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

New Mexico Environment Department
Hazardous and Radioactive Materials Bureau

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Acknowledgments

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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:

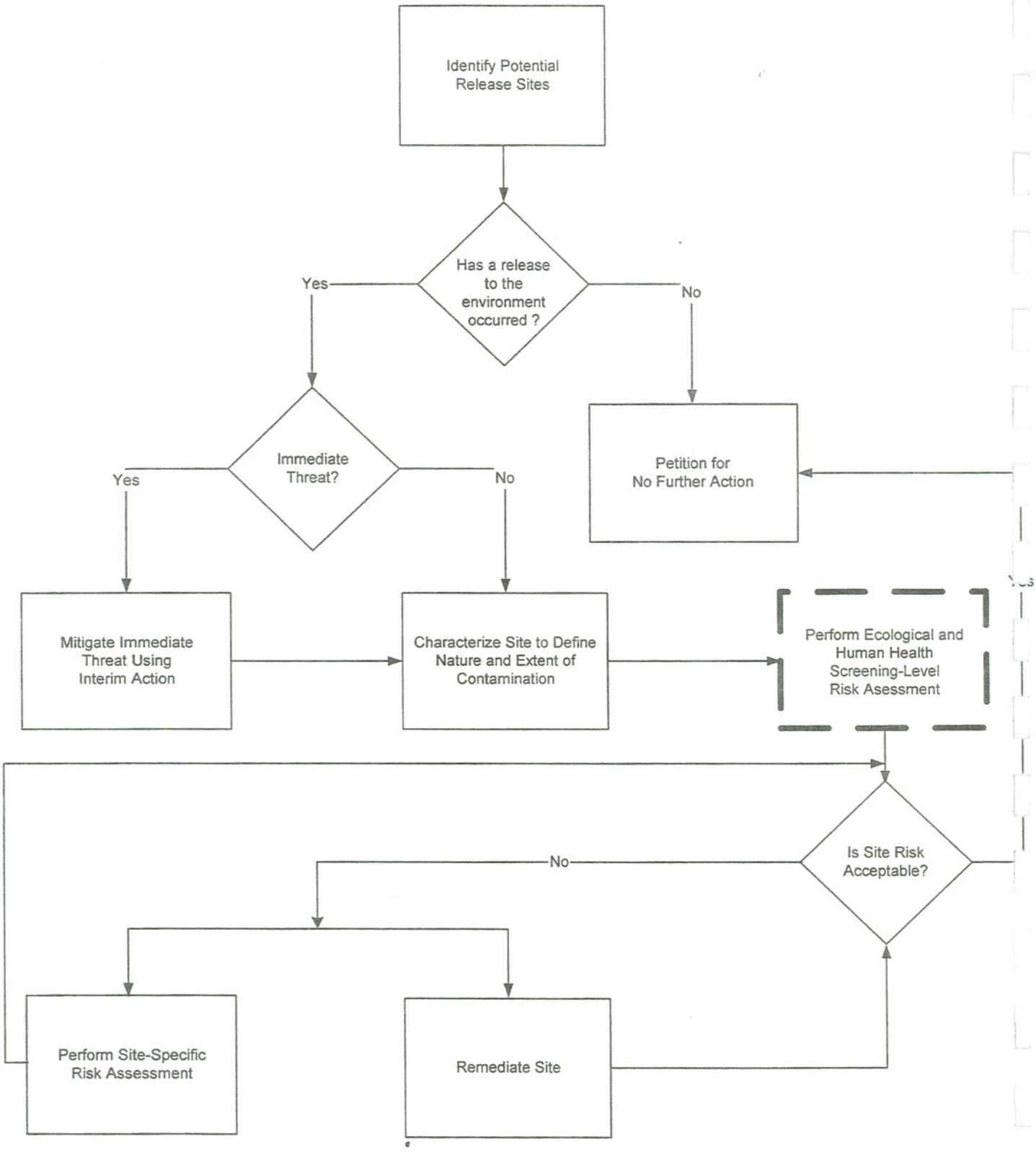
- Determining the need for interim action
- Screening sites to determine the need for
- further evaluation
- Prioritizing multiple sites
- Focusing future site-specific risk assessment efforts

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

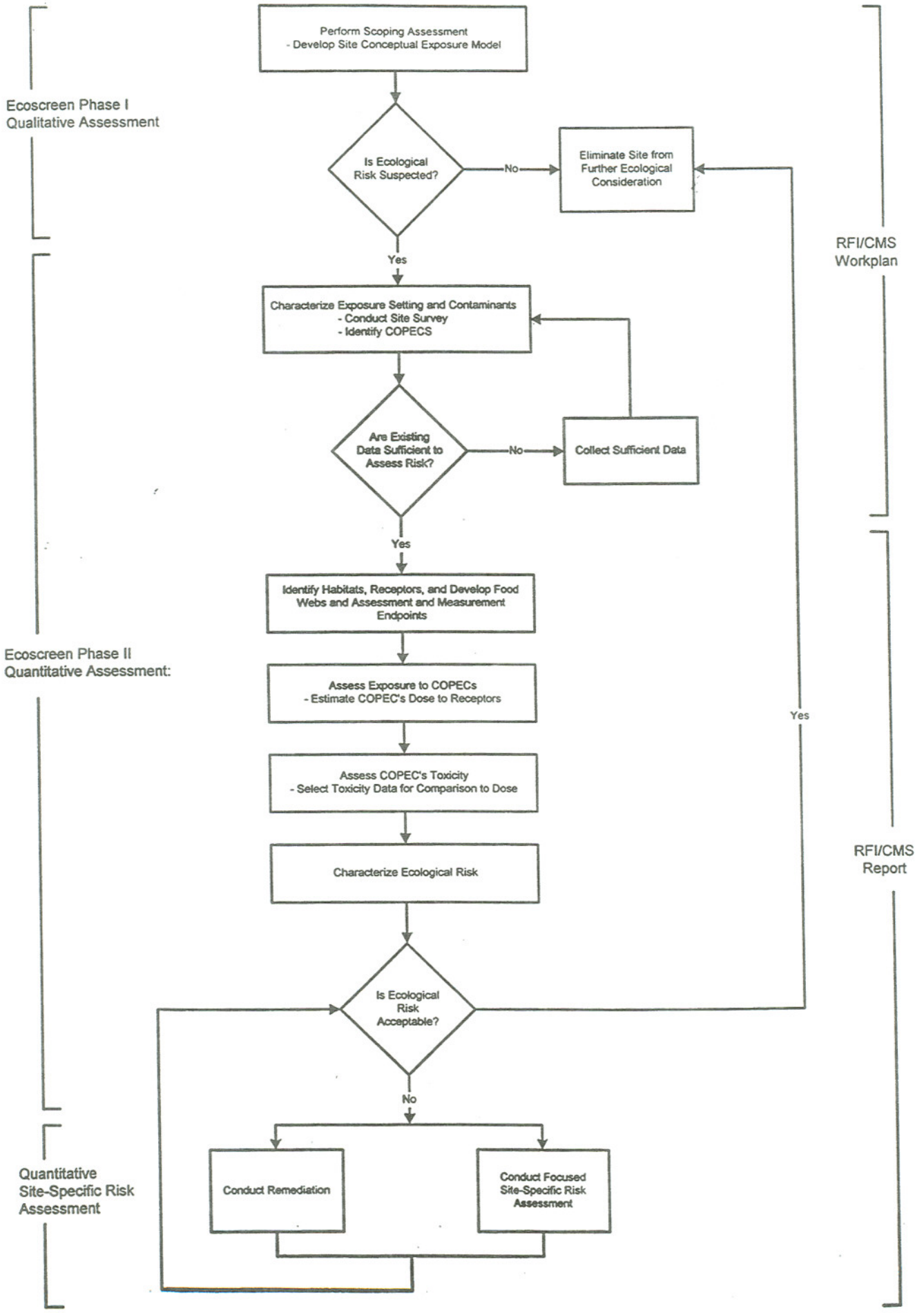
Site characterization must be sufficient to define the nature and extent of contamination in order to assess the impact on ecological receptors. To conduct a risk assessment the type, quantity, and distribution of contaminants must be identified along with migration pathways that could potentially allow 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

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[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

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[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.

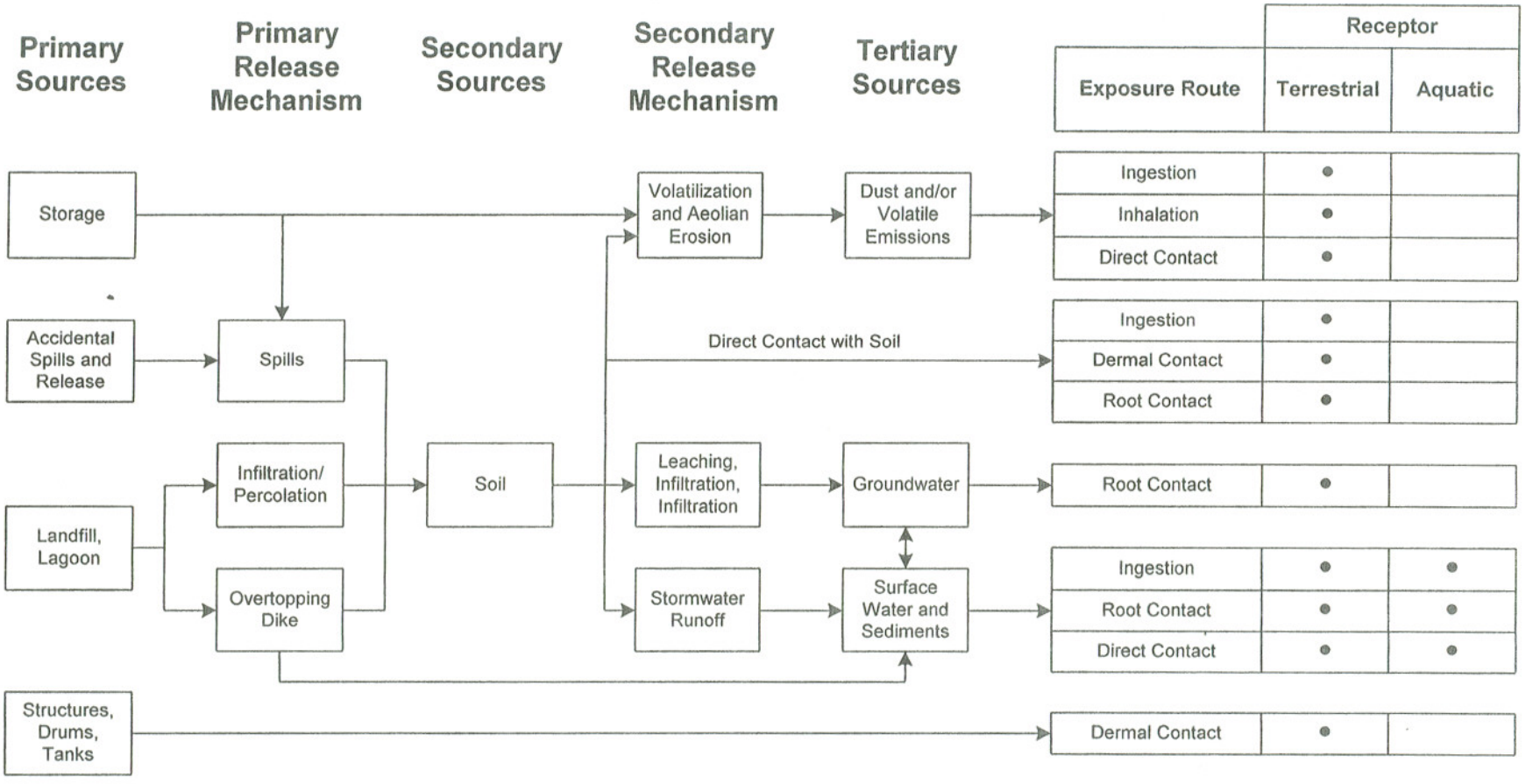

Figure 3. Example Ecological Conceptual Exposure Model for a Hypothetical Site

✦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.

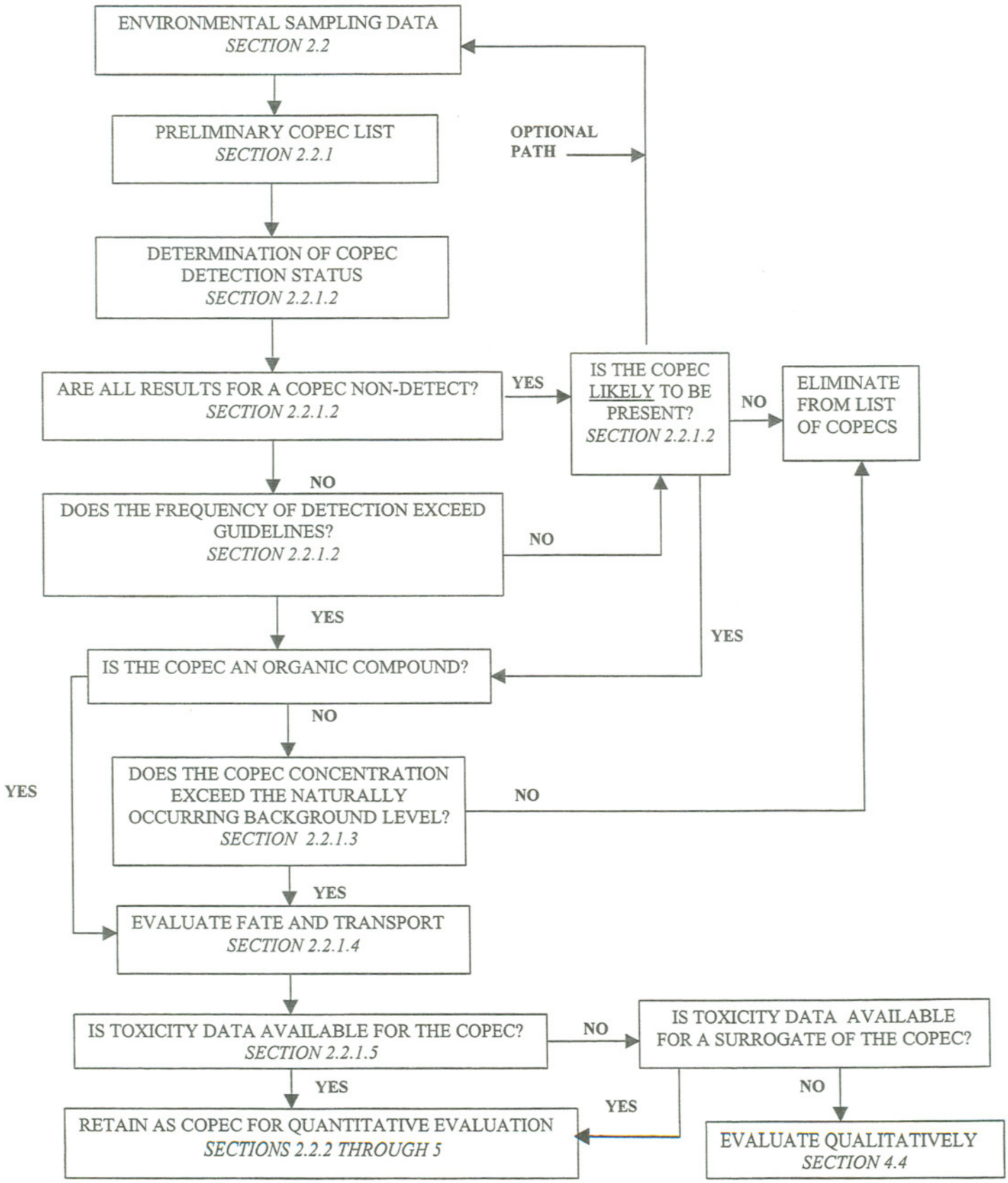
1. Gather all data available from the site investigation(s) for all preliminary COPECs and media (Section 2.2.1.1),
2. Evaluate a preliminary COPEC detection status (Section 2.2.1.2)
3. Compare preliminary COPEC concentrations with inorganic background values (Section 2.2.1.3)
4. Evaluate environmental 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

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[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 and (2) evaluation of sampling adequacy at the site and (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

[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-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-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-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-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 10^{th} 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.

REFERENCES

40 CFR 9, 122, 123, 131, and 132. Tuesday, March 23, 1996. *Final Water Quality Guidance for the Great Lakes System*; Final Rule.

Bain M.B., T.C. Hughes, and K.K. Arend. 1999. "Trends in Methods for Assessing Freshwater Habitats." *Fisheries*. Vol. 24, No. 4, pp. 16-20

Calabrese, E.J. and L.A. Baldwin. 1993. *Performing Ecological Risk Assessment.* Lewis Publishers. Chelsea, Michigan. 215 pp.

Canadian Council of Ministers of the Environment. 1995. *Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life*. Report CCME EPC-98E. Prepared by the Task Group on Water Quality Guidelines, Winnipeg, Manitoba. 38 pp.

Chapman, P.M., A. Fairbrother, and D. Brown. 1998. "A Critical Evaluation of Safety (Uncertainty) Factors for Ecological Risk Assessment." *Environmental Toxicology and Chemistry.* Vol. 17, pp. 99-108.

Connel, D.W. and R.D. Markwell. 1990. "Bioaccumulation in the Soil to Earthworm System." *Chemosphere.* Vol. 20, pp. 91-100.

Connolly J.P. and C.J. Pedersen. 1988. "A Thermodynamic-Based Evaluation of Organic Chemical Accumulation in Aquatic Organisms." *Environmental Science and Technology.* Vol. 22, No. 1, pp. 99-103.

Cooperrider A.Y., R.J. Boyd, and H.R. Stuart. 1986. *Inventory and Monitoring of Wildlife Habitat*. US Department of the Interior, Bureau of Land Management. Washington, D.C.

Dourson, M.L. and J. F. Stara. 1983. "Regulatory History and Experimental Support of Uncertainty (Safety) Factors." *Regulaory Toxicology and Pharmacology.* Vol. 3, pp.224-238.

Environment Canada. 1995. *Interim Sediment Quality Guidelines*, Soil and Sediment Quality Section Guidelines Division, Ecosystem Conservation Directorate, Evaluation and Interpretation Branch, Ottawa, Ontario

Foxx T.S., G.D. Tierney, and J.M. Williams. 1984. *Rooting Depths of Plants on Low-Level*

Waste Disposal Sites. Los Alamos National Laboratory, Los Alamos, NM. LA-10253-MS. UC-70B. 23 p.

Gilbert R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. John Willey & Sons, Inc. New York, New York

Gobas, F. 1993. "A Model for Predicting the Bioaccumulation of Hydrophobic Organic Chemicals in Aquatic Food-Webs: Application to Lake Ontario." *Ecological Modeling*. 69: 1-17.

Isensee A.R., P.C. Kearney, E.A. Woolson, G.E. Jones, and V.P. Williams. 1973. "Distribution of Alkyl Arsenicals in Model Ecosystems." *Environmental Science and Technology*. Vol. 7, No. 9, pp. 841-845

Long E.R. and L.G. Morgan. 1990. *The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program*. NOAA Technical Memorandum NOS OMA 52.

Long E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. *Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Esturine Sediments*. Environmental Management 19 (1): 81-97

MacDonald D.D. 1992. *Development of an Integrated Approach to the Assessment of Sediment Quality in Florida*. Prepared for Florida Department of Environmental Regulation. MacDonald Environmental Services, Ltd. Ladysmith, British Columbia.

Ney, R.E. 1998. *Fate and Transport of Organic Chemicals in the Environment: A Practical Guide*. Third Edition. Government Institues, Inc., Rockville, MD 371 p.

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 Quality*. Vol. 13, No. 4, pp. 651-654

Southworth, G., Beauchamp, J., and P. Schmeider. 1978. "Bioaccumulation Potential of Polycyclic Aromatic Hydrocarbons in *Daphnia Pulex*." *Water Research*. 12: 973-977.

Suter G.W., II and J.B. Mabrey. 1994. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1994 Revision*. Oak Ridge

National Laboratory, Oak Ridge, TN. ES/ER/TM-96/R1.

Taiz, L. and E. Geiger. 1991. *Plant Physiology*. Benjamin/Cammius Publishing Co. Redwood City, CA. 559 pp.

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

US EPA. 1984. *Sediment Sampling Quality Assurance User's Guide*. Environmental Monitoring Support Laboratory. Las Vegas, NV. NTIS: PB-85-233-542

US EPA. 1989 a. *Statistical Methods for Evaluating the Attainment of Cleanup Standards. Vol. 1: Soils and Solid Media.* Office of Policy, Planning, and Evaluation. Washington, D.C. EPA 230/02-89-042.

US EPA. 1989 b. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A, Baseline Risk Assessment).* Interim Final. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002. NTIS PB90-155581

US EPA. 1989 c. *Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual.* Interim Final. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/001.

US EPA. 1989 d. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance*. Office of Solid Waste, Waste Management Division, Washington, D.C. NTIS PB89-151047

US EPA. 1989 e. *Soil Sampling Quality Assurance Guide*. Review Draft. Environmental Monitoring Support Laboratory. Las Vegas, NV.

US EPA. 1992 a. *Guidance for Data Useability in Risk Assessment (Part A): Final.* Office of Emergency and Remedial Response. Washington, D.C. NTIS PB92-963356/XAB.

US EPA. 1992 b. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities*. Draft Addendum to Interim Final Guidance. Office of Solid Waste Permits and State Programs Division. Washington, D.C.

US EPA. 1992 c. *Supplemental Guidance to RAGS: Calculating the Concentration Term.* Office of Solid Waste and Emergency Response, Washington, D.C. OSWER Directive 9285.7-081.

U.S. EPA. 1993 a. *Sediment Quality Criteria for the Protection of Benthic Organisms: Acenaphthene.* September 1993.

U.S. EPA. 1993 b. *Sediment Quality Criteria for the Protection of Benthic Organisms: Dieldrin.* September 1993.

U.S. EPA. 1993 c. *Sediment Quality Criteria for the Protection of Benthic Organisms: Endrin.* September 1993.

U.S. EPA. 1993 d. *Sediment Quality Criteria for the Protection of Benthic Organisms: Fluoranthene.* September 1993.

U.S. EPA. 1993 e. *Sediment Quality Criteria for the Protection of Benthic Organisms: Phenanthrene.* September 1993.

US EPA. 1993 f. *Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria.* Memorandum from M.G. Prothro to Water Management Division Directors, ESD Directors, Regions I-X. October 1.

U.S. EPA, 1993 g. Wildlife Exposures Factor Handbook. Volume I of II. EPA/600/R-93/187. Office of Health and Environmental Assessment, Office of Research and Development, Washington, DC.

U.S. EPA. 1993 h. *Technical Basis for Deriving Sediment Quality Criteria for Nonionic Organic Contaminants for the Protection of Benthic Organisms by Using Equilibrium Partitioning.* Office of Water. Washington, D.C. EPA-822-R-93-011.

US EPA. 1994 a. *Guidance for the Data Quality Objectives Process.* EPA QA/G-4. Office of Research and Development, Washington, D.C. EPA/600/R-96/055.

US EPA. 1994 b. *RCRA Corrective Action Plan.* Final. Office of Waste Programs Enforcement, Office of Solid Waste. OSWER Directive 9902.3-24

US EPA. 1994 c. *US EPA Contract Laboratory Program National Functional Guidelines for*

Inorganic Data Review. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/R-94/013. NTIS PB94-963502.

US EPA. 1994 d. *US EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/R-94/012. NTIS PB94-963501.

US EPA. 1994 e. *Statistical Methods for Evaluating the Attainment of Cleanup Standards. Vol. 3: Reference-Based Standards for Soils and Solid Media.* Office of Policy, Planning, and Evaluation. Washington, D.C. June 1994. EPA 230-R-94-004.

US EPA Region IV. 1995 a. *Ecological Screening Values*. In: *Supplemental Guidance to RAGS: Region 4 Bulletins - Ecological Risk Assessment*, Bulletin No. 2, Waste Management Division, Atlanta, Georgia. November 1995. (http://www.epa.gov/region4/wastepgs/oftecser/otsguid.htm)

US EPA. 1995 b. *Environmental Monitoring and Assessment Program, Surface Water Field Operations and Methods for Assessing the Ecological Conditions of Wadeable Streams*. Section 6: Physical Habitat Assessment. Office of Research and Development. Cincinnati, OH. EPA/620/R-94/004

US EPA. 1995 c. *RCRA Sampling Procedures Handbook*. No EPA ID given. RCRA Technical Section Enforcement Branch, Region 6 US EPA, Dallas, TX. April.

US EPA Region V. 1996 a. *Ecological Data Quality Levels*. Office of RCRA. Chicago, Il

US EPA. 1996 b. *Ecotox Thresholds, ECO Update*, Office of Solid Waste and Emergency Response, Intermittent Bulletin Vol. 3, No. 2, Publication 9345.0-12FSI, EPA 540/F-95-038 PB95-963324 (http://www.epa.gov/superfund/oerr/r19/ecotox)

US EPA. 1996 c. *Guidance for Data Quality Assessment: Practical Methods for Data Analysis*. EPA QA/G-9. Office of Research and Development. Washington, D.C. EPA/600/R-96/084

US EPA. 1997 a. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment*. Interim Final. EPA540/R-97/006

US EPA. 1997 b. *Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers:*

Periphyton, Benthic Macroinvertebrates, and Fish. Office of Water. Washington, D.C. EPA/841/D-97/002

US EPA. 1998 a. *Test Methods for Evaluating Solid Waste.* Volume IA: Laboratory Manual Physical/Chemical Methods. November 1989 SW-846. Third Edition. Office of Solid Waste and Emergency Response, Washington, D.C.

US EPA. 1998 b. *Guidelines for Ecological Risk Assessment.* Final. Risk Assessment Forum, Washington, D.C. EPA/630/R-95/002F.

US EPA. 1999 a. *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities.* Peer Review Draft. Vol. 1. EPA-530-D-99-001A.

US EPA, 1999 b. *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities.* Peer Review Draft. Vol. 3. EPA-530-D-99-001C.

US EPA. 1999 c. *National Recommended Water Quality Criteria - Correction.* Office of Water, April 1999. EPA 822-Z-99-001.

US EPA. 1999 d. *Ecological Risk Assessment and Risk Management Principles for Superfund Sites.* Office of Solid Waste and Emergency Response. Washington, D.C. OSWER Directive 9285.7-28P.

US EPA. 1999 e. *Integrated Risk Information System (IRIS).* Duluth, Minnesota.

U.S. FWS, 1980. *Habitat Evaluation Procedures (HEP).* Ecological Services Manual 102. U.S. Fish and Wildlife Service. Washington, D.C.

APPENDIX A

SPECIES/HABITAT GUIDES

REFERENCES FOR SAMPLING GUIDANCE

EPA SITE CHECKLISTS

Brown, D.E. 1982. Biotic Communities of the American Southwest - United States and Mexico. *Desert Plants*, Vol.4, Nos. 1-4, pp. 1-324

Dunning, J.B. 1993. *CRC Handbook of Avian Body Masses*, CRC Press, Boca Raton, FL.

Elmore, F. 1976. *Shrubs and Trees of the Southwest Uplands.* Southwest parks and Monuments Association, Tuscon, AZ.

Findley, J.S. 1987. *The Natural History of New Mexico Mammals*, University of New Mexico Press, Albuquerque, NM..

Inventory of Rare and Endangered Plants of New Mexico, Third Edition, Sivinski R. and K. Lightfoot (eds), New Mexico Forestry Division, Energy, Minerals and Natural Resources Department. Miscellaneous Publication No. 4, August 1995 [http://www.emnrd.state.nm.us/endplntlistr.htm]

Kircher J. 1993. *Peterson Field Guides: Ecology of Western Forests.* Houghton Mifflin Co. Boston, MA.

Little, E. 1986. *Audobon Society Nature Guides: Trees*. Alfred A. Knopf Publisher, New York.

McMahon, J. 1986. *Audobon Society Nature Guides: Deserts*.Alfred A. Knopf Publisher, New York.

Spellenberg, R. 1986. *Audobon Society Nature Guides: Wildflowers*.Alfred A. Knopf Publisher, New York.

This portion of the Appendix contains a listing of some references that may be of value in defining the nature and extent of site environmental contamination.

1. Barth D.S., B.J. Mason, T.H. Starks, and B.J. Mason, and K.W. Brown. 1989. *Soil Sampling Quality Assurance User's Guide*. Second Edition. Environmental Monitoring and Support Laboratory. U.S. Environmental Protection Agency. Las Vegas, Nevada. EPA/600/8-89/046. March, 1989.
2. Desu M.M. and D. Raghavarao. 1990. *Sample Size Methodology*. San Diego, CA: Academic Press.
3. Devitt D.A., R.B. Evans, W.A. Jury, T.H. Starks, B. Eklund, and A. Gnolson. 1987. *Soil Gas Sensing for Detection and Mapping of Volatile Organics.* National Water Well Association. Dublin, Ohio 43017.
4. Driscoll, F.B. 1986. (New Version) *Ground Water and Wells.* Johnson Filtration Systems, Inc., St. Paul Minnesota.
5. Gilbert R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* New York: Von Nostrand Reinhold.
6. Horowitz A.J., C.R. Demas, K.K. Fitzgerald, T.L. Melelr, and D.A. Rickert. 1994. *U.S. Geological Survey Protocol for the Collection and Processing of Surface-Water Samples for the Subsequent Determination of Inorganic constituents in Filtered Water.* U.S. Geological Survey. Open-File Report 94-539. Reston, Virginia.
7. Mason B.J. 1992. *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies.* Environmental Monitoring Systems Laboratory Office of Research and Development, U.S. Environmental Protection Agency. Las Vegas, Nevada. EPA/600/R-92/128. July, 1992.
8. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods and Final Update.* SW-846. Third Edition, November 1986 and updates.
9. U.S. Environmental Protection Agency (EPA). 1984. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air.* EPA/600/4-84/041. April, 1984.
10. U.S. Environmental Protection Agency (EPA). 1984. *Characterization of Hazardous Waste Site - A methods Manual, Volume II: Available Sampling Methods.* Second Edition. EPA/600/4-84/076. December, 1984.
11. U.S. Environmental Protection Agency (EPA). 1985. *Characterization of Hazardous Waste Sites - A Methods Manual, Volume 1: Site Investigations.* EPA/600/4-84/075. April, 1985.
12. U.S. Environmental Protection Agency (EPA). 1985. *Practical Guide for Ground-Water Sampling.* EPA/600/2/85/104. September, 1985.
13. U.S. Environmental Protection Agency (EPA). 1987. *RCRA Ground-Water Monitoring Technical Enforcement Guidance Document.* OSWER-9950.1
14. U.S. Environmental Protection Agency (EPA). 1988. *Ground-Water Modeling: An Overview and Status Report.* EPA/600/2-89/028. December, 1988
15. U.S. Environmental Protection Agency (EPA). 1989. *Transport and Fate of Contaminants in the Subsurface.* EPA/625/4-89/019. September 1989.
16. U.S. Environmental Protection Agency (EPA). 1989 *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.* EPA/600/4-89/034.

October 1989.

17. U.S. Environmental Protection Agency (EPA). 1989. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities.* Interim Final. EPA/530/SW-89/026. April, 1989.
18. U.S. Environmental Protection Agency (EPA). 1989. *Statistical Methods for Evaluating the Attainment of Cleanup Standards: Volume 1: Soils and Solid Media.* Office of Policy, Planning and Evaluation. EPA 230/02-89-042.
19. U.S. Environmental Protection Agency (EPA). 1991. *Site Characterization for Subsurface Remediation.* EPA/625/4-91/026. Office of Research and Development. Washington, D.C. November, 1991.
20. U.S. Environmental Protection Agency (EPA). 1991. *Description and Sampling of Contaminated Soils.* EPA/625/12-91/002. November, 1991.
21. U.S. Environmental Protection Agency (EPA).1992. *Final Guidance for Data Useability in Risk Assessment.* Part A. OSWER Directive 9285.7-09A. April, 1992.
22. U.S. Environmental Protection Agency (EPA). 1992. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities. Draft Addendum to Interim Final Guidance.* Office of Solid Waste, Permits and State Programs Division. Washington, D.C. July, 1992.
23. U.S. Environmental Protection Agency (EPA). 1992. *RCRA Ground Water Monitoring: Draft Technical Guidance.* EPA/530-R-93-001. November, 1992.
24. U.S. Environmental Protection Agency (EPA). 1992. *Statistical Methods for Evaluating the Attainment of Cleanup Standards: Volume 3: Reference-Based Standards for Soils and Solid Media.* Office of Policy, Planning and Evaluation. EPA 230-R-94-004.
25. U.S. Environmental Protection Agency (EPA). 1992. *Statistical Methods for Evaluating the Attainment of Cleanup Standards: Volume 2: Ground Water.* Office of Policy, Planning and Evaluation. EPA 230-R-92-014.
26. U.S. Environmental Protection Agency (EPA). 1993. *Subsurface Characteristic and Monitoring Techniques, A Desk Reference Guide, Volume 1: Solids and Groundwater*(Appendices A and B) and Volume 2: *The Vadose Zone, Field Screening and Analytical Methods* (Appendices C and D). EPA/625/R-93/003 a and b. May, 1993.
27. U.S. Environmental Protection Agency (EPA). 1993. *Ground Water Sampling - A Workshop Summary.* EPA/600/R-94/205. Dallas, Texas. November 30-December 2, 1993.
28. U.S. Environmental Protection Agency (EPA). 1994. *Identification and Compilation of Unsaturated/Vadose Zone Models.* EPA/600/RA-94/028. March, 1994.
29. U.S. Environmental Protection Agency (EPA). 1994. *RCRA Corrective Action Plan.* OSWER Directive 9902.3-2A. Final, May, 1994.
30. U.S. Environmental Protection Agency (EPA). 1994. *Guidance for the Data Quality Objectives Process.* EPA QA/G-4. Office of Research and Development, Washington, D.C. EPA/600/R-96/055.
31. U.S. Environmental Protection Agency (EPA). 1995. *RCRA Sampling Procedures Handbook.* RCRA Technical Section Enforcement Branch. Region 6 US EPA, Dallas, TX. April 1995.
32. U.S. Environmental Protection Agency (EPA). 1997. *Field Analytical and Site Characterization Technologies Summary of Applications.* EPA-542-R-97-011.

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.

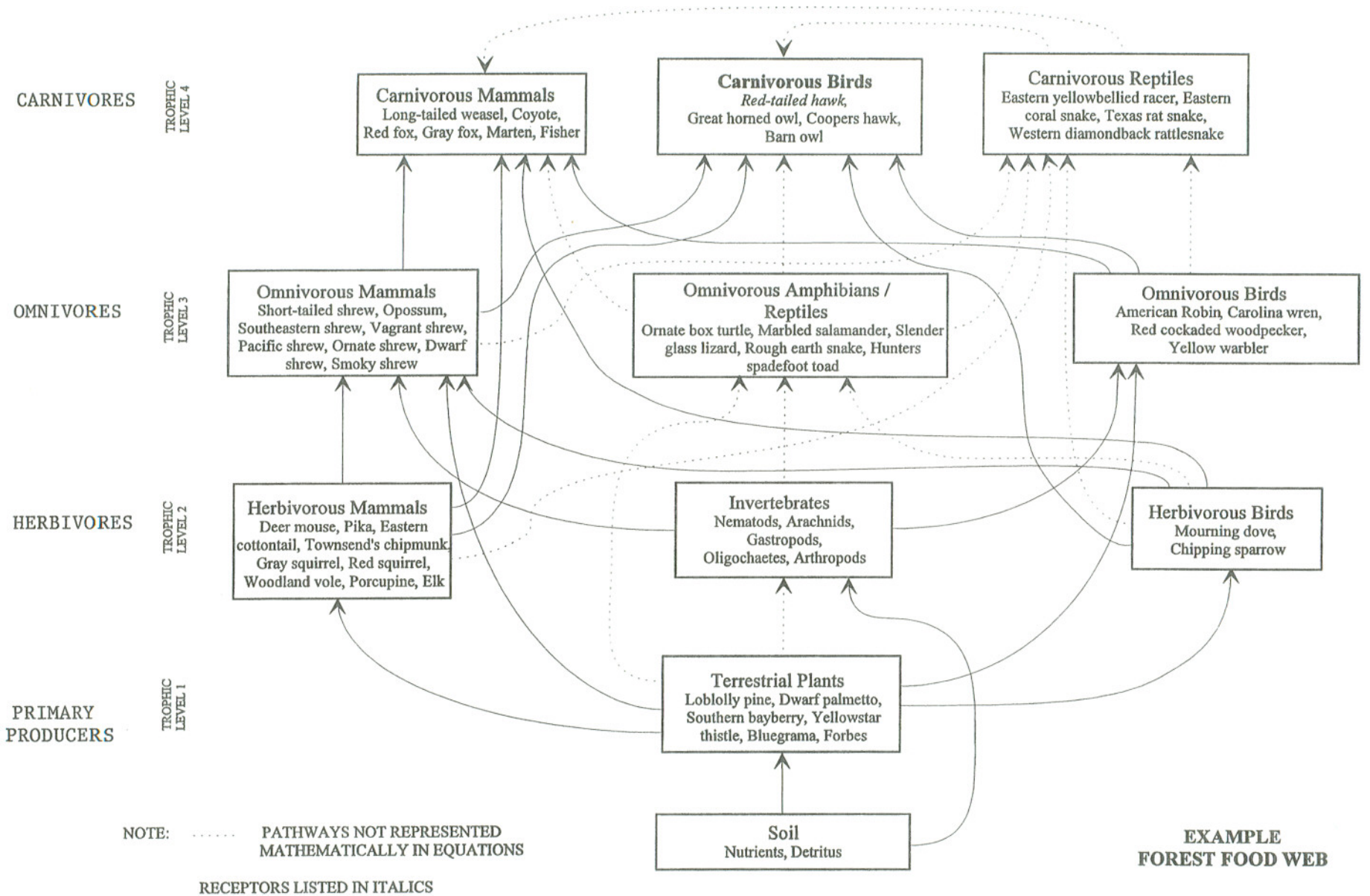
Color (blue/gray, brown, black, mottled) _____

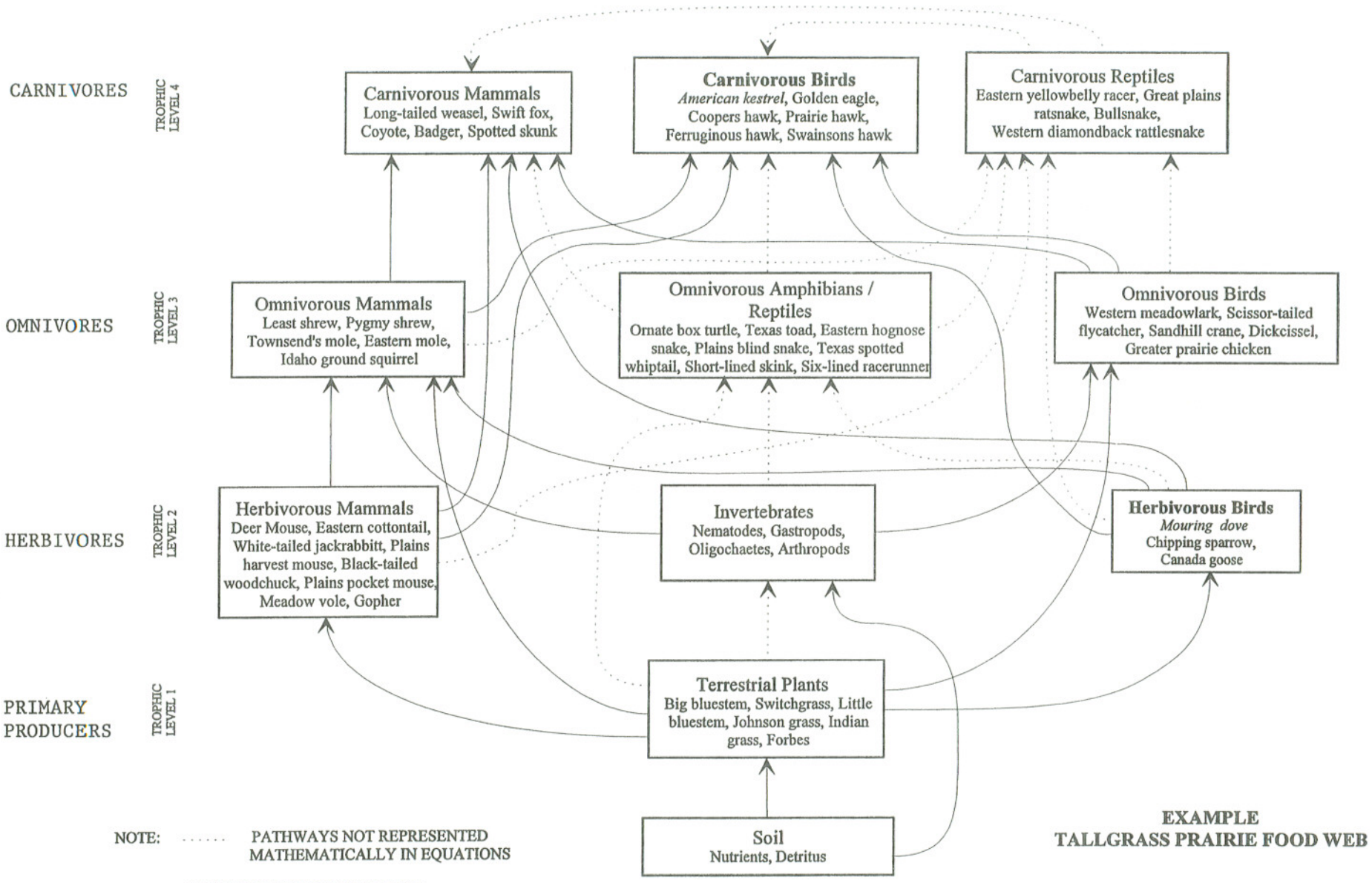
Water content (dry, wet, saturated/unsaturated) _____

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

APPENDIX B

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

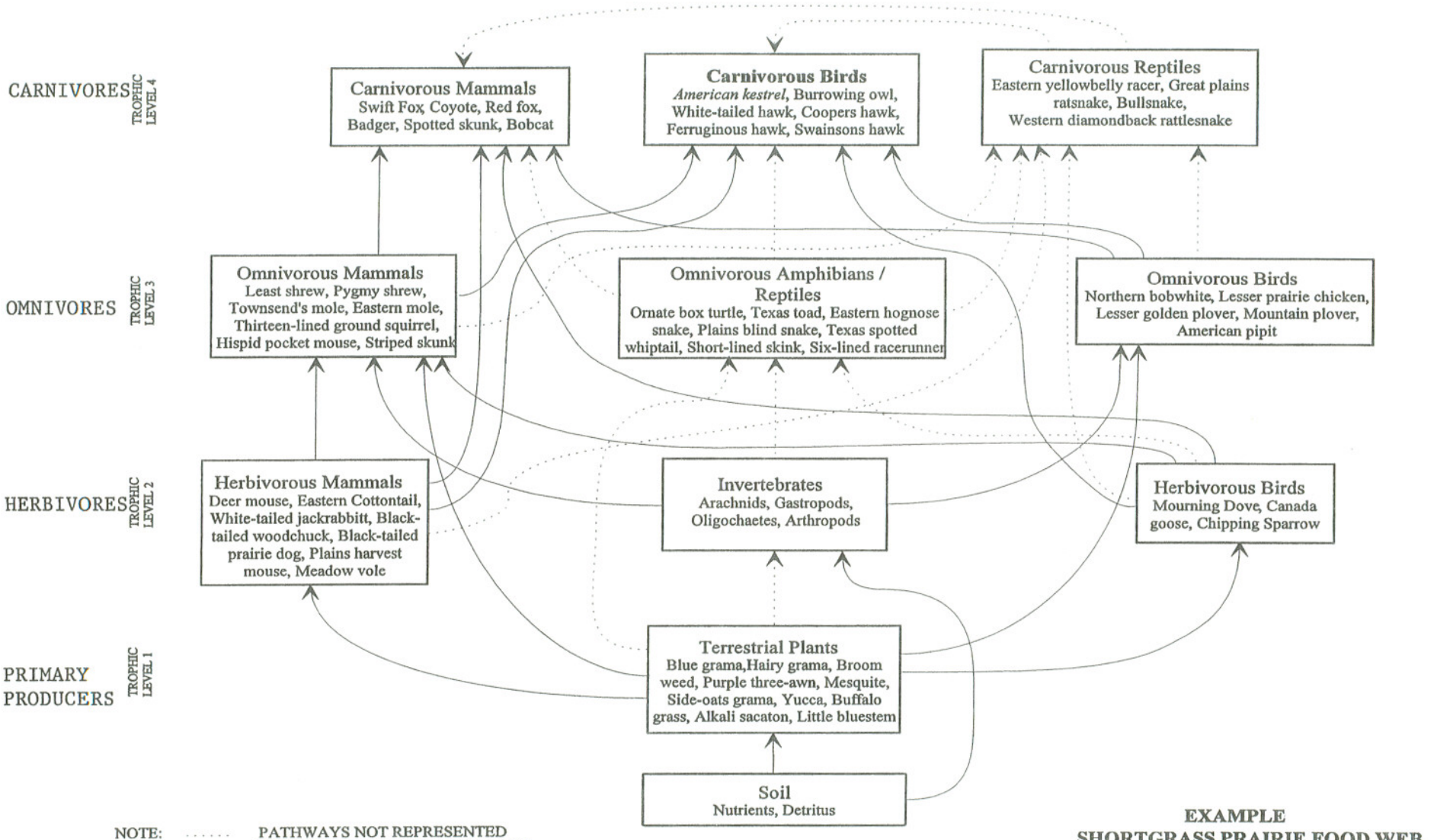

CARNIVORES
TROPHIC LEVEL 4
OMNIVORES
TROPHIC LEVEL 3
HERBIVORES
TROPHIC LEVEL 2
PRIMARY PRODUCERS
TROPHIC LEVEL 1
Carnivorous Mammals
Long-tailed weasel, Coyote, Red fox, Gray fox, Marten, Fisher
Carnivorous Birds
Red-tailed hawk, Great horned owl, Coopers hawk, Barn owl
Carnivorous Reptiles
Eastern yellowbellied racer, Eastern coral snake, Texas rat snake, Western diamondback rattlesnake
Omnivorous Mammals
Short-tailed shrew, Opossum, Southeastern shrew, Vagrant shrew, Pacific shrew, Ornate shrew, Dwarf shrew, Smoky shrew
Omnivorous Amphibians / Reptiles
Ornate box turtle, Marbled salamander, Slender glass lizard, Rough earth snake, Hunters spadefoot toad
Omnivorous Birds
American Robin, Carolina wren, Red cockaded woodpecker, Yellow warbler
Herbivorous Mammals
Deer mouse, Pika, Eastern cottontail, Townsend's chipmunk, Gray squirrel, Red squirrel, Woodland vole, Porcupine, Elk
Invertebrates
Nematods, Arachnids, Gastropods, Oligochaetes, Arthropods
Herbivorous Birds
Mourning dove, Chipping sparrow
Terrestrial Plants
Loblolly pine, Dwarf palmetto, Southern bayberry, Yellowstar thistle, Bluegrama, Forbes
Soil
Nutrients, Detritus
NOTE: ..... PATHWAYS NOT REPRESENTED MATHEMATICALLY IN EQUATIONS
RECEPTORS LISTED IN ITALICS ARE MEASUREMENT RECEPTORS
EXAMPLE FOREST FOOD WEB



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

RECEPTORS LISTED IN ITALICS ARE MEASUREMENT RECEPTORS

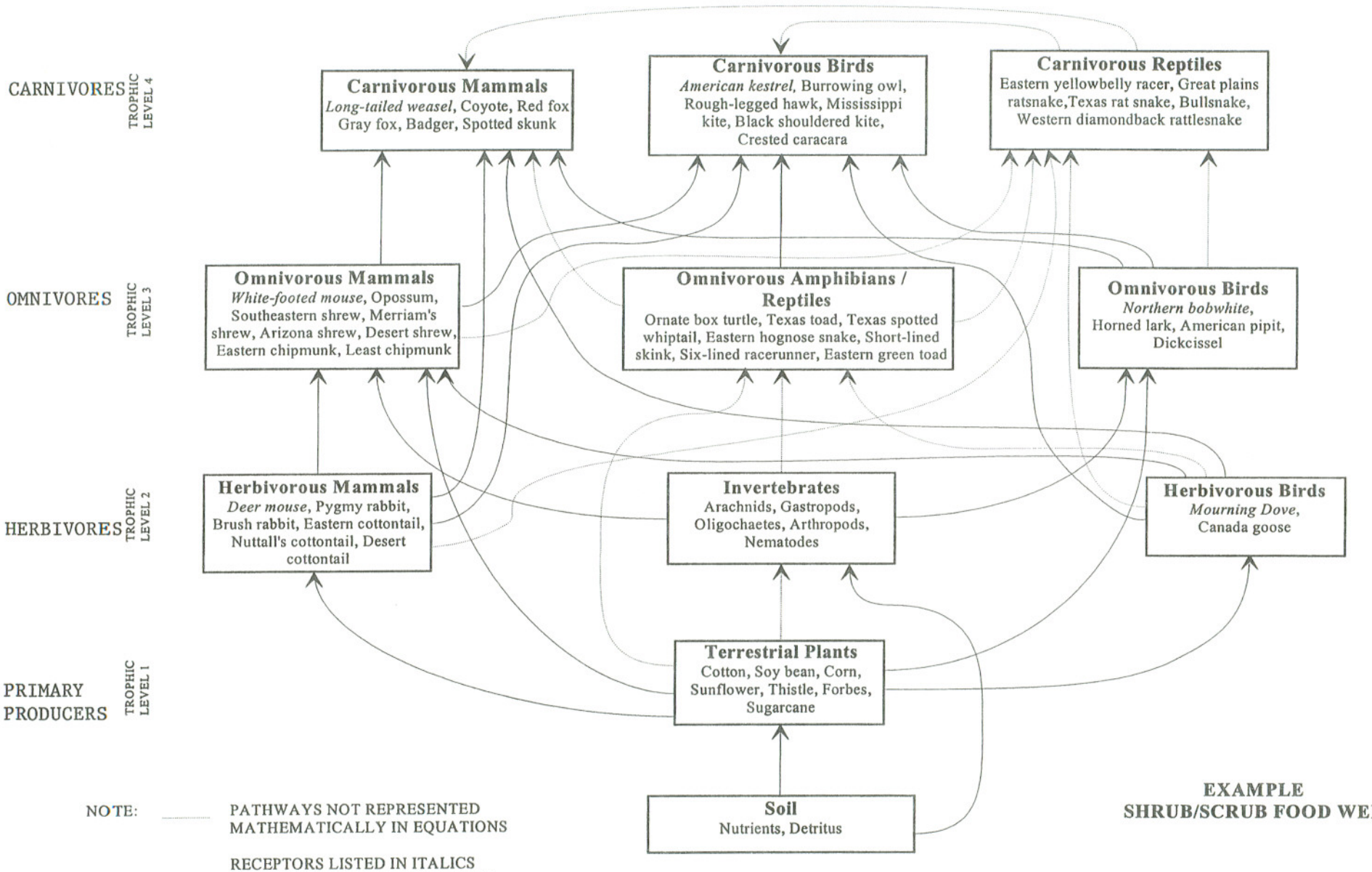
EXAMPLE TALLGRASS PRAIRIE FOOD WEB

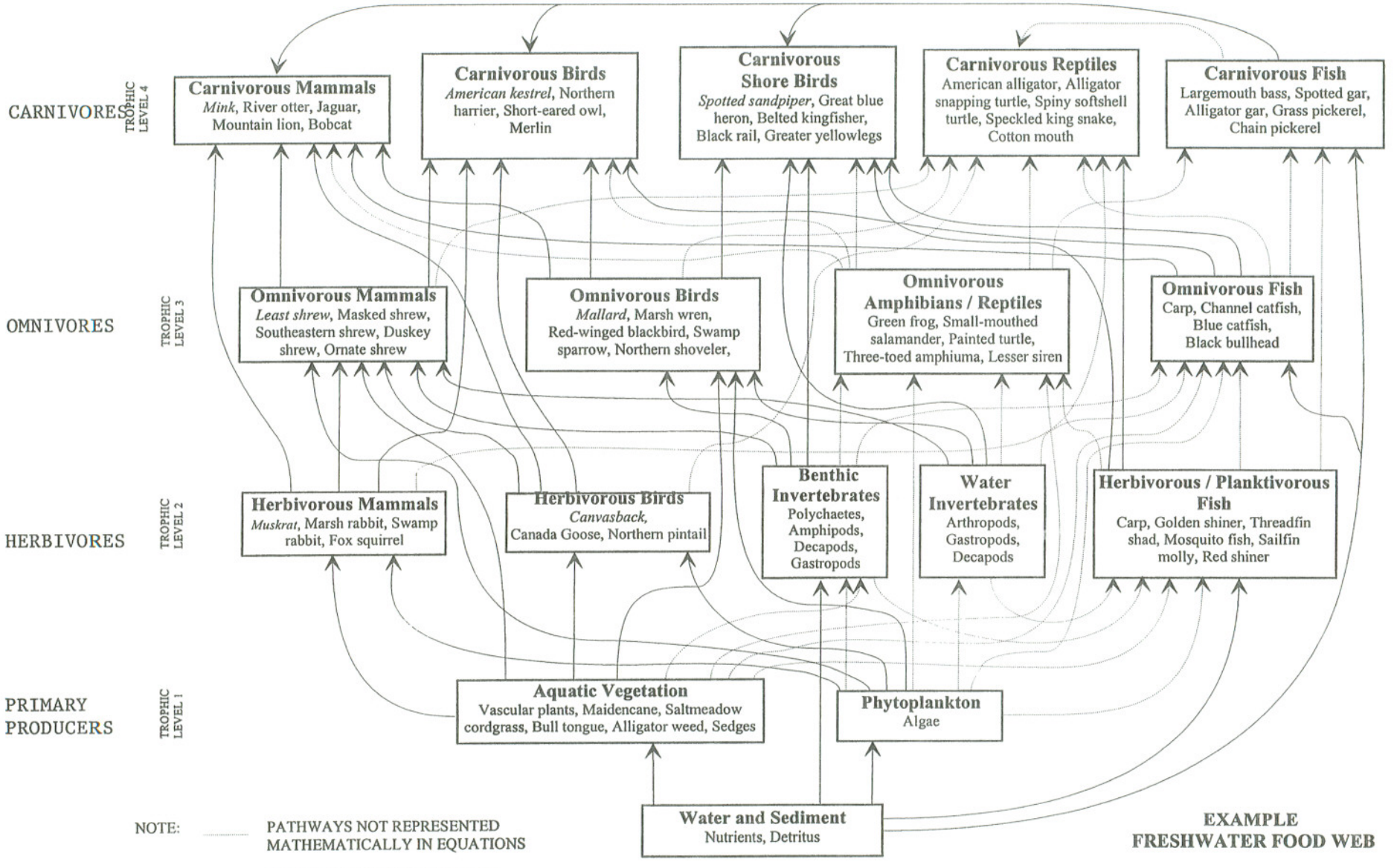


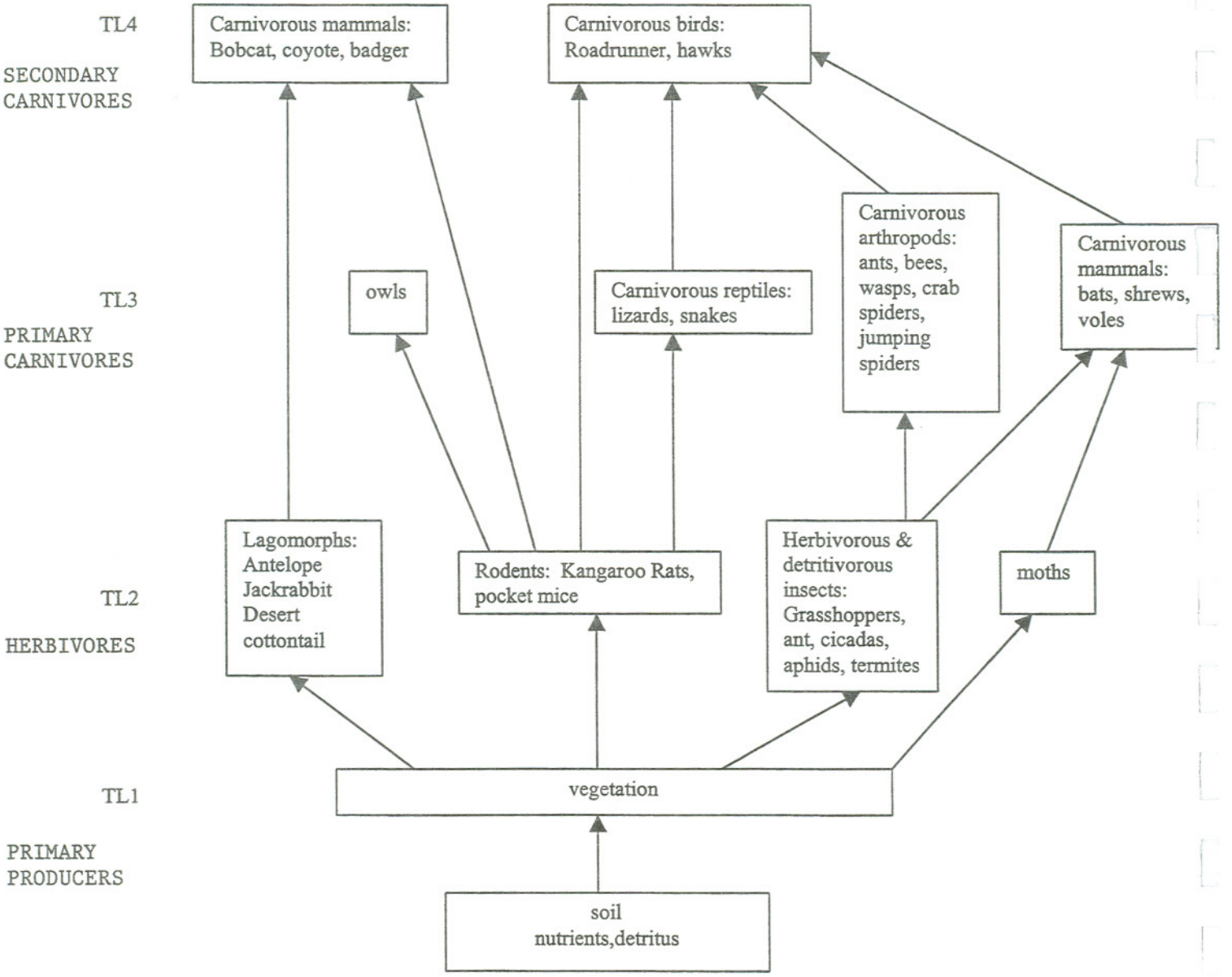
NOTE: ..... PATHWAYS NOT REPRESENTED MATHEMATICALLY IN EQUATIONS

RECEPTORS LISTED IN ITALICS ARE MEASUREMENT RECEPTORS

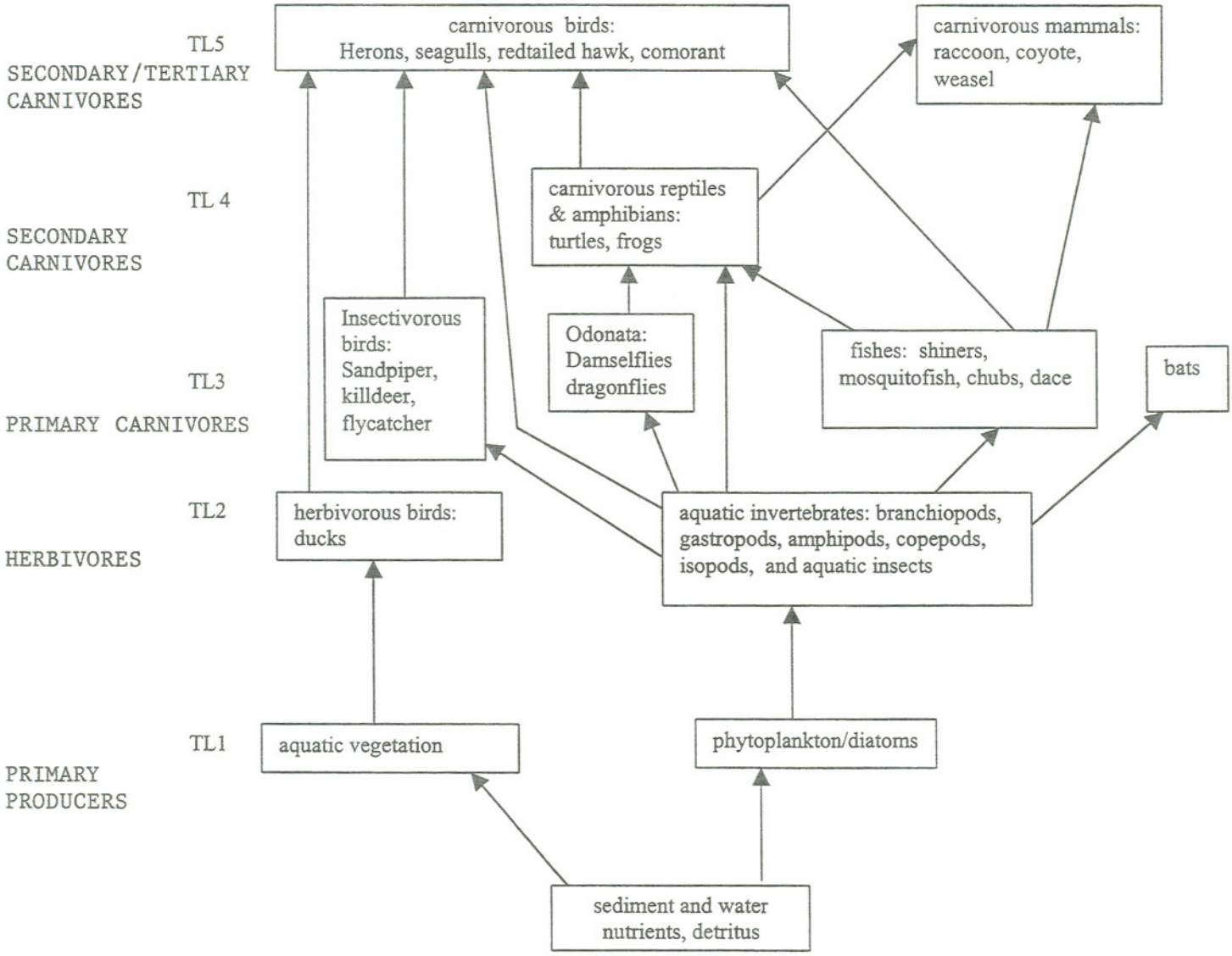
EXAMPLE SHORTGRASS PRAIRIE FOOD WEB


CARNIVORES
TROPHIC LEVEL 4
OMNIVORES
TROPHIC LEVEL 3
HERBIVORES
TROPHIC LEVEL 2
PRIMARY PRODUCERS
TROPHIC LEVEL 1
Carnivorous Mammals
Long-tailed weasel, Coyote, Red fox Gray fox, Badger, Spotted skunk
Carnivorous Birds
American kestrel, Burrowing owl, Rough-legged hawk, Mississippi kite, Black shouldered kite, Crested caracara
Carnivorous Reptiles
Eastern yellowbelly racer, Great plains ratsnake,Texas rat snake, Bullsnake, Western diamondback rattlesnake
Omnivorous Mammals
White-footed mouse, Opossum, Southeastern shrew, Merriam's shrew, Arizona shrew, Desert shrew, Eastern chipmunk, Least chipmunk
Omnivorous Amphibians / Reptiles
Ornate box turtle, Texas toad, Texas spotted whiptail, Eastern hognose snake, Short-lined skink, Six-lined racerunner, Eastern green toad
Omnivorous Birds
Northern bobwhite, Horned lark, American pipit, Dickcissel
Herbivorous Mammals
Deer mouse, Pygmy rabbit, Brush rabbit, Eastern cottontail, Nuttall's cottontail, Desert cottontail
Invertebrates
Arachnids, Gastropods, Oligochaetes, Arthropods, Nematodes
Herbivorous Birds
Mourning Dove, Canada goose
Terrestrial Plants
Cotton, Soy bean, Corn, Sunflower, Thistle, Forbes, Sugarcane
Soil
Nutrients, Detritus
NOTE:
PATHWAYS NOT REPRESENTED MATHEMATICALLY IN EQUATIONS
RECEPTORS LISTED IN ITALICS ARE MEASUREMENT RECEPTORS
EXAMPLE
SHRUB/SCRUB FOOD WEB


CARNIVORES
TROPHIC LEVEL 4
Carnivorous Mammals
Mink, River otter, Jaguar, Mountain lion, Bobcat
Carnivorous Birds
American kestrel, Northern harrier, Short-eared owl, Merlin
Carnivorous Shore Birds
Spotted sandpiper, Great blue heron, Belted kingfisher, Black rail, Greater yellowlegs
Carnivorous Reptiles
American alligator, Alligator snapping turtle, Spiny softshell turtle, Speckled king snake, Cotton mouth
Carnivorous Fish
Largemouth bass, Spotted gar, Alligator gar, Grass pickerel, Chain pickerel
OMNIVORES
TROPHIC LEVEL 3
Omnivorous Mammals
Least shrew, Masked shrew, Southeastern shrew, Duskey shrew, Ornate shrew
Omnivorous Birds
Mallard, Marsh wren, Red-winged blackbird, Swamp sparrow, Northern shoveler,
Omnivorous Amphibians / Reptiles
Green frog, Small-mouthed salamander, Painted turtle, Three-toed amphiuma, Lesser siren
Omnivorous Fish
Carp, Channel catfish, Blue catfish, Black bullhead
HERBIVORES
TROPHIC LEVEL 2
Herbivorous Mammals
Muskrat, Marsh rabbit, Swamp rabbit, Fox squirrel
Herbivorous Birds
Canvasback, Canada Goose, Northern pintail
Benthic Invertebrates
Polychaetes, Amphipods, Decapods, Gastropods
Water Invertebrates
Arthropods, Gastropods, Decapods
Herbivorous / Planktivorous Fish
Carp, Golden shiner, Threadfin shad, Mosquito fish, Sailfin molly, Red shiner
PRIMARY PRODUCERS
TROPHIC LEVEL 1
Aquatic Vegetation
Vascular plants, Maidencane, Saltmeadow cordgrass, Bull tongue, Alligator weed, Sedges
Phytoplankton
Algae
Water and Sediment
Nutrients, Detritus
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 [l]	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:

$$\text{IR kg WW/kg BW-day} = (\text{IR kg DW/BW-day})/(1 - \%\ \text{moisture}/100)$$

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.