/kg BW-day)						

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Compound	Basis for TRV				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose[b]	Uncertainty Factor [c]		
Acetone	Acute (5 days) NOAEL	Coturnix quail	5,200,000	0.01[h]	52,000	Hill and Camardese (1986)
Acrylonitrile	--	--	--	--	--	Toxicity value not available.
Chloroform	--	--	--	--	--	Toxicity value not available.
Crotonaldehyde	--	--	--	--	--	Toxicity value not available.
1,4-Dioxane	--	--	--	--	--	Toxicity value not available.
Formaldehyde	--	--	--	--	--	Toxicity value not available.
Vinyl chloride	--	--	--	--	--	Toxicity value not available.
Other chlorinated organics (μg/kg BW-day)						
Hexachlorobenzene	Acute (5 days) NOAEL	Coturnix quail	22,500	0.01	225	Hill and Camardese (1986)
Hexachlorobutadiene	Chronic (3 months) NOAEL	Japanese quail	3185	Not applicable	3185	Schwertz et al. (1974)
Hexachlorocyclopentadiene	--	--	--	--	--	Toxicity value not available.
Pentachlorobenzene	--	--	--	--	--	Toxicity value not available.
Pentachlorophenol	Acute (5 days) NOAEL	Quail	403,000	0.01	4,030	Hill and Camardese (1986)
Pesticides (μg/kg BW-day)						
4,4'-DDE	Acute (5 days) LOAEL (mortality)	Coturnix quail	84,500	0.01	845	Hill and Camardese (1986). Test data for 1,1'-DDE used as a surrogate for 4,4'-DDE.

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BIRD TOXICITY REFERENCE VALUES

(Page 4 of 13)

Compound	Basis for TRV				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose[b]	Uncertainty Factor [c]		
Heptachlor	Acute (5 days) LOAEL (mortality)	Quail	6,500	0.01	65	Hill and Camardese (1986)
Hexachlorophene	Acute LD50	Bobwhite quail	575,000	0.01	5,750	Meister (1994)
Inorganics (mg/kg BW-day)						
Aluminum	Chronic (4 -months) NOAEL (reproduction)	Ringed Turtle Dove	110	1.0	100	Carriere et al. (1986)
Antimony	--	--	--	--	--	Toxicity value not available. Ridgeway and Karnofsky (1952) reported LD50 for doses to eggs; however, that value could not be converted to a dose based on post-hatching environmental exposure.
Arsenic	Chronic (7 months) NOAEL	Brown-headed cowbird	2.46	1.0	2.46	U.S. Fish and Wildlife Service (1969)
Barium	Subchronic (4 weeks) NOAEL	One day old chick	208.26	0.1	20.8	Johnson et al. (1960)
Beryllium	--	--	--	--	--	Toxicity value not available.
Cadmium	Chronic (90 days) NOAEL	Mallard drake	1.45	Not applicable	1.45	White and Finley (1978)
Chromium (hexavalent)	Chronic (5 months) NOAEL	Black duck	1.0	Not applicable	1.0	Haseltine et al. (1985). TRV based on trivalent chromium.
Copper	Chronic (10 weeks) NOAEL (growth)	1-day old chicks	46.97	1.0	46.97	Mehring et al. (1960)

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BIRD TOXICITY REFERENCE VALUES

(Page 5 of 13)

Compound	Basis for TRV				TRV	Reference and Notes [d]
	Duration and Endpoint [a]	Test Organism	Dose[b]	Uncertainty Factor [c]		
Total Cyanide	Acute LD50	American kestrel	4	0.01	0.04	Wiemeyer et al. (1986). Sodium cyanide is used as a surrogate for total cyanides.
Lead	Acute (7 days) LOAEL (altered enzyme levels)	Ringed turtle dove	25	0.001	0.025	Kendall and Scanlon (1982)
Mercuric chloride	Acute (5 days) LOAEL (mortality)	Coturnix quail	325	0.01	3.25	Hill and Camardese (1986)
Methyl mercury	Chronic (3 generations) LOAEL (mortality)	Mallard	0.064	0.1	0.0064	Heinz (1979)
Nickel	Subchronic (5 days) NOAEL	Coturnix quail	650	0.1	65	Hill and Camardese (1986)
Selenium	Chronic (78 days) NOAEL	Mallard	0.5	1.0	0.5	Heinz et al. (1987)
Silver	Subchronic (14 days) NOAEL	Mallard	1,780	0.1	178	U.S. EPA (1997)
Thallium	Acute LD50	Starling	35	0.01	0.35	Schafer (1972)
Zinc	Chronic (44 weeks) NOAEL	Leghorn hen and New Hampshire rooster	130.9	1.0	130.9	Stahl et al. (1990)

TABLE E-8

BIRD TOXICITY REFERENCE VALUES

Notes:

a The duration of exposure is defined as chronic if it represents about 10 percent or more of the test animal's lifetime expectancy. Acute exposures represent single exposure or multiple exposures occurring within about two weeks or less. Subchronic exposures are defined as multiple exposures occurring for less than 10 percent of the test animal's lifetime expectancy but more that 2 weeks.

b Reported value which were dose in diet or water were converted to dose based on body weight and intake rate using Opresko, Sample, and Suter (1996).

c Uncertainty factors are used to extrapolate a reported toxicity value to a chronic NOAEL TRV. See Chapter 5 (Section 5.4) of the SLERAP for a discussion on the use of uncertainty factors. The TRV was calculated by multiplying the toxicity value by the uncertainty factor. A "not applicable" uncertainty factor is equivalent to a value equal to 1.0.

d The references refer to the study from which the endpoint and doses were identified. Complete reference citations are provided below.

e Best scientific judgement used to identify uncertainty factor. See Chapter 5 (Section 5.4.1.2) for a discussion on the use of best scientific judgement. Factors evaluated include test duration, ecological relevance of endpoint, experimental design, and availability of toxicity data.

HMW = High molecular weight
LOAEL = Lowest Observed Adverse Effect Level
LD50 = Concentration lethal to 50 percent of the test organisms.
NOAEL = No Observed Adverse Effect Level
TRV = Toxicity Reference Value

TABLE E-8

BIRD TOXICITY REFERENCE VALUES

REFERENCES

Sample, Opresko, and Suter II (1996) provides a comprehensive review of bird toxicity information. This source was reviewed to identify studies to develop TRVs for birds. Based on the information presented, one or more references were obtained and reviewed to identify compound-specific toxicity values. For some compounds, the available information identified a single study meeting the requirements for a TRV, as discussed in Chapter 5 (Section 5.4) of the SLERAP. In most cases, each reference was obtained and reviewed to identify a single toxicity value to develop a TRV for each compound. As noted below, additional compendia were reviewed to identify toxicity studies to review. In a few cases where a primary study could not be obtained, a toxicity value is based on a secondary source. For compounds not discussed in Sample, Opresko, and Suter II (1996), the scientific literature was searched, and relevant studies were obtained and reviewed. The references reviewed are listed below. The study selected for the TRV is highlighted in bold.

Polychlorinated dibenzo(p)dioxins

Nosek, J.A., S.R. Craven, J.R. Sullivan, S.S. Hurley, and R.E. Peterson. 1992. "Toxicity and Reproductive Effects of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in Ring-Necked Pheasant Hens." *Journal of Toxicology and Environmental Health.* Volume 35. Pages 187-198.

U.S. EPA. 1993. *Interim Report on Data and Methods for Assessment of 2,3,7,8-Tetrachlorodibenzop-dioxin Risks to Aquatic Life and Associated Wildlife.* EPA/600/R-93/055. Office of Research and Development. Washington, D.C. March. This report identified the two studies listed below.

Greig, J.B., G. Jones, W.H. Butler, and J.M. Barnes. 1973. "Toxic Effects of 2,3,7,8-Tetrachlorodibenzo-p-dioxins. *Food and Cosmetics Toxicology*. Volume 11. Pages 585-595.

Hudson, R., R.Tucker, and M. Haegele. 1984. *Handbook of Toxicity of Pesticides to Wildlife.* Second Ed. U.S. Fish and Wildlife, Resources Publication No. 153. Washington, D.C.

Benzo(a)pyrene

Brunström, B., D. Broman, and C. Näf. 1991. "Toxicity and EROD-Inducing Potency of 24 Polycyclic Aromatic Hydrocarbons (PAHs) in Chick Embryos." *Archives of Toxicology.* Volume 65. Pages 485-489.

Benzo(a)anthracene

Brunström, B., D. Broman, and C. Näf. 1991. "Toxicity and EROD-Inducing Potency of 24 Polycyclic Aromatic Hydrocarbons (PAHs) in Chick Embryos." *Archives of Toxicology.* Volume 65. Pages 485-489.

Benzo(k)fluoranthene

TABLE E-8

BIRD TOXICITY REFERENCE VALUES

Brunström, B., D. Broman, and C. Näf. 1991. "Toxicity and EROD-Inducing Potency of 24 Polycyclic Aromatic Hydrocarbons (PAHs) in Chick Embryos." *Archives of Toxicology.* Volume 65. Pages 485-489.

Chyrsene

Brunström, B., D. Broman, and C. Näf. 1991. "Toxicity and EROD-Inducing Potency of 24 Polycyclic Aromatic Hydrocarbons (PAHs) in Chick Embryos." *Archives of Toxicology.* Volume 65. Pages 485-489.

Dibenz(a,h)anthracene

Brunström, B., D. Broman, and C. Näf. 1991. "Toxicity and EROD-Inducing Potency of 24 Polycyclic Aromatic Hydrocarbons (PAHs) in Chick Embryos." *Archives of Toxicology.* Volume 65. Pages 485-489.

Indeno(1,2,3-cd)pyrene

Brunström, B., D. Broman, and C. Näf. 1991. "Toxicity and EROD-Inducing Potency of 24 Polycyclic Aromatic Hydrocarbons (PAHs) in Chick Embryos." *Archives of Toxicology.* Volume 65. Pages 485-489.

Polychlorinated Biphenyls

Peakall, D.B., J.L. Lincer, S.E. Bloom. 1972. "Embryonic Mortality and Chromosomal Alterations Caused by Aroclor 1254 in Ring Doves." *Environmental Health Perspectives.* Volume 1. Pages 103-104.

Dahlgren, R.B., R.L. Linder, and C.W. Carlson. 1972. "Polychlorinated Biphenyls: Their Effects on Penned Pheasants." *Environmental Health Perspectives*. Volume 1. Pages 89-101.

McLane, M.A.R., and D.L. Hughes. 1980. "Reproductive Success of Screech Owls Fed Aroclor 1248." *Archives of Environmental Contamination and Toxicolog*. Volume 9. Pages 661-665.

1,3-Dinitrobenzene

Schafer, E.W. 1972. "The Acute Oral Toxicity of 369 Pesticidal, Pharmaceutical and Other Chemicals to Wild Birds." *Toxicological and Applied Pharmacology.* Volume 21. Pages 315-330.

TABLE E-8

BIRD TOXICITY REFERENCE VALUES

Pentachloronitrobenzene

Dunn, J. S., P. B. Bush, N. H. Booth, R.L. Farrell, D. M. Thomason, and D. D. Goetsch. 1979. Effect of Pentachloronitrobenzene upon Egg Production, Hatchability, and Residue Accumulation in the Tissues of White Leghorn Hens. *Toxicology and Applied Pharmacology.* Volume 48. Pages 425-433.

Bis(2-ethylhexyl)phthalate

Peakall, D.B. 1974. "Effects of Di-n-butyl and Di-2-ethylhexyl Phthalate on the Eggs of Ring Doves. *Bulletin of Environmental Contamination and Toxicology.*" Volume 12. Pages 698-702.

Acetone

Hill, E.F., and M.B. Camardese. 1986. "Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix." Fish and Wildlife Service. Technical Report 2.

1,4-Dioxane

Giavini, E., C. Vismara, and L. Broccia. 1985. "Teratogenesis Study of Dioxane in Rats." *Toxicology Letters*. Volume 26. Pages 85-88. This study did not evaluate an ecologically relevant endpoint. Therefore, the data were not used to develop a TRV.

Hexachlorobenzene

Hill, E.F., and M.B. Camardese. 1986. "Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix." Fish and Wildlife Service. Technical Report 2.

Hexachlorobutadiene

Schwetz, B.A., J.M. Norris, R.J. Kociba, P.A. Keeler, R.F. Cornier, and P.J. Gehring. 1974. "Reproduction Study in Japanese Quail Fed Hexachlorobutadiene for 90 Days." *Toxicology and Applied Pharmacology*. Volume 30. Pages 255-265.

Pentachlorophenol

Hill, E.F., and M.B. Camardese. 1986. "Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix." Fish and Wildlife Service. Technical Report 2.

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BIRD TOXICITY REFERENCE VALUES

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4,4'-DDE

Hill, E.F., and M.B. Camardese. 1986. "Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix." Fish and Wildlife Service. Technical Report 2.

Mendenhall, V.M., E.E. Klaas, and M.A.R. McLane. 1983. "Breeding Success of Barn Owls (*Tyto alba*) Fed Low Levels of DDE and Dieldrin." *Archives of Environmental Contamination and Toxicology. Volume*12. Pages 235-240.

Shellenberger, T.E. 1978. "A Multi-Generation Toxicity Evaluation of P-P'-DDT and Dieldrin with Japanese Quail. I. Effects on Growth and Reproduction." *Drug Chemistry and Toxicology. Volume* 1. Pages 137-146

Heptachlor

Hill, E.F., and M.B. Camardese. 1986. "Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix." Fish and Wildlife Service. Technical Report 2.

Hexachlorophene

Meister, R.J. (ed.) 1994. *Farm Chemicals Handbook '94*. Meister Publishing Company, Willoughby, Ohio. Volume 80. Page C189.

Aluminum

Carriere, D., K.L. Fischer, D.B. Peakall, and P. Anghern. 1986. "Effects of Dietary Aluminum Sulphate on Reproductive Success and Growth of Ringed Turtle Doves (*Streptopelia risoria*)." *Canadian Journal of Zoology*. Volume 64. Pages 1500-1505.

Carriere, D., K. Fischer, D. Peakall, and P. Angehrn. 1986. "Effects of Dietary Aluminum in Combination with Reduced Calcium and Phosphorus on the Ring Dove (*Streptopelia risoria*)." *Water, Air, and Soil Pollution*. Volume 30. Pages 757-764.

Antimony

Ridgeway, L.P. and D.A. Karnofsky. 1952. "The Effects of Metals on the Chick Embryo: Toxicity and Production of Abnormalities in Development." *Annals of New York Academy of Sciences*. Volume 55. Pages 203-215.

TABLE E-8

BIRD TOXICITY REFERENCE VALUES

Arsenic

U.S. Fish and Wildlife Service. 1969. "Publication 74." Bureau of Sport Fisheries and Wildlife. As cited in Sample, Opresko, and Suter II (1996).

Barium

Johnson, D., Jr., A.L. Mehring, Jr., and H.W. Titus. 1960. "Tolerance of Chickens for Barium." *Proceedings o fthe Society for Experimental Biology and Medicine.* Volume 104. Pages 436-438.

Cadmium

White, D.H., and M.T. Finley. 1978. "Uptake and Retention of Dietary Cadmium in Mallard Ducks." *Environmental Research.* Volume 17. Pages 53-59.

Chromium

Haseltine, S.D., and others. 1985. "Effects of Chromium on Reproduction and Growth of Black Ducks." As cited in U.S. Fish and Wildlife Service. 1986. *Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* January. Page 38.

Copper

Mehring, A.L.Jr., J.H. Brumbaugh, A.J. Sutherland, and H.W. Titus. 1960. "The Tolerance of Growing Chickens for Dietary Copper." *Poultry Science.* Volume 39. Pages 713-719.

Cyanide

Wiemeyer, S.N., E.F. Hill, J.W. Carpenter, and A.J. Krynitsky. 1986. "Acute Oral Toxicity of Sodium Cyanide in Birds." *Journal of Wildlife Diseases.* Volume 22. Pages 538-46.

Lead

Kendall, R.J., and P.F. Scanlon. 1982. "The Toxicology of Ingested Lead Acetate in Ringed Turtle Doves *Stretopelia risoria.*" *Environmental Pollution.* Volume 27. Pages 255-262.

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BIRD TOXICITY REFERENCE VALUES

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Edens, F., W.E. Benton, S J. Bursian, and G.W. Morgan. 1976. "Effect of Dietary Lead on Reproductive Performance in Japanese Quail, *Coturnix coturnix japonica*." *Toxicology and Applied Pharmacology*. Volume 38. Pages 307-314.

Pattee, O.H. 1984. "Eggshell Thickness and Reproduction in American Kestrels Exposed to Chronic Dietary Lead." *Archives of Environmental Contamination and Toxicology*. Volume 13. Pages 29-34.

Mercuric chloride

Hill, E.F., and M.B. Camardese. 1986. "Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix." Fish and Wildlife Service. Technical Report 2.

Hill, E. F. and C. S. Schaffner. 1976. "Sexual Maturation and Productivity of Japanese Quail Fed Graded Concentrations of Mercuric Chloride." *Poultry Science*. Volume 55. Pages 1449-1459.

Methyl mercury

Heinz, G.H. 1979. "Methylmercury: Reproductive and Behavioral Effects on Three Generations of Mallard Ducks." *Journal of Wildlife Management*. Volume 43. Pages 394-401.

Spann, J.W., G.H. Heinz, M.B. Camardese, E.F. Hill, J.F. Moore, and H.C. Murray. 1986. "Differences in Mortality Among Bobwhite Fed Methylmercury Chloride Dissolved in Various Carriers." *Environmental Toxicology and Chemistry*. Volume 5. Pages 721-724.

Nickel

Hill, E.F., and M.B. Camardese. 1986. "Lethal Dietary Toxicities of Environmental Contaminants and Pesticides to Coturnix." Fish and Wildlife Service. Technical Report 2.

Cain, B.W., and E.A. Pafford. 1981. "Effects of Dietary Nickel on Survival and Growth of Mallard Ducklings." *Archives of Environmental Contamination and Toxicology*. Volume 10. Pages 737-745.

Selenium

Heinz, G., and others. 1987. "Research at Patuxent Wildlife Research Center." As cited in Sample, Opresko, and Suter II (1996).

Heinz, G.H., D.J. Hoffman, A.J. Krynitsky, and D.M.G. Weller. 1987. "Reproduction in Mallards Fed Selenium." *Environmental Toxicology and Chemistry*. Volume 6. Page 423-433.

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Heinz, G.H., D.J. Hoffman, and L.G. Gold. 1989. "Impaired Reproduction of Mallards Fed an Organic Form of Selenium." *Journal of Wildlife Management*. Volume 53. Pages 418-428.

Sample, B.E., D.M. Opresko, G.W. Suter II. 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision.* Risk Assessment Program Health Sciences Research Division, Oak Ridge, Tennessee. Prepared for U.S. Department of Energy.

Silver

U.S. EPA. 1997. Aquatic Toxicity Information Retrieval Database (AQUIRE). Office of Research and Development, National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division. January.

Thallium

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APPENDIX H

SITE-SPECIFIC SOIL SCREENING LEVELS

SITE-SPECIFIC SOIL SCREENING LEVELS[23]

This is an OPTIONAL step that may be appropriate for large facilities which are screening a number of sites with similar habitats for common COPECs. It provides a method for calculating levels of COPECs in abiotic media that should not represent an excessive risk to the ecosystem as a whole because of the conservative assumptions in this method. The media specific screening levels are only protective of the food web exposure pathways for which they were derived; their appropriateness needs to be verified on a site-specific basis.

Establish ecologically based screening levels (EBSLs)

Site specific ecologically based screening levels (EBSLs) are calculated using the dietary exposure model and TRVs developed during the ecoscreen. EBSLs are determined by assembling a reliable set of TRVs from the available toxicity data. These TRVs are used to represent the maximum safe daily ingested dose for class-specific guild measurement receptors or media concentrations for community measurement receptors. In calculating these media concentrations it is assumed that there is no possibility for the transport of contamination between media. EBSLs cannot be calculated for sites where contamination may be transported from one media to another since this transport would alter the media concentration or dose ingested to differ from that calculated using the equations. The dose or media concentration is then put into the equations for each community and feeding guild measurement receptor, which are then solved for the allowable concentration in the media. For community receptors the media would be the one for the community, and for the guild measurement receptors all contaminated media would be included as a route of exposure. For each receptor, acceptable media levels would need to be calculated for all complete pathways. Once the calculations were completed for all receptors, the lowest calculated screening level for each media would be the EBSL for that media.

Calculate screening level hazard quotients (SLHQ) for individual COPECs

A screening level hazard quotient (SLHQ) can be calculated for each COPEC in each media found at each of the sites by dividing the maximum COPEC concentration found at the site by the EBSL developed above for that COPEC. These SLHQ can be used both to screen out sites that do not represent excessive ecological risk and to prioritize the different media at a single site for corrective action.

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[23]See Section 6.0 for limitations of ecologically-based media screening levels.

APPENDIX I

NM WQCC Standards for Surface Water

STATE OF NEW MEXICO

STANDARDS FOR
INTERSTATE AND INTRASTATE SURFACE WATERS

Filed with State Records Center
January 24, 2000
As NMAC 6.1
Effective February 23, 2000

New Mexico Water Quality Control Commission
Harold Runnels Building
1190 St. Francis Drive P.O. Box 26110
Santa Fe, New Mexico 87502

Constituent Agencies:

Environment Department
State Engineer Office
Game and Fish Department
Oil Conservation Division
Department of Agriculture
State Parks Division
Soil and Water Conservation Commission
Bureau of Mines and Mineral Resources
Members-at-Large

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3000. SUBPART III - NUMERIC STANDARDS APPLICABLE TO ATTAINABLE OR DESIGNATED USES.

[2-23-2000]

[3001 - 3099] Reserved.

3100. STANDARDS APPLICABLE TO ATTAINABLE OR DESIGNATED USES UNLESS OTHERWISE SPECIFIED IN SUBPART II OF THIS PART (SECTIONS 2000 through 2999).

A. Coldwater Fishery: Dissolved oxygen shall not be less than 6.0 mg/L, temperature shall not exceed 20°C (68°F), and pH shall be within the range of 6.6 to 8.8. The acute and chronic standards set out in Section 3100.J of this Part are applicable to this use. The total ammonia standards set out in Section 3100.N of this Part are applicable to this use.

B. Domestic Water Supply: Surface waters of the State designated for use as domestic water supplies shall not contain substances in concentrations that create a lifetime cancer risk of more than one cancer per 100,000 exposed persons. The following numeric standards shall not be exceeded:

Dissolved antimony	0.006	mg/L
Dissolved arsenic	0.05	mg/L
Dissolved barium	2.	mg/L
Dissolved beryllium	0.004	mg/L
Dissolved cadmium	0.005	mg/L
Dissolved chromium	0.1	mg/L
Dissolved cyanide	0.2	mg/L
Dissolved lead	0.05	mg/L
Total mercury	0.002	mg/L
Dissolved nickel	0.1	mg/L
Dissolved nitrate (as N)	10.	mg/L
Dissolved selenium	0.05	mg/L
Dissolved thallium	0.002	mg/L
Dissolved uranium	5.0	mg/L
Radium-226 + radium-228	5.	pCi/L
Strontium-90	8	pCi/L
Tritium	20,000	pCi/L
Gross alpha (including radium-226, but excluding radon and uranium)	15	pCi/L

C. High Quality Coldwater Fishery: Dissolved oxygen shall not be less than 6.0 mg/L, temperature shall not exceed 20°C (68°F), pH shall be within the range of 6.6 to 8.8, total organic carbon shall not exceed 7 mg/L, turbidity shall not exceed 10 NTU (25 NTU in certain reaches where natural background prevents attainment of lower turbidity), and conductivity (at 25°C) shall not exceed a limit varying between 300 μmhos/cm and 1,500 μmhos/cm depending on the natural background in particular surface waters of the State (the intent of this standard is to prevent excessive increases in dissolved solids which would result in changes in community

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structure). The acute and chronic standards set out in Section 3100.J of this Part are applicable to this use. The total ammonia standards set out in Section 3100.N of this Part are applicable to this use.

D. Irrigation: The monthly geometric mean of fecal coliform bacteria shall not exceed 1,000/100 mL; no single sample shall exceed 2,000/100 mL. The following numeric standards shall not be exceeded:

Dissolved aluminum	5.0	mg/L
Dissolved arsenic	0.10	mg/L
Dissolved boron	0.75	mg/L
Dissolved cadmium	0.01	mg/L
Dissolved chromium	0.10	mg/L
Dissolved cobalt	0.05	mg/L
Dissolved copper	0.20	mg/L
Dissolved lead	5.0	mg/L
Dissolved molybdenum	1.0	mg/L
Dissolved selenium	0.13	mg/L
Dissolved selenium in presence of >500 mg/L SO_4	0.25	mg/L
Dissolved vanadium	0.1	mg/L
Dissolved zinc	2.0	mg/L

E. Limited Warmwater Fishery: Dissolved oxygen shall not be less than 5 mg/L, pH shall be within the range of 6.6 to 9.0, and on a case by case basis maximum temperatures may exceed 32.2°C. The acute and chronic standards set out in Section 3100.J of this Part are applicable to this use. The total ammonia standards set out in Section 3100.M of this Part are applicable to this use.

F. Marginal Coldwater Fishery: Dissolved oxygen shall not be less than 6 mg/L, on a case by case basis maximum temperatures may exceed 25°C and the pH may range from 6.6 to 9.0. The acute and chronic standards set out in Section 3100.J of this Part are applicable to this use. The total ammonia standards set out in Section 3100.N of this Part are applicable to this use.

G. Primary Contact: The monthly geometric mean of fecal coliform bacteria shall not exceed 200/100 mL, no single sample shall exceed 400/100 mL and pH shall be within the range of 6.6 to 9.0.

H. Warmwater Fishery: Dissolved oxygen shall not be less than 5 mg/L, temperature shall not exceed 32.2°C (90°F), and pH shall be within the range of 6.6 to 9.0. The acute and chronic standards set out in Section 3100.J of this Part are applicable to this use. The total ammonia standards set out in Section 3100.M of this Part are applicable to this use.

I. Fish culture, secondary contact, and municipal and industrial water supply and storage are also designated in particular classified waters of the State where these uses are actually being realized. However, no numeric standards apply uniquely to these uses. Water quality adequate

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for these uses is ensured by the general standards and numeric standards for bacterial quality, pH, and temperature which are established for all classified waters of the State listed in Subpart II of this Part (Sections 2000 through 2999).

J. The following schedule of numeric standards and equations for the substances listed shall apply to the subcategories of fisheries identified in Section 3100 of this Part:

1. Acute Standards

Dissolved aluminum	750	µg/L
Dissolved arsenic	340	µg/L
Dissolved beryllium	130	µg/L
Total mercury	2.4	µg/L
Total recoverable selenium	20.0	µg/L
Dissolved silver	$e^{(1.72[\ln(\text{hardness})]-6.6825)}$	µg/L
Cyanide, weak acid dissociable	22.0	µg/L
Total chlordane	2.4	µg/L
Dissolved cadmium	$(e^{(1.128[\ln(\text{hardness})]-3.6867)})\text{cf}$	µg/L

The hardness-dependent formulae for cadmium must be multiplied by a conversion factor (cf) to be expressed as dissolved values. The acute factor for cadmium is cf = 1.136672 - [(ln hardness)(0.041838)].

Dissolved chromium	$e^{(0.819[\ln(\text{hardness})]+2.5736)}$	µg/L
Dissolved copper	$e^{(0.9422[\ln(\text{hardness})]-1.7408)}$	µg/L
Dissolved lead	$(e^{(1.273[\ln(\text{hardness})]-1.46)})\text{cf}$	µg/L

The hardness-dependent formulae for lead must be multiplied by a conversion factor (cf) to be expressed as dissolved values. The acute and chronic factor for lead is cf = 1.46203 - [(ln hardness)(0.145712)].

Dissolved nickel	$e^{(0.8460[\ln(\text{hardness})]+2.253)}$	µg/L
Dissolved zinc	$e^{(0.8473[\ln(\text{hardness})]+0.8618)}$	µg/L
Total chlorine residual	19	µg/L

2. Chronic Standards

Dissolved aluminum	87.0	µg/L
Dissolved arsenic	150	µg/L
Dissolved beryllium	5.3	µg/L
Total mercury	0.012	µg/L
Total recoverable selenium	5.0	µg/L
Cyanide, weak acid dissociable	5.2	µg/L
Total chlordane	0.0043	µg/L
Dissolved cadmium	$(e^{(0.7852[\ln(\text{hardness})]-[2.715])})\text{cf}$	µg/L

The hardness-dependent formulae for cadmium must be multiplied by a conversion factor (cf) to be expressed as dissolved values. The chronic factor for cadmium is cf = 1.101672 - [(ln hardness)(0.041838)].

Dissolved chromium	$e^{(0.819[\ln(\text{hardness})]+0.534)}$	µg/L

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Dissolved copper	$e^{(0.8545[\ln(hardness)]-1.7428)}$	µg/L
Dissolved lead	$(e^{(1.273[\ln(hardness)]-4.705)})cf$	µg/L

The hardness-dependent formulae for lead must be multiplied by a conversion factor (cf) to be expressed as dissolved values. The acute and chronic factor for lead is cf = 1.46203 - [(ln hardness)(0.145712)].

Dissolved nickel	$e^{(0.846[\ln(hardness)]+0.0554)}$	µg/L
Dissolved zinc	$e^{(0.8473[\ln(hardness)]+0.8699)}$	µg/L
Total chlorine residual	11	µg/L

K. Livestock Watering: The following numeric standards shall not be exceeded:

Dissolved aluminum	5.0	mg/L
Dissolved arsenic	0.2	mg/L
Dissolved boron	5.0	mg/L
Dissolved cadmium	0.05	mg/L
Dissolved chromium	1.0	mg/L
Dissolved cobalt	1.0	mg/L
Dissolved copper	0.5	mg/L
Dissolved lead	0.1	mg/L
Total mercury	0.01	mg/L
Dissolved selenium	0.05	mg/L
Dissolved vanadium	0.1	mg/L
Dissolved zinc	25.0	mg/L
Radium-226 + radium-228	30.0	pCi/L
Tritium	20,000	pCi/L
Total gross alpha (including radium-226, but excluding radon and uranium)	15	pCi/L

L. Wildlife Habitat: Wildlife habitat should be free from any substances at concentrations that are toxic to or will adversely affect plants and animals that use these environments for feeding, drinking, habitat or propagation, or can bioaccumulate and impair the community of animals in a watershed or the ecological integrity of surface waters of the State. In the absence of site-specific information, and subject to the following paragraph, the following chronic numeric standards shall not be exceeded:

Total mercury	0.77	µg/L
Total recoverable selenium	5.0	µg/L
Cyanide, weak acid dissociable	5.2	µg/L
Total chlorine residual	11	µg/L
Total DDT and metabolites	0.001	µg/L
Total PCBs	0.014	µg/L

The discharge of substances which bioaccumulate, in excess of levels specified above is allowed if, and only to the extent that, the substances are present in the intake waters which are diverted and utilized prior to discharge, and then only if the discharger utilizes best available treatment technology to reduce the amount of bioaccumulating substances which are discharged.