ECOLOGICAL RISK MODULE: BACKGROUND AND IMPLEMENTATION FOR THE MULTIMEDIA, MULTIPATHWAY, AND MULTIRECEPTOR RISK ASSESSMENT (3MRA) FOR HWIR99

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Stephen Beaulieu and Jesse Baskir of Research Triangle Institute developed the Ecological Risk module. Stephen Beaulieu and Jesse Baskir of Research Triangle Institute also tested and implemented the current version of the model.

DISCLAIMER

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1.0 Module Overview and Summary of Functionality

1.1 Overview

The Ecological Risk (EcoRisk) module calculates hazard quotients[1] (HQs) for a suite of ecological receptors assigned to habitats delineated for study sites. These receptors fall into eight receptor groups: (1) mammals, (2) birds, (3) herpetofauna, (4) terrestrial plants, (5) soil community, (6) aquatic plants and algae, (7) aquatic community, and (8) benthic community. The spatial resolution of the EcoRisk module is, to a large degree, determined by both the home ranges and habitats delineated at each site. Home range areas are defined both in terms of the habitat and predator-prey interactions, that is, the home ranges are constrained by habitat boundaries[2] and represent predator-prey interactions. Spatially-averaged concentrations in media, plants, and prey items are calculated for each home range and used to estimate the applied dose to receptors in the Ecological Exposure (EcoEx) module. In addition, soil concentrations for each home range are compared to threshold concentrations for adverse effects in plants and soil biota. The habitat area is important in assessing risks to several receptor groups (e.g., benthic community; exposures and associated risks are considered across the entire habitat rather than for one or more home ranges. For example, contaminant concentrations to which the aquatic community is exposed are represented by a habitat-wide average that may include multiple stream reaches. The temporal resolution is based on annual average applied doses (for comparison with EBs) and media concentrations (for comparison with CSCLs). The HQs for the for all receptors assigned to the study site are calculated and placed into one of five risk bins developed to assist decision-makers in creating appropriate risk metrics. The HQ risk bins are used in developing cumulative distribution functions of risk and are defined as: (1) below 0.1, (2) between 0.1 and 1, (3) between 1 and 10, (4) between 10 and 100, and (5) above 100. Each of the HQs calculated by the EcoRisk module has a series of attributes associated with it that allows ecological risks to be interpreted in a number of ways. For instance, distance from the source (i.e., 1 km, 1 km to 2 km, or across the entire site) is important in understanding the spatial

[1] Hazard quotients are defined as: (1) the ratio between applied dose received from the ingestion of contaminated media and food items and an ecological benchmark (EB in units of dose), and (2) the ratio between the concentration in the medium of interest (soil, sediment, or surface water) and a chemical stressor concentration limit (CSCL in units of concentration).

[2] If the home range area is larger than the area of the habitat, the home range is presumed to extend beyond the 2 km radius that defines the area of interest, that is, habitats are exclusive. If the home range is smaller than the habitat, the entire home range is presumed to fall within the habitat boundaries within the area of interest.

character of potential ecological risks. Other attributes considered relevant to ecological risks and regulatory decision-making include the following:

- habitat type (e.g., grassland, pond, permanently flooded forest)
- habitat group (i.e., terrestrial, aquatic, and wetland);
- receptor group (e.g., mammals, amphibians, soil community); and
- trophic level (i.e., producers, TL1, TL2, TL3 top predators).

The maximum HQ across the site is also reported along with its ecological risk attributes. This metric was added for use in "pass/fail" analyses that may be need to prioritize sites for additional analyses.

In calculating receptor-specific HQs, the EcoRisk module does all of the necessary accounting to develop distributions based on the specific receptor and habitat groupings of interest. The EcoRisk module reads in information about the chemical concentrations that each receptor is exposed to, calculates hazard quotients (HQs) based on the EB or CSCL and the chemical exposure information, and provides summaries of ecological risk information for the simulation to determine when critical years with maximum HQs are experienced. For any given year, the set of HQ data is stored as a series of distributions along with their attributes. As indicated above, the cumulative frequency distributions are composed of a series of bins for different ranges of HQ values. The bins are populated based on the number of receptors with HQ values in the range defined for the given bin.

Each site is constructed as a set of habitats, each located within one or more distance rings at the site, and a set of receptors inhabiting ranges within each of those habitats. Habitats have a variety of characteristics, including a unique index identifier, a habitat type and group, a number of Reaches, a number of ranges containing receptors, and the receptors associated with each range. Reaches, habitats, and ranges also have chemical concentrations associated with them. Each receptor has an index, type, name, group, trophic level. To a large degree, the habitats reflect differences in vegetative communities based on various land use and land cover data layers. Home ranges are assigned to each habitat based on the median size of receptor species' foraging and feeding ranges. For the HWIR99 analysis, ecological receptors were grouped into 4 different home range sizes: 1,000,000,000, 10,000,000, 1,000,000, and 100,000 square meters. These home ranges were approximated for size (by an expanding a circular polygon) and randomly placed within each habitat polygon so that they overlap to reflect predator-prey relationships.

Outputs are generated for three areas of the site relative to the distance from the edge of the waste management unit. These distances are termed EcoRings and depict the following: (1) habitats that fall within 1 km of the WMU, (2) habitats that fall between 1 and 2 km from the WMU, and (3) habitats within 2 km of the WMU (i.e. across the entire site). It is important to note that the HQ results for habitats that intersect both EcoRings are attributed to the risk results for both of those distances. In other words, the habitat risks are not apportioned by distance, they are reported as though they are positioned entirely within each distance ring. Because the fundamental unit of this analysis is the representative habitat (not distance to the waste management unit), it was considered inappropriate to truncate risks by distance.

The concentration and dose inputs required by the EcoRisk module are provided by the Ecological Exposure (EcoEx) module, the Terrestrial Food Web module (TerFW), and the Surface Water (SW) module. These inputs are completely described in Appendix A and include:

Ecological Exposure

- applied dose to receptors by home range and habitat

Terrestrial Food Web

- spatially-averaged surficial soil concentration by home range

Surface Water

- average, reach-specific total concentration in sediment
- average, reach-specific total concentration in surface water
- average, reach-specific dissolved concentration in surface water

1.2 Summary of Functionality

The major computational functions performed by the Aquatic Food Web module may be summarized as follows:

- *Time series management*. The EcoRisk module determines the overall duration of the time period to be simulated (including concentration data from discontinuous time periods), and identifies the individual years within the overall duration that will be simulated.

- *Module loops over the time series, through habitats, and receptors.* The EcoRisk module has three basic loops: (1) over the time series, (2) over each habitat, and (3) over each receptor assigned to the habitat.

- *Calculation of time series hazard quotients for ecological receptors.* The EcoRisk module predicts HQs for each year of the simulation for receptors in each habitat. These HQs are defined in terms of a number of attributes to facilitate clarity in the risk characterization.

The major steps performed by the EcoRisk module that are required to predict ecological risks are summarized as follows:

- Select the ecological distance ring of interest (i.e., 0-1 km; 1-2 km; entire site).

- Read in all data required to calculate HQs for all receptors (e.g., EBs, CSCLs, site layout characteristics such as water hardness).

- Calculate HQs for all receptors within the area of interest for each year of the simulation.
- Calculate probability density functions for each year of the simulation (this is performed in much the same manner as with the Human Risk module).
- Identify and output the cumulative density functions for various receptor and habitat groups for the year in which the maximum total HQ was experienced.
- Identify and output information about the receptor experiencing the maximum HQ across all years of the simulation and the year in which the maximum occurred.

The calculation of time series HQs is described in detail in Section 3.0.

2.0 Assumptions and Limitations

The methodology used in the Ecological Risk module reflects a number of assumptions and/or limitations, which are listed below. Several key assumptions relevant to the EcoRisk module were described in the documentation of the Ecological Exposure module. For example, the assumption that all areas delineated as habitat support wildlife also applies to the EcoRisk module in that HQs calculated within each habitat are presumed to reflect potential risks to ecological receptors. For convenience, these assumptions are included below as well as assumptions/limitations that are unique to the EcoRisk module.

Assumptions

- *Study area is bounded at 2 km.* We assumed that significant risks to source-related contaminants do not occur for ecological receptors that are beyond 2 km of the source. Consequently, HQs were not calculated for receptors outside of the study area, measured from the corner of the source to a point 2 km away.

- *All areas delineated as habitat support wildlife.* It is assumed that habitats delineated at each site are capable of sustaining a variety of wildlife. Since the predator-prey interactions for each habitat are represented by a simple food web, each habitat is assumed to be of sufficient quality to support multiple trophic levels and, at least, one reproducing pair of upper trophic level predators. Hence, risk calculations assume that the receptors of interest are present in each habitat.

- *There is only one source for each chemical stressors in the study area.* Background concentrations of constituents were not considered in developing exposure estimates. Contributions to ecological exposures from other sources, or pre-existing conditions such as a fish advisory were not addressed.

- *The most appropriate endpoints for population sustainability are reproductive and developmental effects.* In calculating HQs for populations of mammals and birds, it is implicitly assumed that endpoints associated with the populations' ability to reproduce and grow are an appropriate surrogate for true population-level endpoints (e.g., adverse effects leading to a 10% reduction in the population size).

- *One and only one population of each wildlife species is carried by a given habitat.* For example, although there may be a number of receptors assigned to a habitat, multiple populations of shrews or robins are not evaluated. Each receptor

population has the same spatial characteristics, as defined by the home range. Hence, there is one HQ calculated for each receptor in each habitat.

- *Maximum HQ estimates are based on a single year of exposure.* The ecological HQ estimates are based on annual averages: the smallest increment of time that for which the 3MRA system is designed. This time step represents much longer than lifetime exposures for some receptors, and substantially less than lifetime for other receptors.

Limitations

- *The HQs are not calculated at the population or community level; ecological risks must be inferred to higher levels of biological organization.* Ecosystems are enormously complex, and our understanding of even simple community dynamics is limited. Data on chemical stressors are seldom available above the level of an individual organism; that is, the study endpoints focus on individual organisms rather than processes crucial to assemblages of organisms. Even the CSCLs developed to evaluate risks to communities are derived by statistical inference on toxicity data for individual organisms. Therefore, the data are generally insufficient to allow us to truly evaluate effects at the population or community levels. This is currently a limitation in the state-of-the-science, particularly for national analyses.

- *It is not possible to verify that reproductive and developmental endpoints are, in all cases, sufficient to protect the assessment endpoints for wildlife populations.* The endpoints for certain wildlife populations (i.e., mammals, birds) were almost exclusively taken from reproductive and developmental studies. Although reproductive and developmental endpoints have been recognized by EPA as relevant to population sustainability, they are not always the critical effect associated with a chemical stressor. The assumption that other effects that may occur at lower environmental concentrations are not significant with respect to the population sustainability limits confidence in predicting ecological risk. Studies regarding this question are inconclusive and, therefore, there is some uncertainty in using only reproductive and developmental studies to address the assessment endpoint of population sustainability.

- *The HQ estimates are generated based on one, and only one, home range area.* For the purposes of creating the site layout file, four home range areas are placed in each habitat. Once these areas are delineated and appropriate receptors are assigned, the spatial characteristics of the risk for each home range is established. Variability associated with exposures in different areas of the habitat is not reflected in this scheme. This limitation may result in significant differences for receptors with small home ranges, and can influence the risk estimates for predators with large home ranges (i.e., home range $\approx$ habitat) since tissue concentrations in prey items are constrained by the same spatial characteristics.

As a result, the representativeness of the HQs with regard to the spatial character of the exposure is limited.

- *The effects of multiple stressors (chemical and non-chemical) are not considered in developing estimates of potential ecological risk.* This is a source of considerable uncertainty in the HQ estimates. The EcoRisk module is executed within the FRAMES system within a system-level chemical loop such that only a single chemical is evaluated per iteration of the model. As a result, risks are predicted assuming a single chemical exposure. Data availability on the antagonistic and synergistic effects associated with multiple stressors are extremely limited at this time (with the possible exception narcotic contaminants in aqueous systems) and prevented the development of a multi-stressor analytical approach for the HWIR universe of constituents. Data limitations notwithstanding, the inability to consider multiple stressors is a limitation in our ability to interpret the risk results generated by this module.

- *The HQ estimates for the aquatic and benthic communities, respectively, are resolved at the habitat, rather than reach level.* There is some uncertainty associated with calculating risks to aquatic life across an entire habitat (as defined within the study area). Species of fish such as brown trout tend to utilize certain segments of stream habitats and, therefore, HQs at the reach level may be more appropriate. Conversely, establishing artificial boundaries between stream reaches is contrary to the goals of the assessment strategy, namely, to evaluate ecological risks using the habitat as the fundamental unit.

- *The HQ estimates reflect different endpoints at varying levels of effect.* The HQ methodology - the ratio of an exposure to a benchmark - is applied uniformly across all ecological receptors. However, the data supporting the HQ calculation vary in that they include endpoints from lethality to reproductive fitness and address and community-level effects by inference. To some degree, the HQ estimates for different receptor groups represent different risk metrics. The interpretation of these HQ estimates is, therefore, limited by our understanding of the potential ecological significance of the measures of effect as well as overall confidence in the data used to support the calculations.

3.0 Methodology

The Ecological Risk module calculates a hazard quotient for each receptor assigned to the site. For receptors lacking suitable toxicity data to generate an EB or CSCL, the EcoRisk module returns an HQ value of -999 and does not include this "HQ" in creating the cumulative density functions. The core calculations of the module may be thought of in four basic steps:

1. Calculate an average surface water and sediment concentrations for each habitat.

2. Adjust CSCLs for environmental conditions, as appropriate.

3. Calculate HQs for community-based receptors (e.g., soil community) and receptors whose primary exposure route is presumed to be through direct contact (e.g., amphibians).

4. Calculate HQ's for receptors that are exposed through the ingestion of contaminated food and media.

Below, Section 3.1 describes each of these core calculations and provides details on the chemical-specific subroutines needed to adjust the benchmarks or CSCLs supplied by the chemical properties database. Section 3.2 discusses the development of cumulative density functions of the ecological HQs that are required by the Exit Level Processor (ELP); these functions include the array of attributes described in Section 1 (e.g., receptor group; trophic level; habitat type). Section 3.3 provides a concise summary of the steps executed by the EcoRisk module in compiling risk results.

3.1 Calculating Hazard Quotients

3.1.1 Calculate Average Surface Water and Sediment Concentration

Prior to calculating HQs, the EcoRisk module identifies which habitats are aquatic and wetland, determines the number of reaches that are part of that habitat, and calculates an average surface water concentration for both the total and freely dissolved phases as shown in Equations 3-1 and 3-2:

$$C^{t}_{w_{habitat\ i}} = \sum_{j=1}^{N} \frac{C^{t}_{w_{reach\ j}}}{NumReach_{habitat\ i}} \qquad (3\text{-}1)$$

$$C_{w\ habitat\ i}^{fd} = \sum_{j=1}^{N} \frac{C_{w\ reach\ j}^{fd}}{NumReach_{habitat\ i}} \quad (3\text{-}2)$$

where

$C^{t}_{w\_habitat\ i}$ = average total concentration in surface water for habitat i (mg/L)

$C^{t}_{w\_reach\ j}$ = total concentration in surface water for reach j in habitat i (mg/L)

$C^{fd}_{w\_habitat\ i}$ = average freely dissolved concentration in surface water for habitat i (mg/L)

$C^{fd}_{w\_reach\ j}$ = freely dissolved concentration in surface water for reach j in habitat i (mg/L)

$NumReach_{habitat\ i}$ = number of reaches in the habitat i

The average sediment concentration for each habitat is estimated using Equation 3-3 where N is the total number of stream reaches:

$$C_{sed_{habitat\ i}} = \frac{\sum_{j=1}^{N} C_{sed_{reach\ j}}}{NumReach_{habitat\ i}} \quad (3\text{-}3)$$

and

$C_{sed\_habitat\ i}$ = average sediment concentration for habitat i (mg/kg)
$C_{sed\_reach\ j}$ = total sediment concentration for reach j in habitat i (mg/kg)
$NumReach_{habitat\ i}$ = number of reaches in the habitat i

3.1.2 Adjust CSCLs for Environmental Conditions

Because the toxicity values for some constituents are dependent on environmental conditions, we designed the EcoRisk module to adjust toxicity values based on environmental parameters. For constituents that are dependent on environmental parameters, the module will check certain flags in the database (e.g., ChemType) and make the necessary adjustments to the CSCLs. For example, the aquatic toxicity of some metals is dependent on water hardness. For metal constituents, the module checks to see whether toxicity is hardness dependent and recalculates the CSCL based on the water hardness of watebody networks at the site. An example for cadmium is provided:

$$CSCL_{w\ receptor}^{fd} = [e^{(0.7852\ (\ln\ WaterHardness)\ -\ 2.715)}]\ 0.0001\ (mg/L) \quad (3\text{-}4)$$

where

$CSCL_{w\ receptor}^{fd}$ = chemical stressor concentration limit adjusted for water hardness (mg/L)

WaterHardness = water hardness given by concentration of $CaCO_3$ (mg/L)

Similarly, the sediment CSCLs for organic compounds, dioxin-like chemicals, and "special" chemicals (e.g., PAHs) must be adjusted for the organic carbon content of the sediment. This calculation is given by:

$$CSCL_{sed_{receptor}} = CSCL_{w\ receptor}^{t} \times foc_{sed} \times K_{oc} \quad (3\text{-}5)$$

where

$CSCL_{sed\_receptor}$ = chemical stressor concentration limit adjusted for water hardness (mg/kg)

$CSCL_{w\ receptor}^{t}$ = chemical stressor concentration limit based on total concentration in surface water (mg/L)

foc_{sed} = fraction of organic carbon in sediment

K_{oc} = organic carbon partition coefficient (L/kg)

3.1.3 Calculate HQs for Receptors Exposed Primarily through Direct Contact

Once the CSCL is adjusted for environmental conditions (if appropriate), we calculate the receptor-specific HQs for constituents with suitable data in the chemical properties database. For habitats containing surface water bodies, the habitat-averaged dissolved surface water concentration is used in the HQ calculation provided that a CSCL is available for the dissolved fraction. If a CSCL for dissolved chemical is not available, the HQ for is based on the habitat-averaged total water concentration and the CSCL for total concentration (i.e., dissolved plus bound fraction). This calculation is performed for three receptors: amphibians,[3] aquatic biota, and aquatic macrophytes and is illustrated by Equation 3-6:

[3] Amphibians are assumed to be exposed during sensitive life stages in all habitats with intermittent or permanent surface water bodies (e.g., reach order 2 streams; ponds).

$$HQ_{habitat_{receptor}^{i}} = \frac{C_{w_{habitat}^{i}}}{CSCL_{receptor}} \quad (3\text{-}6)$$

where

$HQ_{habitat}^{i}{}_{\_receptor}$ = hazard quotient for receptor in habitat i (unitless)

$C_{w\_habitat}^{i}$ = either freely dissolved or total surface water concentration in habitat i (mg/L)

$CSCL_{receptor}$ = chemical stressor concentration limit for receptor for either freely dissolved or total surface water concentration (mg/L)

The HQs for sediment organisms in freshwater reaches and wetlands are calculated in a similar manner. Once the site-specific CSCL is derived (if appropriate), the HQ is calculated as follows:

$$HQ_{habitat_{receptor}^{i}} = \frac{C_{sed_{habitat}^{i}}}{CSCL_{sed_{receptor}}} \quad (3\text{-}7)$$

where

$HQ_{habitat}^{i}{}_{\_receptor}$ = hazard quotient for sediment biota in habitat i (unitless)
$C_{sed\_habitat}^{i}$ = sediment concentration in habitat i (mg/L)
$CSCL_{sed\_receptor}$ = chemical stressor concentration limit for sediment biota (mg/kg)

For the two terrestrial receptors that are considered community-based (soil fauna and plants), the EcoRisk module loops through each habitat and calculates an HQ for each of the four home range sizes delineated in the habitat. For many terrestrial habitats, the largest two home range sizes encompass the entire habitat, that is, the home range size is larger than the habitat size. In these instances, it was considered inappropriate to report HQs for each home range size because the values would be redundant (i.e., the HQs would be identical and reflect the same spatial averaging within the habitat). Therefore, the EcoRisk module only outputs terrestrial HQs for plants and soil biota that are unique with respect to spatial averaging of chemical contaminants. The HQs for terrestrial plants and soil biota are calculated as the ratio of the average soil concentration estimated by the Terrestrial Food Web module for each home range and the soil CSCL as shown in Equation 3-8:

$$HQ_{HomeRange_{rec}} = \frac{C_{soil_{HomeRange}}}{CSCL_{Soil_{receptor}}} \quad (3\text{-}8)$$

where

$HQ_{HomeRange\_rec}$ = hazard quotient for receptor in each home range
$C_{soil\_HomeRange}$ = depth-averaged soil concentration for each home range (mg/kg)
$CSCL_{soil\_receptor}$ = ecological benchmark for receptor (mg/kg)

3.1.4 Calculate HQs for Receptors Primarily Exposed through Contaminated Prey

The module loops over the habitats, and receptors for which a dose has been predicted by the Ecological Exposure (EcoEx) module. The HQs for these receptors include mammals and birds and are calculated as the ratio of the applied dose to the ecological benchmark (EB) shown by Equation 3-9:

$$HQ_{habitat\ rec}^{\ i} = \frac{Dose_{receptor}}{EB_{receptor}} \quad (3\text{-}9)$$

where

$HQ_{habitat\ rec}^{\ i}$ = hazard quotient for receptor in habitat i
$Dose_{receptor}$ = applied dose to receptor (mg/kg-day)
$EB_{receptor}$ = ecological benchmark for receptor (mg/kg-day)

3.2 Developing Cumulative Density Functions

Before developing the cumulative density functions of HQ values, the EcoRisk module calculates the probability densities for the various groups of interest (trophic level, receptor group, habitat group, habitat type, and for the overall site receptor group/habitat group combinations and trophic level habitat group combinations). For each distance ring, the appropriate receptor group/habitat group and trophic level/habitat group density functions are selected and incremented according to one of five bins established for hazard quotients as described in Section 1.0.

Once the probability density functions have been constructed, they are converted into cumulative distribution functions. Starting with the second bin of the density function, the number in the current bin is added to the number in the prior bin and the total is stored in the current bin. Once the cumulative distribution has been constructed, the bin that exceeds the regulatory percentile (EcoRegPercentile) for allowable ecological risks is determined. This is done by, starting at the first bin, cycling through all the bins until the number of receptors in the bin divided by the total number of receptors with valid hazard quotients (expressed as a percent) is greater than the EcoRegPercentile, i.e. finding j where:

$$100 \times (Number\ of\ Receptors)_j \ /\ (Total\ Number\ of\ Receptors) > EcoRegPercentile \quad (3\text{-}10)$$

The first bin that satisfies this condition is stored in the parameter "BinStop." The total hazard quotient (TotHQ) is then calculated as shown in Equation 3-11:

$$TotHQ = \sum_{i=1}^{BinStop} (Number\ of\ Receptors)_i \times (HQMin_i + HQMax_i) / 2 \qquad (3\text{-}11)$$

The summation is taken over all bins up through and including the bin at which the EcoRegPercentile is first exceeded (BinStop). The first term in the summation is the number of receptors in the given bin of the cumulative distribution while the second term is the average of the minimum and maximum hazard quotient for the bin.

3.3 Summary of Steps Executed by EcoRisk Module

To complement the preceding discussion on the architecture and functionality of the EcoRisk module, the following summary is provided to highlight the steps required to derive the cumulative density functions of ecological hazard quotients. As implemented for each distance ring (i.e., from 0-1 km; from 1-2 km), the EcoRisk module determines:

- the maximum hazard quotient experienced across all receptors in the area of interest;
- the year in which the maximum HQ occurred;
- the receptor index, receptor group, and trophic level for the receptor that experienced the maximum hazard quotient;
- the habitat group and habitat type for the habitat containing the receptor that experienced the maximum hazard quotient;
- the year in which the maximum hazard quotient was experienced for each habitat group and habitat type;
- the year in which the maximum hazard quotient was experienced for each receptor group and receptor trophic level;
- the cumulative distribution of HQs for each habitat group and habitat type for the year in which the maximum total HQ across all receptors was experienced; and
- the cumulative distribution of HQs for each receptor group and receptor trophic level for the year in which the maximum total HQ across all receptors was experienced.

For the entire site, the EcoRisk module determines:

- the year in which the maximum hazard quotient was experienced for each receptor group/habitat group combination for the year in which the maximum total HQ across all receptors was experienced;
- the year in which the maximum hazard quotient was experienced for each trophic level/habitat group combination for the year in which the maximum total HQ across all receptors was experienced;
- the cumulative distribution of HQs for each receptor group/habitat group combination; and
- the cumulative distribution of HQs for each trophic level/habitat group combination.

4.0 Implementation

The flowchart shown in Figure 4-1 illustrates the generalized structure of the Ecological Risk module.

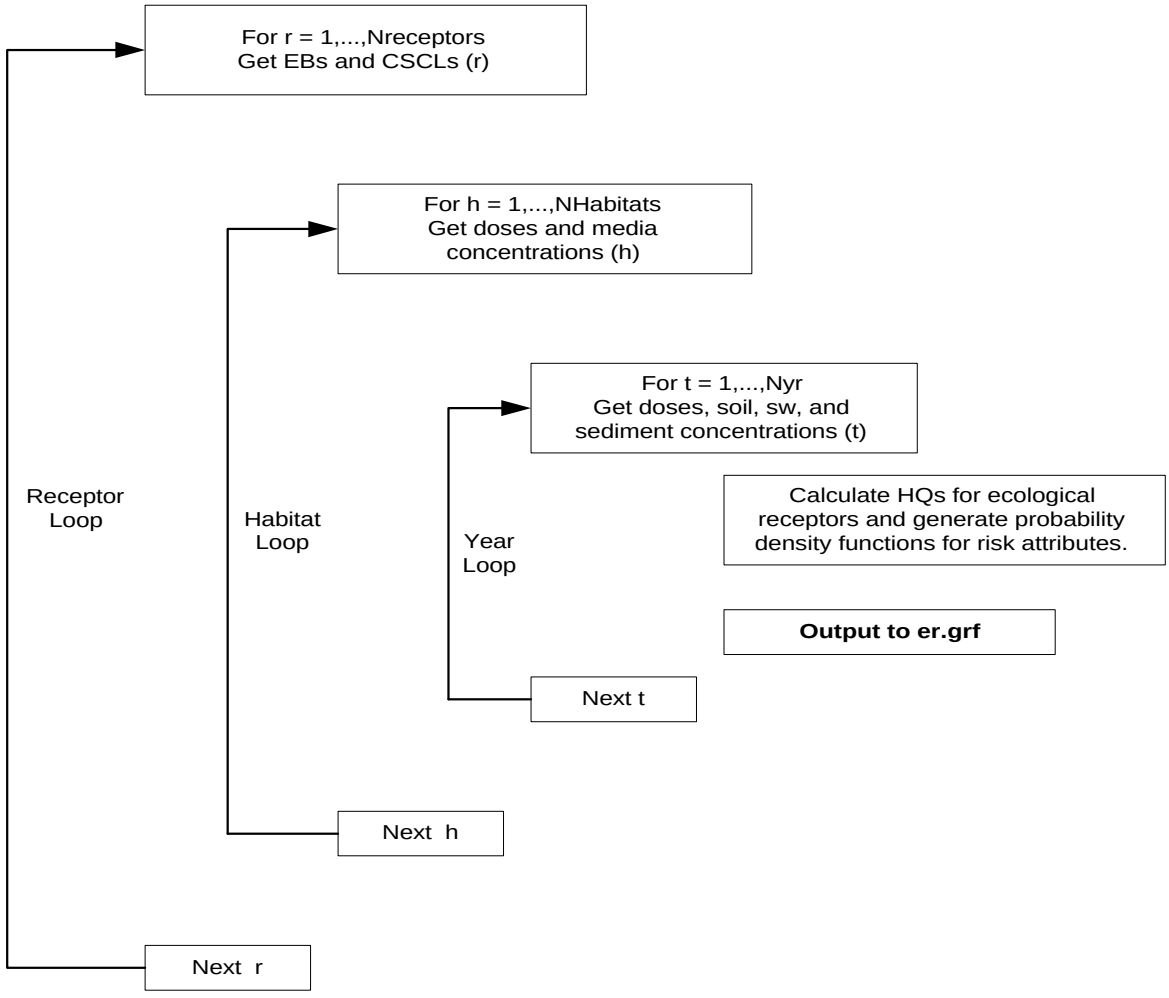

Figure 4-1. Conceptual flow diagram of major functionality of Ecological Risk Module.

5.0 References

U.S. EPA (Environmental Protection Agency). 1998. *Guidelines for Ecological Risk Assessment.* EPA/630/R-95/002F. Risk Assessment Forum. Washington, DC. April.

Appendix A

Inputs and Outputs

Appendix A

Inputs and Outputs

The Ecological Risk module receives inputs from its module-specific input file, er.ssf, the generic site layout file (sl.ssf), the chemical properties file (cp.ssf), and modeled inputs from the Surface Water module (sw.grf), Terrestrial Food Web module, and the Ecological Exposure module. The Ecological Risk module outputs are written to the er.grf file.

All input and output variables are listed and described in Tables A-1 through A-7.

Table A-1. er.ssf Parameter Inputs (Module-Specific Inputs)

Input Parameters	Units	Description
EcoRegPercentile	unitless	Policy criterion for selecting critical year for maximum HQ

Table A-2. sl.ssf Input Parameters (Module-Specific Site Layout Inputs)

Input Parameters	Units	Description
NumEcoBin	unitless	Number of bins for cumulative distribution function
EcoRingNumHab	unitless	Number of habitats in each ecoring
EcoBinRange_Min	unitless	Minimum HQ for each ecobin
NumEcoRing	unitless	Number of ecorings at the site
EcoRingHabIndex	unitless	Habitat index for a habitat in a given ecoring
HabNumRange	unitless	Number of ranges in a given habitat
HabNumWBNRch	unitless	Number of reaches in a given habitat
HabType	not applicable	String description of the habitat type for a given habitat
ReceptorType	not applicable	String description of the receptor type for a given receptor
ReceptorName	not applicable	Receptor name
RecGroup	not applicable	String description of receptor group
RecTrophicLevel	not applicable	String description of receptor trophic level
HabRangeRecIndex	unitless	Index for a given receptor in a given habitat
WBNWaterHardness	mg CaCO3 eq/L	Water hardness for a given waterbody network type
HabWBNIndex	unitless	Waterbody network index for a given reach in a given habitat
HabWBNRchIndex	unitless	Reach index for a given reach in a waterbody network in a given habitat
WBNRchBodyType		String description of reach body type for a given reach in a given waterbody network

Table A-3. cp.ssf Input Parameters (Module-Specific Chemical Inputs)

Input Parameters	Units	Description
ChemCASID		Chemical abstracts service registry number for the chemical
ChemType		Chemical type
ChemKoc	mL/g	Organic carbon partition coefficient for the chemical
ChemEBRec	mg/kg-day	Ecological benchmark for the chemical for a given receptor
ChemCSCLWaterDissRec	mg/L	Chemical stressor concentration limit for the chemical dissolved in water for a given receptor
ChemCSCLWaterTotRec	mg/L	Chemical stressor concentration limit for the total chemical in water for a given receptor
ChemCSCLSedimentRec	ug/g	Chemical stressor concentration limit for the chemical in sediment for a given receptor
ChemCSCLSoilRec	ug/g	Chemical stressor concentration limit for the chemical in soil for a given receptor

Table A-4. sw.grf Input Parameters (Surface Water Input Parameters)

Input Parameters	Units	Description
WBNNumChem		Number of chemical species for the chemical
WBNConcWaterDiss	mg/L	Dissolved concentration of chemical in a given WBN reach in a given year
WBNConcWaterTot	mg/L	Total concentration of a chemical in a given WBN reach in a given year
WBNConcBenthTot	ug/g	Total concentration of a chemical in the benthic column of a given WBN reach in a given year
WBNfocBenth	fraction	Fraction organic carbon in the benthic column of a given WBN reach in a given year

Table A-5. tf.grf Input Parameters (Terrestrial Food Web Inputs)

Output Parameters	Units	Description
CTdaAveHabRange	ug/g	Depth-averaged total chemical concentration in soil, averaged over a given habitat and range in a given year

Table A-6. ee.grf Input Parameters (Ecological Exposure Inputs)

Output Parameters	Units	Description
Dose_rec	mg/kg-day	The chemical dose experienced by a receptor in a given habitat and range in a given year

Table A-7. er.grf Output Parameters (Ecological Risk Outputs)

Output Parameters	Units	Description
HQcdf_HabGroup	unitless	Cumulative percentile of receptor HQs, by habitat group for each ecoring for the
HQcdf_HabType	unitless	Cumulative percentile of receptor HQs, by habitat type
HQcdf_RecGroup	unitless	Cumulative percentile of receptor HQs, by receptor group
HQcdf_RGHabGroup	unitless	Cumulative percentile of receptor HQs, by receptor group and habitat group (ecoring 3 only)
HQcdf_TLHabGroup	unitless	Cumulative percentile of receptor HQs, by trophic level and habitat group (ecoring 3 only)
HQcdf_TrophicLevel	unitless	Cumulative percentile of receptor HQs, by trophic level
HQHabTypeTcrit	year	Time output at which maximum HQ occurs for each habitat type
HQHabGroupTcrit	year	Time output at which maximum HQ occurs for each habitat group
HQMax	unitless	Maximum HQ across the ecoring
HQMaxHabGroup	unitless	Habitat group index for the maximum HQ in the ecoring
HQMaxHabType	not applicable	Habitat type for the maximum HQ in the ecoring
HQMaxRec	unitless	Receptor index for the maximum HQ in the ecoring
HQMaxRecGroup	not applicable	Receptor group for the maximum HQ in the ecoring
HQMaxTcrit	year	Year with maximum HQ across all eco receptors in the ecoring
HQMaxTrophicLevel	unitless	Trophic level of receptor for the maximum HQ in the ecoring
HQRecGroupTcrit	year	Time output at which maximum HQ occurs for each receptor group
HQRGHabGroupTcrit	year	Time output at which maximum HQ occurs for each receptor group/habitat group combination
HQTLHabGroupTcrit	year	Time output at which maximum HQ occurs for each trophic level/habitat group combination
HQTrophicLevelTcrit	year	Time output at which maximum HQ occurs for each trophic level