



BIOACCUMULATION RISK ASSESSMENT MODELING SYSTEM (BRAMS)

USERS GUIDE

The screenshot displays the BRAMS software interface. On the left is a 'Chemicals' explorer tree listing various PAHs and pesticides. The main window shows a table with columns: Name, Type, Cancer Slope, Reference Dose, Steady State, Bio Magnific, Human Toxic, FDA Action Level, and Ecological Effect. Below the table are several panels: 'BRA' (Basic Risk Assessment) showing cancer and non-cancer risk metrics; 'Risk List' showing chemical-specific risk calculations; 'FDA Action Levels and Ecological Risk' showing regulatory compliance; and 'Contaminant Specific Risk' showing detailed risk breakdowns for specific chemicals. A small inset image in the top right shows a person holding a large fish.

Prepared By:
Kelsie Baker and John Thomas Vogel II
U.S. Army Engineer Research and Development Center,
Environmental Lab

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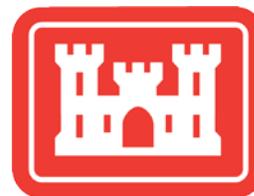


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Introduction

This manual describes the Bioaccumulation Risk Assessment Modeling System (BRAMS) program components and features, guides the user in creating both Trophic Trace (TT) and Bioaccumulation Evaluation Screening Tool (BEST) models and details the assumptions and equations used in each model.

PART I: Getting Started

1. What is BRAMS?*

The Bioaccumulation Risk Assessment Modeling System (BRAMS) is a stand-alone tool for calculating the potential human health and ecological risks associated with bioaccumulation of contaminants in dredged sediments. It contains two separate models, Trophic Trace (TT) and the Bioaccumulation Evaluation Screening Tool (BEST), which use separate equations and inputs to calculate risks. The program is designed to provide health- and ecologically-protective estimates of potential risk using results from sediment chemistry tests and/or 28-day bioaccumulation tests. The program calculates the risks based on the characteristics of the site including the environment, species and chemicals involved, and food chain dynamics and contaminant concentrations. The user can edit inputs in an established template model or create entirely new models based on different trophic structures, human and ecological exposure scenarios and site-specific conditions. Model outputs include total carcinogenic and non-carcinogenic risks to humans and toxicity quotients for ecological receptors as well as risks from specific chemicals and dietary species. The program also compares risks to specified risk thresholds for easy screening. The algorithms incorporated into BRAMS follow USEPA and USACE risk assessment guidance (USEPA, 1989; 1997a; USEPA/USACE, 1998; Cura et al., 1999).

2. Background

Required by the Marine Protection Research and Sanctuaries Act (MPRSA), the current approach for evaluating dredged materials is outlined in the Ocean and Inland Testing Manuals (OTM; ITM) (EPA/USACE, 1991; 1998). It involves comparing the bioaccumulation test results of dredged materials with reference sediment test results and FDA action levels. These toxicological measures are indicative of a contaminant's potential for adverse effects to human and ecological receptors. The OTM, commonly referred to as the "Green Book," provides a general protocol for evaluating sediment toxicity and determining the suitability of dredged materials for open-water disposal. EPA and USACE share the responsibility for regulation of this dredged material. In general, the Corps issues permits for dredged material disposal which are then subject to EPA review and concurrence before ocean disposal can occur. The tiered approach to evaluation of potential environmental impacts of ocean dumping is outlined in the Ocean and Inland Testing Manuals (OTM & ITM). BRAMS can be used in Tiers I through IV to

* This section is adapted from the TrophicTrace 4.0 Users Manual. von Stackelberg, K. and A. Burmistrova. 2004. TrophicTrace 4.0 Users Manual: A Tool for Assessing Risks from Trophic Transfer of Sediment-Associated Contaminants. January 28, 2009. 34 pp.

provide information about potential risks associated with bioaccumulation. Specific guidance for sampling and testing in accordance with the OTM and ITM is provided in Regional Implementation Manuals.

Since 1999, EPA Region 1 has evaluated bioaccumulation test results using a screening tool that considers whether contaminants accumulated in test organisms might result in a risk to human or ecological receptors by direct or indirect consumption (Battelle, 2005). Also in 1999, Menzie-Cura & Associates, Inc. developed a mechanistic, process-based bioaccumulation risk model, *TrophicTrace*, to calculate the potential human and ecological impacts of bioaccumulation from sediment-associated contaminants (Bridges *et al.*, 2002; von Stackelberg *et al.*, 2004). The BRAMS program, released in 2012, includes two fully customizable models, Trophic Trace and BEST, based on the 2005 USACE *TrophicTrace* and the 1999 EPA Region 1 bioaccumulation risk assessment model frameworks, respectively.

Trophic Trace (TT):

In the Trophic Trace model, human and ecological receptors are exposed to potential contaminants in dredged materials via ingestion of prey. The model estimates expected concentrations using a sediment-based food web for organic compounds, via trophic transfer factors from invertebrates to fish for certain metals, and via bioconcentration factors from water to fish for the remaining metals and hydrophilic organic compounds. Water concentrations are estimated using a partitioning approach based on the user-specified sediment concentration or the user can input a water concentration directly (the model requires a freely dissolved concentration, but can estimate one from an input whole water concentration). Details of the model framework are discussed in Part V Section 1.

Uncertainty: Trophic Trace allows users to characterize uncertainty using trapezoidal fuzzy numbers (e.g., a minimum, a range of likeliest values or probable values, and a maximum) for each input parameter. These uncertainties are propagated throughout the analysis using principles of fuzzy arithmetic. Model results are also presented as trapezoidal fuzzy numbers representing a minimum value, a range of two most probable values, and a maximum value. Trapezoidal fuzzy numbers are explained in detail in Part V Section 3.

Included Trophic Trace Example: The BRAMS software includes a Trophic Trace example model that contains several human receptor population data libraries built into the demonstration form of the model, including recreational anglers (children and adult) in the New York and New Jersey (NY/NJ) area, and members of the general public (children and adult). The example exposure assumptions used for these demonstration receptor populations are obtained from the USEPA Exposure Factors Handbook (USEPA, 1997a; 1997b) as well as from the New Jersey Department of Health (NJDA, 1994). The values provided in the Trophic Trace model are for demonstration purposes only. All model runs should be based on site-specific information. The Trophic Trace example is also parameterized for several ecological receptors, including fish, osprey, bald eagle, mink, and otter. The example food web included in the model is sediment based. Following the Gobas model, Trophic Trace assumes that organic compounds partition from organic carbon in sediment to the lipid fraction of benthic invertebrates. The example model is parameterized for a simple sediment based food web that is representative of a food

web that might be found in the Northeast Region. The example invertebrate in Trophic Trace is the sandworm (*Nereis virens*). The model assumes that a forage fish represented by the mummichog (*Fundulus heteroclitus*), consumes sandworms and that a piscivorous fish represented by the summer flounder (*Paralichthys dentatus*) consumes the mummichog. The user can create additional food webs by modifying or adding invertebrates and fish species, such as pelagic invertebrates that derive the bulk of their exposure from the water column, and fish that consume both benthic and pelagic invertebrates.

Bioaccumulation Evaluation Screening Tool (BEST):

The BEST model is based on EPA Region 1’s Bioaccumulation Risk Assessment Model framework. This model was designed to evaluate dredged material for open water disposal in the New England region in accordance with Green Book testing protocol (EPA and USACE, 1991). BEST estimates expected concentrations in humans by (1) calculating the edible tissue concentration in human diet species including test organisms and their predators, (2) calculating an average daily dose to humans that consume these species, and (3) multiplying or dividing average daily dose by risk factors (e.g. oral cancer slope factor and oral reference dose) to determine potential risks. BEST model framework is discussed in detail in Part V Section 2. In the BEST model output, risk results for dredged sediments are compared to reference site risks, and acceptable risk thresholds. Tissue concentrations are compared to FDA action levels and ecological effects levels. The model can be tailored to each specific project by modifying species, food webs and exposure scenarios in templates or creating entirely new templates and models.

Included BEST Template: The BEST template model included in BRAMS is based on the structure and input values of the 1999 EPA Region 1 Bioaccumulation Risk Assessment Model (Batelle, 2005). For the standard bioaccumulation risk assessment, the user enters 28-Day Bioaccumulation test results for the two invertebrate test species, *Macoma nasuta* and *Nereis virens*, which have been exposed to either the proposed dredge material or reference sediments. The model then calculates predator body burden in a fish fillet, lobster muscle, and lobster hepatopancreas. A lifetime daily average dose (LADD) is then determined using standard EPA default exposure factors (USEPA, 1989) and regional fish consumption rates (USEPA, 1988; Ruffle et al., 1994; RI Department of Health, 1997). Carcinogenic and non-carcinogenic risks to human health from fish, lobster, and molluscan shellfish consumption are calculated using standard risk factors (e.g. oral CSF, RfD, TEF) for contaminants present at the test site.

3. Installation and StartUp

3.1 System Requirements

Central processor	Intel Pentium 1GHz or better
Operational memory	512 MB or more
Free space on hard disk	20MB

Operating system
Third-party software

Windows XP/Vista/7, Mac OS X or Linux
Java Runtime Environment (JRE) Version 6 Update 21 or later

3.2 Installation

- Insert the BRAMS disk into your computer.
- Locate the BRAMS CD on your Windows disk (D) drive or your Mac Desktop and double click it.
- Drag and drop or Copy and Paste the BRAMS-Dist Folder to the appropriate location on your hard drive or run the program directly from the CD.

3.3 StartUp

To open BRAMS, select BRAMS-Dist → bin → BRAMS.jar. Double clicking the file, BRAMS.jar, will open the program.

The StartUp window will then appear while BRAMS is loading.

Once BRAMS has finished loading, the User Identification window will appear prompting the user to enter their User Name. Enter your User Name and click *Continue* to continue to the main BRAMS window.

The user is now ready to create, edit, and run BRAMS models from the Main Window.

4. User Interface

4.1 Main Window

The main BRAMS window includes 6 general sections:

- Menu
- Toolbar
- Explorer Pane
- Table Pane
- Properties Pane
- Notes Pane

These sections are explained in further detail below in sections 4.2 - 4.7.

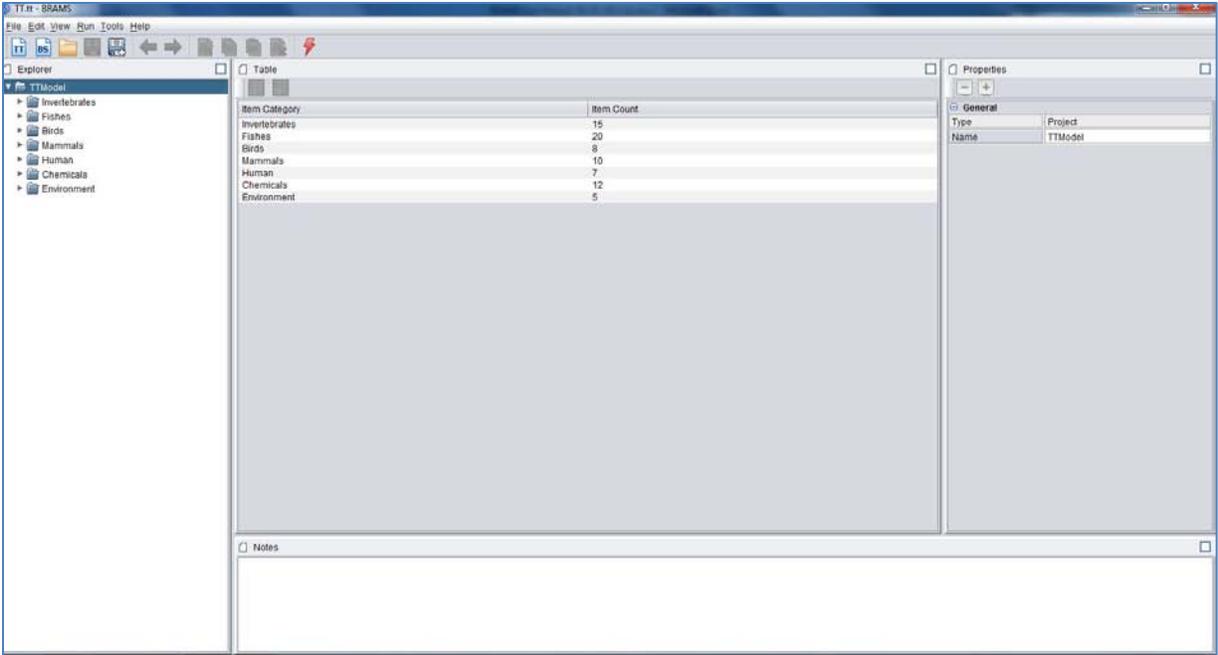


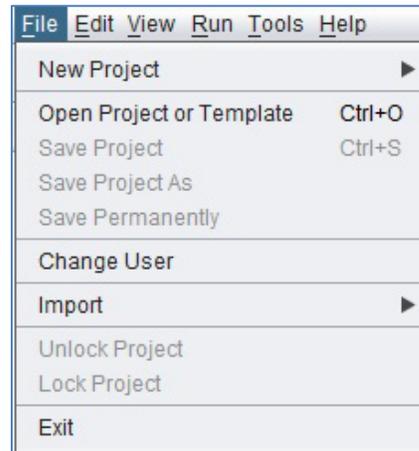
Figure 1: Main BRAMS Window

4.2 Menu

The menu consists of:

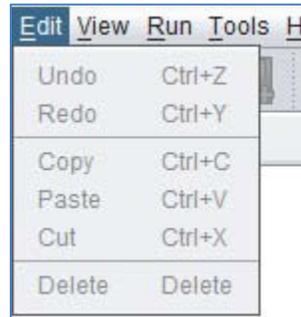
File: Here the user can create, open or save a project or template, change the user, import data from Excel files, lock and unlock model inputs and exit the program.

- File:
 - New Project
 - New TT Project
 - New BEST Project
 - Open Project or Template
 - Save Project
 - Save Project As
 - Save Permanently
 - Change User
 - Import
 - Bioaccumulation Test Results
 - Chemicals
 - Unlock Project
 - Lock Project
 - Exit



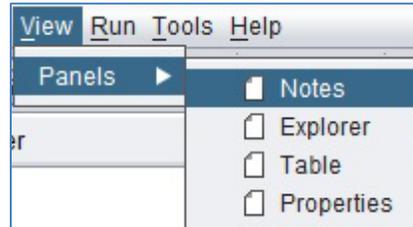
Edit: Here the user can access tools for editing script while inputting text into the properties pane.

- Edit
 - Undo
 - Redo
 - Copy
 - Paste
 - Cut
 - Delete



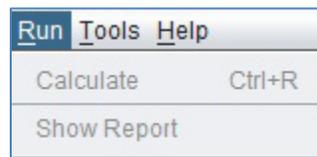
View: Here the user can change aspects of the main window by choosing to include or remove any of the panes (Notes, Explorer, Table, or Properties) or switch to and from full screen viewing.

- View
 - Full Screen
 - Panels
 - Notes
 - Explorer
 - Table
 - Properties



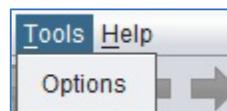
Run: Here the user can choose to perform the TT or BEST model calculations or show the Report. The Show Report button will generate the model results and launch the ReportViewer window in front of the main window.

- Run
 - Calculate
 - Show Report



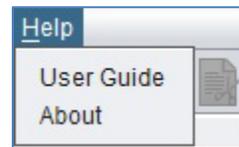
Tools: Here the user can edit several features of the software, including the output format and how the templates are generated.

- Tools
 - Options
 - Reports
 - Paths
 - Other



Help: Here you can access the BRAMS About window and this User Guide, which describes the program components and guides the user in creating, editing, and running bioaccumulation models.

- Help
 - User Guide
 - About



4.3 Toolbar

The toolbar consists of the following buttons:



Figure 2: BRAMS main toolbar

Project Tools



Create new TT project: Displays the Create New Project window that asks whether the user would like to create a new TT project. Selecting *No* will return you to the main window with no changes. Selecting *Yes* will exit the current project and start a new blank TT project.



Create new BEST project: Displays the Create New Project window that asks whether the user would like to create a new BEST project. Selecting *No* will return you to the main window with no changes. Selecting *Yes* will exit the current project and start a new blank BEST project.



Open project: Displays the Open Project window where the user can search for, select and open an existing project. Once the project has been selected, click *Open* to open the project. To return to the Main window without opening a project, click *Cancel*.



Save project: If the project has already been saved previously, clicking this button will overwrite the previous file and save the updated version under the same name and location. If the project has not been saved previously, clicking this button displays the Save Project as... window where the user can name and specify a location to save their current project. If the project has been saved permanently, this option will not be available because the project file cannot be overwritten.



Save project as: Displays the Save Project as... window where the user can name and specify a location to save the current project.

Editing Tools



Back: Undo last action.



Forward: Redo last action that was undone.



Cut selected item: Cut selected text.



Copy selected item: Copy selected text.



Paste selected item: Paste last Cut or Copied text.



Remove selected item: Delete selected text.

Reporting Tools



Show Detailed Report: If all necessary model parameters have been entered, brings up *Show Report* window. If model is incomplete, information window will appear and explain what must be added or corrected before the report can be generated.



Show Summary Report (BEST Model only): The summary report shows only a select set of results including total carcinogenic and non-carcinogenic risks and contaminant specific risks for each invertebrate, as well as contaminant concentrations compared with FDA Action Levels, and Ecological Risk Levels.

4.4 Notes Pane

The Notes pane, located at the bottom of the main window, allows the user to enter text for each model item. Once an item is selected from either the Explorer or Table panes, notes about that item previously added by the user will appear in the Notes pane.

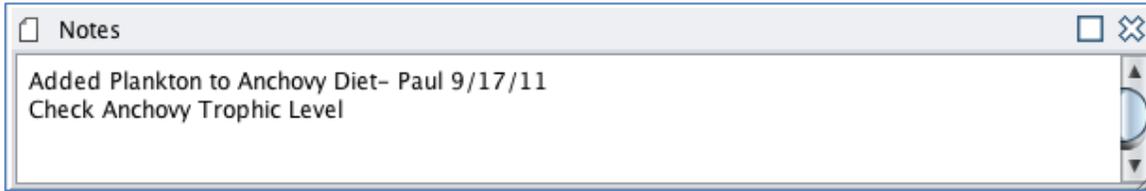


Figure 3: Notes Pane with example text.

4.5 Explorer Pane

The Explorer pane shows the model components and hierarchy. It allows the user to see the model items in each category and navigate between different items.

Each of these model components can or must include specific items such as invertebrates, chemicals, or environments. Selecting a category (e.g. Invertebrates) or an item (e.g. Worm) in the Explorer pane will display all items in that category and selected item properties in the Table pane. Selecting an item in the Explorer pane will also display its attributes in the Properties pane.

For the TT model, the Explorer pane includes:

- Project
- Invertebrates
- Fishes
- Birds
- Mammals
- Human
- Chemicals
- Environment

For the BEST model, the Explorer pane includes:

- Project
- Invertebrates
- Predators
- Humans
- Chemicals

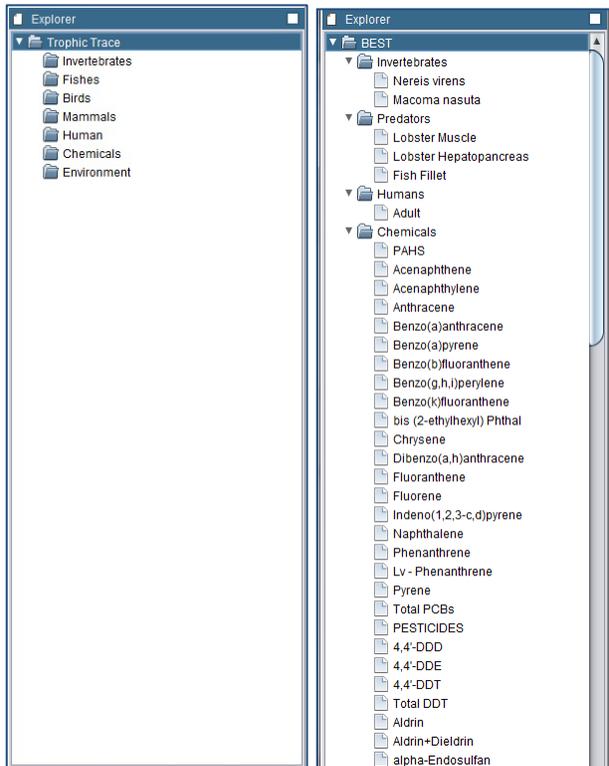
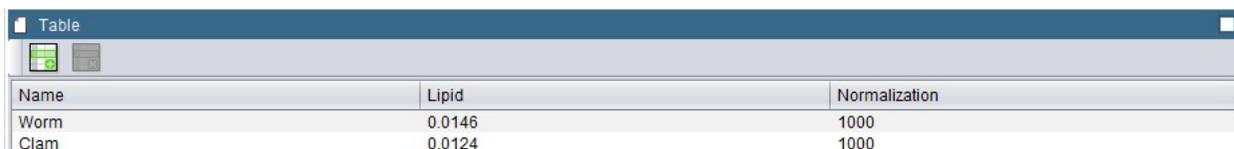


Figure 4: TT (left) and BEST (right) Explorer Panes.

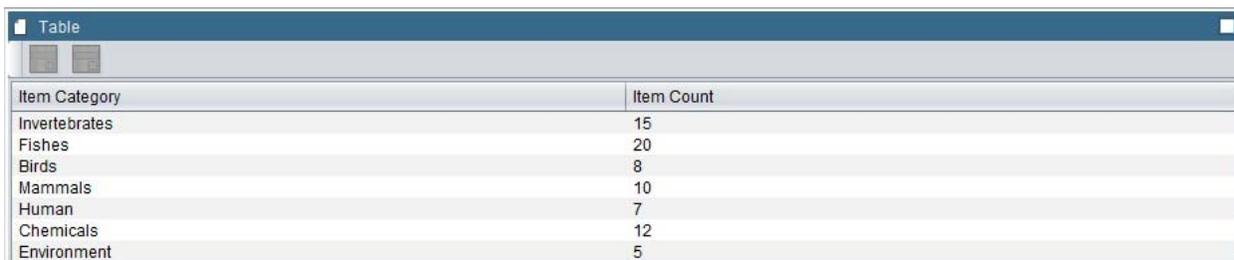
4.6 Table Pane

The Table pane shows all the model items and their certain attributes in the selected category in the Explorer pane. Selecting one of the items in the Table pane will display its properties in the Properties pane.



Name	Lipid	Normalization
Worm	0.0146	1000
Clam	0.0124	1000

Figure 5: Example BEST model Table pane showing defined values of characteristics of invertebrates including their Name, Lipid Content, and Normalization



Item Category	Item Count
Invertebrates	15
Fishes	20
Birds	8
Mammals	10
Human	7
Chemicals	12
Environment	5

Figure 6: Example TT model Table pane showing defined characteristics of invertebrates including their Name, Environment, Lipid, and Diet Pathway.

4.7 Properties Pane

The Properties pane shows the properties of the selected item. Here, property values can be assigned and edited by the user. Editable attributes either have a  button where the user must choose from a dropdown menu of possible values, or a  button where the user must directly input the values. Once the user selects or inputs the value for an item, it will appear in the Table pane. The properties vary for different categories (e.g. Invertebrates vs. Mammals). If the project is locked (File → Lock Project), item properties, except for Bioaccumulation Test results, will not be editable. To edit these values, the user must unlock the project by selecting File → Unlock Project and entering the appropriate password.

For the **TT model**, the Properties pane includes properties under the categories:

- General – All items
- Specific – All items
- Toxicity- Fish, Birds, Mammals
- Chemical Of Concern Table - Environment
- 28-Days Bioaccumulation Test - Invertebrates

- Diet – Fish, Birds, Mammals, Human

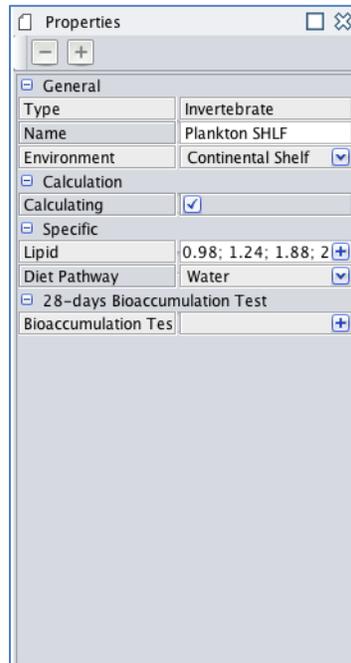


Figure 7: Example TT model Properties pane showing input properties of an invertebrate including its Type, Name, Environment, Lipid content, Diet Pathway, and Bioaccumulation Test results.

For the **BEST model**, the Properties pane includes properties under the categories:

- General – All items and Project
- Specific – All items
- Calculation – Humans and Chemicals
- Diet – Predators and Humans
- 28-Day Bioaccumulation Test – Invertebrates
- Risk Thresholds – Project
- Reference Project – Project
- Levels – Chemicals

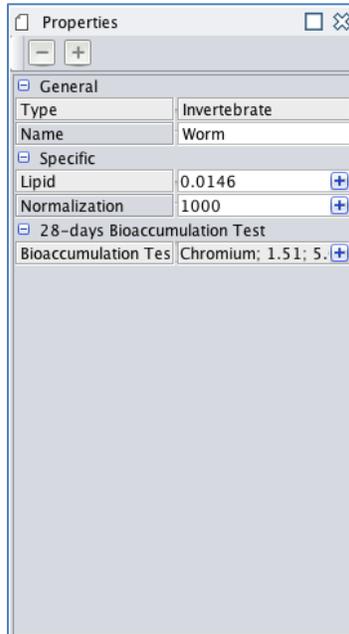


Figure 8: Example BEST model Properties pane showing input properties of an invertebrate including its Type, Name, Lipid content, Normalization, and Bioaccumulation Test results.

4.8 ReportViewer Window

The ReportViewer window shows the results of the risk assessment including risk endpoints such as the carcinogenic and non-carcinogenic risks for BEST and TT and NOAELTQ and LOAELTQ for TT. It also displays contaminant tissue concentrations and doses for model species and human and ecological receptors. Information included in the ReportViewer window depends on the model and report type. The ReportViewer appears when the user clicks the ⚡ button or selects Run → Calculate. A summary report is also available for the BEST model, which can be accessed by clicking the ⚡ button or by selecting Run → Show Summary Report. From the ReportViewer window, the user can navigate, adjust, save or print the risk assessment results.

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Fishes		1
<i>Anchovy NSHR</i>		1
<i>Anchovy HCNYN</i>		4
<i>Anchovy CNYN</i>		6
<i>Anchovy SHLF</i>		9
<i>Sole NSHR</i>		11
<i>Sole HCNYN</i>		14
<i>Sole CNYN</i>		18
<i>Sole SHLF</i>		21
Humans		24
<i>Pier/Shore CTE</i>		24

Sole

Fishes

Fish Name Anchovy NSHR
Body Weight 20
Lipid 3.5; 10.7; 24.6
Site Use Factor 1

Risk List

Chemical Name	Calculation Method	NOAELTQ	LOAELTQ	NOAELTQ Eggs	LOAELTQ Eggs
DDD	Equilibrium Partitioning	0	0	0.0001	0.00006
				0.00016	0.0001
				0.00053	0.00033
				0.00222	0.00138
DDE	Equilibrium Partitioning	0	0	0.00002	0.00001
				0.00004	0.00002
				0.00014	0.00009
				0.00061	0.00038
DDT	Equilibrium Partitioning	0	0	0.00001	8.913E-6
				0.00002	0.00001
				0.0001	0.00006
				0.00038	0.00024
Chlordane	Equilibrium Partitioning	0.01299	0.00564	0	0
		0.02012	0.00873		
		0.03174	0.01377		
		0.13117	0.05692		
Dieldrin	Equilibrium Partitioning	0	0	0	0
Endosulfan II	Equilibrium Partitioning	0.00002	1.774E-6	0	0
		0.00005	5.341E-6		
		0.00005	5.363E-6		
		0.00012	0.00001		

Figure 9: Example TT model ReportViewer window page 1.

PART II: Building the Model

For a quick, step by step guide to creating BRAMS models, see Part IV - Step By Step Model Creation.

1. User Identification

Users should identify themselves by entering their user name in the User Identification window. To access this window select File → Change User. When opening BRAMS for the first time the User Identification window will appear automatically prompting the user to enter their User Name. This User Name will appear on the last page of the Reports.

2. Create or open a project or template

Create a new project:

BEST: From the main window select File → New Project → New BEST Project from the Menu bar or click  in the toolbar. Then select *Yes* when the Create new project window appears.

TT: From the main window select File → New Project → New TT Project from the Menu bar or click  in the toolbar. Then select *Yes* when the Create new project window appears.

To open an existing model or template:

From the main window select File → Open Project or Template or click , and then choose an existing model from the Open Project window.

3. Add a new item

In the Explorer pane, select the item category you wish to add to (e.g. Chemicals) then click  in the Table pane to add a new item to that category. A new item will then appear in the Explorer pane under the selected category and in the Table pane with default values for the item's properties. Items can be added to the model in any order but item properties must be input in the order specified in section 4.1 below.

BEST model: Inputs other than Bioaccumulation Test results may be password protected if the project has been locked. If so, the project must be unlocked to edit inputs. To lock or unlock a project, see Part II Section 6.

4. Add or edit project and item properties

4.1 General

For each item, the user must specify values for each property in the Properties pane. Because some value choices depend on other inputs, add property values to items in each category in the Properties Pane in the order:

- BEST:
1. Chemicals
 2. Invertebrates
 3. Predators
 4. Humans

BEST model: Inputs other than Bioaccumulation Test results may be password protected if the project has been locked. If so, the project must be unlocked to edit inputs. To lock or unlock a project, see Part II Section 6.

- TT:
1. Chemicals
 2. Environment
 3. Invertebrates
 4. Fish
 5. Birds, Mammals, or Humans

BRAMS properties may be input using one of these four input methods:

Excel Input (BEST Model Only): Some Project, Chemical and Invertebrate items and properties are imported into the current BEST project directly from selected Microsoft (MS) Excel files with the appropriate format. See Part II section 4.3 for a complete description of the MS Excel Input method and input formats. MS Excel input templates are also included in the BRAMS software package.

Text Box: Click inside the text box directly right of the property name; delete any unwanted text and type new text.

Drop Down Menu :

Click  to the right to of the property you wish to edit to view possible choices. Double click the appropriate choice.

Add Button :

Click  to the right of the property you wish to edit. This will either display a drop down window with four possible numerical inputs (for parameter uncertainty in TT models only) or a drop down table with information relating the current item to another item type (e.g.

Concentrations of specific Chemicals in specific Invertebrate's tissue according to the 28-day Bioaccumulation test). After clicking , add values depending on the property type:

Independent Numerical Values – Double click the specific input value in the dropdown window that you wish to edit, delete the current value and enter the new value.

Other Item Dependent Values - Click  in the bottom right corner of the drop down table to add an existing item from within the related item category. Then click  below the new item category to see the list of existing items. Choose one of the existing items by double clicking it. Next, specify values for each attribute by double clicking the cell corresponding to each and entering the desired value. Click  to delete an item from the list.

4.2 By model type and item category

4.2.1 BEST model:

To edit an item's properties:

- (1) In the Explorer pane, select the item category.
- (2) In the Table pane, select the specific item.
- (3) In the Properties pane, edit properties as described below.

Project properties:

General:

Specify the Project Name, Project Number and Location by either, (1) clicking inside the text boxes to the right of each corresponding property name, deleting any contents, and entering the appropriate data or (2) importing the data from the 28-day Bioaccumulation Test Results Excel sheet (See Part II section 4.3 on Excel Inputs).

Risk Thresholds:

Enter carcinogenic and non-carcinogenic risk thresholds in the General Project Properties pane by clicking inside the corresponding text boxes and entering values. Calculated risk levels exceeding these thresholds will be highlighted in red in the Total Risks and Contaminant Specific Risks sections of the BEST Summary Report.

Reference (For Optional Test and Reference site risk comparison):

Once a reference project has been completed and saved, its risk results can be loaded into another project for comparison in the Total and Contaminant Specific Risks sections of the BEST Summary Report. To specify the reference project, click  to the right of Reference Project in the Project Properties pane. The Open window will appear where you can search for and select the .best file corresponding to the current project's reference project. Cancer and Non-Cancer risks from the reference project will then appear in the Reference rows of the Total Risks and Contaminant Specific Risks sections of the BEST Summary Report.

Item properties:

For each item, the user must specify property values within the property categories including:

- General – All items
- Calculation – Humans and Chemicals
- Specific – All items
- Diet – Predators and Humans
- 28-Day Bioaccumulation Test – Invertebrates
- Levels – Chemicals

While the item you wish to edit is selected in the Table Pane, specify its properties by entering values into the boxes within the Properties pane.

Chemicals: All chemical data can be entered automatically by importing the data from the Chemical Input Excel sheet (See Part II section 4.3 on Excel Inputs). To enter chemical data manually, follow the directions below. If the value of any property is unknown, enter NA in the text box (default value).

General:

- (1) Name: Specify the name of the item by clicking inside the text box to the right of Name, deleting the current name, and typing a new one.

Calculation:

- (2) Calculating: Specify whether or not to include the chemical in the model calculations. Check the box to the right of to include the item, uncheck the box to exclude the item.
- (3) TEF Reference Chemical: Specify whether the chemical is a TEF Reference Chemical (ex. 2,3,7,8-TCDD and benzo(a)pyrene) by checking (Yes) or un-checking (No) the box to the right of Reference Chemical. Chemicals designated as TEF reference chemicals will then be added to the TEF calculation drop down menu.
- (4) TEF Relation: Specify if or how a Human Toxicity Equivalency Factor (TEF) applies. Select NA for all items that do not have a TEF (NA is the default value). For items such as individual dioxin congeners, coplanar PCB compounds and selected PAH compounds that have assigned TEF values, select the reference chemical their TEF applies to. This information can be entered manually or imported directly from a Chemical Excel file. To enter TEF information by importing from Excel, see Part II Section 3.3. To enter TEF information manually, click to the right of TEF to display a dropdown menu of possible TEF choices. See Part V Section 2.3 for additional information on TEF application to chemicals in the BEST model.

Specific:

- (5) Chemical Type: Click to specify whether the chemical is Organic or Metal. Organic and metal contaminant transfer are calculated differently.

- (6) Cancer Slope Factor (mg/kg-day)⁻¹: Specify the Oral Cancer Slope factor associated with the chemical by clicking inside the textbox and entering the appropriate value. This value will be used to determine Carcinogenic Risk.
- (7) Reference Dose (mg/kg-day): Specify the Reference Dose associated with the chemical by clicking inside the textbox and entering the appropriate value. This value will be used to determine Noncarcinogenic Risk.
- (8) Biomagnification Factor: Specify the Reference Dose associated with the chemical by clicking inside the textbox and entering the appropriate value. This value will be used to determine contaminant transfer from invertebrates to predators.
- (9) Human Toxicity Equivalence Factor: If a TEF does not apply, the selected chemical should have 'N/A' selected in the TEF Relation property field above and 'NA' will appear in the Human Toxicity Equivalence Factor text box. If a TEF does apply, click inside the textbox and enter the appropriate TEF value relating this chemical's toxicity to a chemical of known toxicity.
- (10) Steady State Correction Factor: Specify the steady state correction factor associated with the chemical by clicking inside the textbox and entering the appropriate value. This value will be used to correct for underestimates of contaminant transfer from sediment to invertebrates during 28-day bioaccumulation testing.

Levels:

- (11) FDA Action Level: Specify the FDA Action Level (ppm) associated with the chemical by clicking inside the textbox and entering the appropriate value.
- (12) Ecological Effect Level: Specify the Ecological Effect Level (ppm) associated with the chemical by clicking inside the textbox and entering the appropriate value.

Invertebrates:

General:

- (1) Name: Specify the name of the item by clicking inside the text box to the right of Name, deleting the current name, and typing a new one.

Specific:

- (2) Lipid: Specify the invertebrate's lipid content (g lipid/g tissue) by clicking inside the text box, deleting the current value and entering the new value.

28-Days Bioaccumulation Test:

- (3) Bioaccumulation Test: There are two ways to enter 28-day bioaccumulation test data:
 - a. Import data directly from a 28-day Bioaccumulation Test Results Excel sheet as described in Part II Section 4.3 or

- b. Enter the data manually by first clicking  to display a drop down window where you can add chemicals from the Chemicals category and Mean and Max Tissue Concentrations. Then click  in the bottom right corner of the drop down window to add a new row. Next, click  in the Chemical column of the new row to choose from the existing chemicals. Finally, specify values for Mean Tissue Concentration and Max Tissue Concentration by double clicking the corresponding cells and typing their values. Organic tissue concentrations should be in units of ng/g, while metal tissue concentrations should be in units of µg/g. Click  to delete a chemical from the table.

Predators:

General:

- (1) Name: Specify the name of the item by clicking inside the text box to the right of Name, deleting the current name, and typing a new one.

Specific:

- (2) Lipid: Specify the invertebrate's lipid content (g lipid/g tissue) by clicking inside the text box, deleting the current value and entering the new value.

Diet:

- (3) Predator Diet: First click  to display a drop down window where you can add each predator's potential prey species. Click  in the bottom right corner of the drop down window to add a new prey species. Then click  to the right of the new row to specify which of the existing Invertebrate species to add.

Humans:

General:

- (1) Name: Specify the name of the item by clicking inside the text box to the right of Name, deleting the current name, and typing a new one.

Calculation:

- (2) Calculating: Specify whether or not to include the item in the model calculations. Check the box to the right of Calculating to include the item, uncheck the box to exclude the item from the model calculations.

Specific:

- (3) Body Weight: Specify the human's body weight in kilograms by clicking inside the text box, deleting the current value and entering the new value.
- (4) Averaging Time: Specify the averaging time in days to be used in the human's average daily dose calculation by clicking inside the text box, deleting the current value and entering the new value.

Diet:

(5) Human Diet: Click  to display a drop down table where you can add species that make up the selected human's diet. Click  in the bottom right corner of the table to add a new row. Then click  below the Prey column in the new row to choose from the existing lower trophic level species. Then specify values for fraction ingested, frequency (days/year), ingestion rate (kg/day), and exposure duration (years), by double clicking the space below each and entering the appropriate values. These values will be used to calculate the human's average daily dose of contaminants in each diet species. Click  to delete a row from the list.

4.2.2 TT Model:

For each item, the user must specify property values within three or more categories including:

- General – All items
- Specific – All items
- 28-Days Bioaccumulation Test - Invertebrates
- Diet – Fish, Birds, Mammals, Human
- Toxicity- Fish, Birds, Mammals
- Chemical Of Concern Table - Environment

While the item you wish to edit is selected, specify its properties by entering values into the boxes within the Properties pane. For each Properties category, follow the directions below.

General:

Specify the name of the item by clicking the box to the right of Name, deleting the current name, and typing a new one. Specify the environment by clicking the  then the appropriate environment type.

Specific:

Specify values in the Specific category by clicking  to the right of the characteristic you wish to edit. This will display a drop down window with four possible inputs. Double click the input value you wish to edit, delete the current value and enter the new value. If the input value is known with certainty, simply enter the known value in all four spaces. If the input value is uncertain, enter four values representing the range of possibilities according to trapezoidal fuzzy numbering (See Part V Section 3). Or, for some input categories, (Invertebrates-Diet Pathway, Fish-Trophic Level and Reference Invertebrate, Chemicals- Chemical Type) click the  to the right to of the characteristic you wish to edit to display a drop down menu of pre-specified choices and click the desired choice.

28-Days Bioaccumulation Test:

For items in the Invertebrates category, specify Bioaccumulation Test values by clicking  to the right of Bioaccumulation Test. This will display a drop down window where you can input chemicals, their concentrations and whether or not steady state applies. To add a chemical, click  in the bottom right corner of the drop down window. Then click the  in the new row below Chemical, this will display the list of chemicals that have previously been added to the Chemicals category. Click the chemical you wish to add information about and it will appear on the list. Then double click the box corresponding to its concentration. Now you can either add one, certain value by typing it in the box or add four values for uncertain inputs by clicking  to the right of the box and entering the values according to trapezoidal fuzzy numbering (See Part V Section 3). Next, if steady state applies, check the box below Steady State Applies. If it does not apply, leave the box blank.

Diet:

For items in the Fishes, Birds, Mammals and Human categories, specify Diet properties by clicking  to the right of Diet. This will display a drop down window where you can input the selected item's prey species, and the percent of their diet each makes up. To add a prey species, click  button in the bottom right corner of the drop down window. Then click the  in the new row below Prey, to will display the list of potential prey species that have previously been added to the model. Click the species that make up the selected item's diet and they will appear on the list. Then double click the Percent box and type the percent of the selected item's diet that each prey species makes up. Enter prey species until the total diet percent adds up to 100.

Toxicity:

For items in the Fishes, Birds, and Mammals categories, specify Toxicity properties by clicking  to the right of Toxicity and, for Fishes and Birds, Eggs Toxicity. For both, this will display a drop down window where you can input chemicals, and their NOAEL and LOAEL Residue values. To add a chemical, click  in the bottom right corner of the drop down window then  below the Chemical category in the dropdown window. This will display the list of chemicals that have previously been added to the Chemicals category. Click the chemical you wish to add information about and it will appear on the list. Then double click the box corresponding to NOAEL Residue. Now you can either add one, certain value by typing it in the box or add four values for uncertain inputs by clicking  to the right of the box and entering the values according to trapezoidal fuzzy numbering (See Part V Section 3). Next add values to LOAEL Residue in the same way.

Chemical of Concern Table:

For items in the Environment category, specify Chemical Of Concern properties by clicking  to the right of Chemical Of Concern. This will display a drop down window where you can input chemicals, and their concentrations in water and sediment. To add a chemical, click the green Insert Row button in the bottom right corner of the drop down window, and then click  below the Chemical category in the dropdown window. This will display the

list of chemicals that have previously been added to the Chemicals category. Click the chemical you wish to add information about and it will appear on the list. First specify whether you will enter the Total or the Dissolved concentration by clicking  below Concentration Type in the dropdown window and then clicking either Total or Dissolved. Then, for both the Water and Sediment categories, double click the boxes corresponding to each and either add one, certain value by typing it in the box or add four values for uncertain inputs by clicking  to the right of the box and entering the values according to trapezoidal fuzzy numbering (See Part V Section 3).

4.3 Import Data From Excel (BEST Model)

Invertebrates and their 28-day Bioaccumulation Test Results as well as Chemicals and all chemical properties can be entered directly into a BEST model by importing values from Microsoft Excel spreadsheets according to established templates. In order for BRAMS to read the values correctly, they must be uploaded in accordance with specific Excel templates included in the BRAMS software package. Templates for the 28-day Bioaccumulation Test Input and Chemicals Input are provided with the software package and shown below in figures 9-11. To add certain invertebrate or chemical items (e.g. *Macoma nasuta*) or properties (e.g. Mean Tissue Concentration from 28-day Bioaccumulation Test results for “Lead” in “*Macoma nasuta*”) the Chemical and Invertebrate names must match those in the model exactly, otherwise new items will be created.

Once all desired values have been correctly entered into the Excel Input templates, select File → Import → Import Bioaccumulation Results or Import Chemicals. The Open Excel window will appear where you can select the appropriate Excel file. Once you have selected the desired file, click *Open*. The window will then close and the data within the selected Excel file will be added to the model.

Chemical Inputs should be entered in the format shown in Figure 10 and Figure 11 below. Properties of each chemical (e.g. Oral Cancer Slope Factor, Oral Reference Dose, Biomagnification Factor, etc.) entered here will be automatically entered into the Chemicals section. NA will be assigned to properties, which either have the value, ‘NA’ or that have no contents in the corresponding Excel cells. If chemical properties that correspond to blank cells in Excel appear as ‘0’ instead of ‘NA’ once imported into BRAMS, go back to the cells and use the Excel function ‘Clear Contents’ to empty the cells. An extensive chemical library is included in the BRAMS package and in the included BEST template file.

	A	B	C	D	E
1	Chemicals				
2					
3	Name	Chemical Type	Oral Cancer Slope Factor (mg/kg-day) ⁻¹	Oral Reference Dose (mg/kg-day)	Biomagnification Factor
4					
5	c1	Organic	1.00	1.00	1.00
6	c2	Organic	1.00	1.00	1.00
7	c3	Metal	1.00	1.00	1.00
8	c4	Organic	1.00	N/A	1.00

Figure 10: Excel Chemicals Input Sheet, Columns A-E.

	F	G	H	I	J	K
1						
2						
3	Human Toxicity Equivalence Factor	TEF Reference Chemical	TEF Relation	Steady State Correction Factor	FDA Action Level (mg/kg)	Ecological Effects Level (mg/kg)
4						
5	1.00	Y	NA	1.00	1.00	1.00
6	0.01	N	c1	1.00	1.00	1.00
7	NA	N	NA	1.00	1.00	1.00
8	NA	N	NA	1.00	1.00	1.00

Figure 11: Excel Chemicals Input Sheet, Columns F-K.

The **28-day Bioaccumulation Test Results** must be input into the software in the format shown in Figure 12. The user must include the organism, contaminant, mean tissue concentration and maximum tissue concentration as well as the Project Name, Project Number and Location. For unit consistency, [Tissue]/Normalization Factor must equal units of mg/kg. For example if the Normalization Factor (Invertebrate property) = 1000, enter tissue concentration in ng/g. If the Normalization Factor (Invertebrate property) = 1, enter tissue concentration in µg/g.

	A	B	C	D
1	28-days Bioaccumulation Test Results			
2	Project Name:	pname1		
3	Project Number:	pnumber1		
4	Location	l1		
5				
6	Organism	Contaminant	Mean Tissue Concentration ([Tissue]/Normalization Factor = µg/g)	Max Tissue Concentration ([Tissue]/Normalization Factor = µg/g)
7				
8	o1	c1	1.00	1.00
9	o1	c2	1.00	1.00
10	o1	c3	1.00	1.00
11	o1	c4	1.00	1.00
12	o2	c1	1.00	1.00
13	o2	c2	1.00	1.00
14	o2	c3	1.00	1.00
15	o2	c4	1.00	1.00
16				

Figure 12: Excel Bioaccumulation Test Results Input Sheet

5. Using Templates

Using templates as a base to build each project model from saves time and effort and ensures consistency between related projects. Instead of entering all items and properties for each new project, templates allow the user to start with all or most of the project components, except for certain project specific data, already entered into the model. Included BRAMS templates can be found in the Examples folder. Once a template has been created, values can be protected by locking the model or saving it permanently.

6. Locking and Unlocking BEST Model Properties

The majority of BEST model users should base their risk assessment models on templates with established property values and should only need to edit the 28-days Bioaccumulation Test

Results. To prevent users from changing the established values (e.g. Lipid content of *N. virens*, Oral Cancer Slope Factor of DDT), these values can be locked. Property values other than 28 Day Bioaccumulation Results will become grayed-out and password protected.

Lock: To lock a project, select File → Lock Project. This will display the Password Protection window where the user should enter a password and click continue.

Unlock: To unlock a project, select File → Unlock Project. This will display the Password Protection window where the user should enter the previously set password and click continue. Property values should once again be freely editable.

7. Saving Permanently

The Save Permanently feature allows users to save a project file so that it cannot be overwritten. A permanently saved file can be accessed and edited but then must be saved under a different name. This feature is designed to preserve templates for future use and finalized projects for future review.

To save a file permanently, select File → Save permanently. This will display the usual *Save Project As...* window where the user can name and specify a location to save the current project permanently.

Part III: Results

1. Generate Report

Once all items and their properties necessary for the risk assessment have been specified, click either Run → Calculate or Run → Show Report in the Menu or click the Show Report button  in the Toolbar to generate the report. An additional summary report is available for the BEST model. This report can be accessed by selecting Run → Show Summary Report or clicking the Show Summary Report button . The ReportViewer window will then appear showing results of the model analysis. The different outputs for TT and BEST are detailed in Section 2 below. Reports can be exported to multiple file formats by selecting File → Export Report or printed by selecting File → Print Report.

2. Outputs

Trophic Trace

Trophic Trace evaluates risks with different endpoints for humans and ecological receptors.

For a given ecological receptor, the Trophic Trace output report will first provide a description of the receptor including its name, body weight, lipid content and site use factor. For human receptors, the output first shows the human's name, weight, lifespan and diet information.

Fishes	
Fish Name	Anchovy NSHR
Body Weight	20
Lipid	3.5; 10.7; 24.6
Site Use Factor	1

Figure 13: TT ecological receptor properties report section.

Next, the output displays the receptor's "Risk List." For ecological receptors, this section identifies the chemical names, calculation method, NOAEL TQ, LOAEL TQ, NOAEL TQ for eggs, and LOAEL TQ for eggs. For human receptors, the Risk List section shows the calculation method, incremental lifetime cancer risk (LCR), and noncarcinogenic hazard index (Hazard) from each chemical.

Risk List					
Chemical Name	Calculation Method	NOAELTQ	LOAELTQ	NOAELTQ Eggs	LOAELTQ Eggs
DDD	Equilibrium Partitioning	0	0	0.0001 0.00016 0.00053 0.00222	0.00006 0.0001 0.00033 0.00138
DDE	Equilibrium Partitioning	0	0	0.00002 0.00004 0.00014 0.00061	0.00001 0.00002 0.00009 0.00038
DDT	Equilibrium Partitioning	0	0	0.00001 0.00002 0.0001 0.00038	8.913E-6 0.00001 0.00006 0.00024
Chlordane	Equilibrium Partitioning	0.01299 0.02012 0.03174 0.13117	0.00564 0.00873 0.01377 0.05692	0	0
Dieldrin	Equilibrium Partitioning	0	0	0	0
Endosulfan II	Equilibrium Partitioning	0.00002 0.00005 0.00005 0.00012	1.774E-6 5.341E-6 5.363E-6 0.00001	0	0

Figure 14: TT ecological receptor Risk List report section.

The next set of information displayed for each ecological and human receptor is the “Exposure Concentration.” Included as part of this are diet items, the environment, diet percent, chemical, and concentration of that chemical.

Exposure Concentration				
Diet Item	Environment	Diet Percent	Chemical	Concentration
Plankton NSHR	Nearshore	100.0	DDD	0.00575 0.00727 0.02294 0.03344
Plankton NSHR	Nearshore	100.0	DDE	0.00159 0.00201 0.00669 0.00975
Plankton NSHR	Nearshore	100.0	DDT	0.00069 0.00087 0.00376 0.00548
Plankton NSHR	Nearshore	100.0	Chlordane	0.01247 0.01577 0.02391 0.03485
Plankton NSHR	Nearshore	100.0	Dieldrin	0.00241 0.00305 0.00463 0.00674
Plankton NSHR	Nearshore	100.0	Endosulfan II	0.00003 0.00004 0.00006 0.00009
Plankton NSHR	Nearshore	100.0	Endosulfan sulfate	0.00004 0.00006 0.00009 0.00013
Plankton NSHR	Nearshore	100.0	Endrin	0.00154 0.00195 0.00295 0.0043
Plankton NSHR	Nearshore	100.0	Toxaphene	0.03867 0.04893 0.07419 0.10813

Figure 15: TT Exposure Concentration report section.

The last section included in the Trophic Trace output report is a graphical representation of the risks including uncertainty bounds. For ecological receptors this includes NOAEL TQ, LOAEL TQ, NOAEL TQ eggs, and LOAEL TQ eggs, for each of the chemicals present at the site. For human receptors, this includes LCR and Hazard for each of the chemicals present at the site.

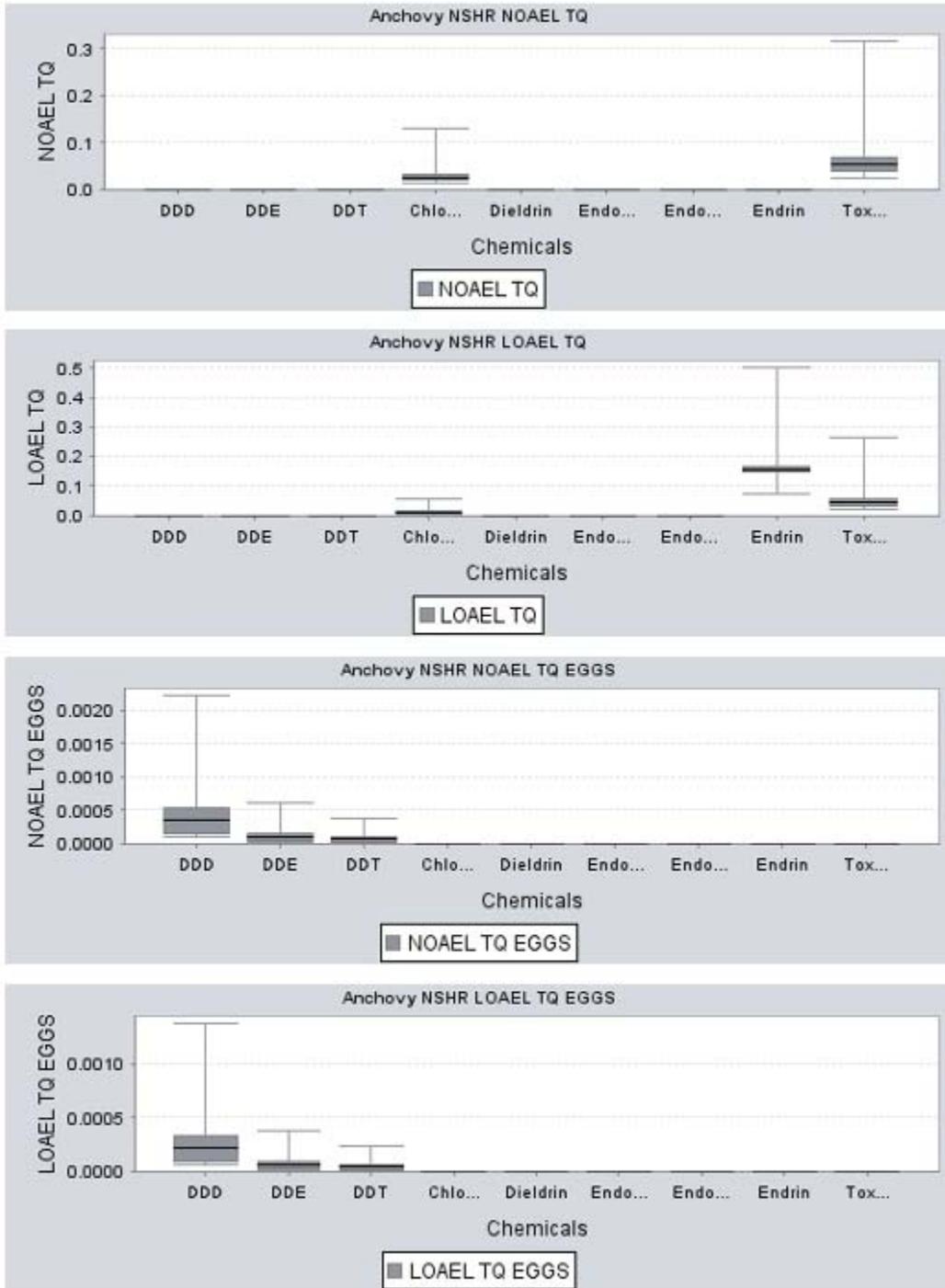


Figure 16: TT Risk Figures report section for ecological receptor.

BEST

The BEST model has two options for output reports: the Summary Report and the Full Report. The Summary Report can be generated by clicking  while the Full Report is generated by clicking .

Summary Report

The BEST Summary Report includes three sections for each Invertebrate species in the model. The first section, “Total Estimated Risks,” includes the total cancer risk and non-cancer risks in each human diet species for both the test and reference sites. The next section, “FDA Action Levels and Ecological Risk,” includes each chemical’s name, mean tissue concentration in the current invertebrate, steady state correction factor, and FDA Action and Ecological Effect Level, as well as whether or not the concentration exceeds each Level. The summary report also includes the “Contaminant Specific Risks,” which lists the cancer and non-cancer risks from each individual chemical in each of the human diet species for the test and reference sites.

Total Estimated Risks			
Contaminant		Lobster Muscle	
		Cancer Risk	Non-cancer Risk
Total	Test	5.032E-7	5.032E-7
	Reference	NA	NA

FDA Action Levels and Ecological Risk						
Chemical	Mean Tissue Concentration	Steady State Correction	FDA Action Level	Exceeds FDA Action Level	Ecological Effect Level	Exceeds Ecological Effect Level
Chem #1	1.51	1	0	Yes	0	Yes

Contaminant Specific Risks			
Contaminant		Lobster Muscle	
		Cancer Risk	Non-cancer Risk
Chem #1	Test	5.032E-7	5.032E-7
	Reference	NA	NA

Figure 17: BEST Summary Report sections.

Full Report

General	
Human Name	Boat CTE
Cancer Risk	2.105E-7
Non-Cancer Risk	2.105E-7

Diet Report		
Diet Name	Cancer Risk	Non-Cancer Risk
Fish Fillet	2.339E-8	2.339E-8
Lobster Muscle	1.871E-7	1.871E-7

Prey Report			
Prey Name	Diet Name	Cancer Risk	Non-Cancer Risk
Worm	Fish Fillet	1.25E-8	1.25E-8
Clam	Fish Fillet	1.089E-8	1.089E-8
Worm	Lobster Muscle	1E-7	1E-7
Clam	Lobster Muscle	8.713E-8	8.713E-8

Chemical Report					
Chemical Name	Diet Name	Edible Tissue Concentration	Average Daily Dose	Cancer Risk	Non-Cancer Risk
Chem #1	Fish Fillet Worm	0.00103	1.25E-8	1.25E-8	1.25E-8
Chem #1	Fish Fillet Clam	0.0009	1.089E-8	1.089E-8	1.089E-8
Chem #2	Fish Fillet Clam	0	0	0	0
Chem #1	Lobster Muscle Worm	0.00274	1E-7	1E-7	1E-7
Chem #1	Lobster Muscle Clam	0.00239	8.713E-8	8.713E-8	8.713E-8
Chem #2	Lobster Muscle Clam	0	0	0	0

Figure 18: BEST Full Report sections

The full report includes the following sections: Diet Report, Prey Report, and Chemical Report. The Diet Report section displays the cancer risk, and the non-cancer risk from each human diet species. The Prey Report displays the prey name, the diet name, the cancer risk, and the non-cancer risk. The Chemical Report displays the chemical name, the diet name, the edible tissue concentration, the average daily dose, the cancer risk, and the non-cancer risk. For example, in the first row of the Chemical Report section of Figure 18, shows the edible tissue

concentration and average daily dose of Chem #1 from eating a Fish Fillet of a fish that ate Worm and the resulting cancer and non-cancer risks from consuming that fish.

Both the Summary and Full BEST Reports are also stamped with the version of the software, the date, and the name of the user who ran that iteration of the software. This provides better record keeping for BRAMS users.

Software version:	BRAMS 3.0
Last date:	04/27/2012
User name:	JOHN DOE

Figure 19: BEST Model Report Identification section.

Part IV: Step by Step Model Creation

This section presents simple, step by step instructions to create and run BRAMS models to conduct bioaccumulation risk assessments. A more detailed description of BRAMS components, and model building and editing is presented in Section II.

1. BEST Model

Below is an example of how to quickly, and efficiently run a Bioaccumulation Risk Assessment using the BEST model. In this example, the user will first create a BEST model for a reference site then create a BEST model for a project test site, and finally generate results that compare the two sites.

This example assumes the user has the following:

- (1) The BRAMS software package saved to the computer. If not, see Part I Section 2.2.
- (2) The appropriate BEST template file (.best) with all or most necessary project inputs except 28-day bioaccumulation testing results. See Part II Section 5 for an explanation of BRAMS templates. See Part II Section 4.2.1 for a detailed instructions of how to create a new model or template starting with a blank model.
- (3) Completed Bioaccumulation Test Result Excel files for the project test and reference sites. If not, see Part II Section 4.3.

Once the user has these items, they may proceed to Step one.

STEP ONE: Getting Started

- Open the BRAMS software by running the executable file BRAMS.jar.
- The StartUp window will then appear while BRAMS is loading.
- If this is the first time the program has been opened, once BRAMS has finished loading, the User Identification window will appear prompting the user to enter their User Name. Enter your User Name and click *Continue* to continue to the main BRAMS window.
- If BRAMS has been previously opened on this computer, the Main Window will appear automatically and the previously entered User Name will be used.
- From the Main Window, the user is now ready to create, open, edit, and run BRAMS models.

STEP TWO: Open the appropriate BEST template file

- From the main menu select File → Open Project or Template or click  in the toolbar.

- The Open Project window will appear where the user should locate and select the appropriate BEST template file for the current project. Once the template file has been selected, click *Open* to load the BEST template file data.

STEP THREE (Optional): Add or Edit Items and Properties

If the project requires any changes to model items or properties from the selected template model, make changes in the following way:

- Add or delete project items:
 - In the Explorer Pane, click and highlight the item category you wish to edit. Items in this category will then appear in the Table Pane.
 - In the Table Pane, Click  to create a new item in the selected category. In the Properties Pane, enter the name of the item in the Name text box.
 - To delete an item, select it and click .
- Edit item or project properties:
 - In the Explorer Pane, select the category of the item you wish to enter properties for or select the Project category.
 - Project category: Project properties will appear in the Properties Pane.
 - Item categories: Select the specific item you wish to edit properties for in the Table Pane. The selected item's properties will then appear in the Properties Pane.
 - In the Properties Pane, edit any properties.
 - For those properties with a : Click the  and select an item from the drop down menu.
 - For those properties with a :
 - Numerical values: If the input value is known with certainty, simply enter the known value in the text box. If the input value is uncertain, click the  and enter four values representing the range of possibilities according to trapezoidal fuzzy numbering (See section Part IV section 3).
 - Tables: Click the  next to the property. A table will appear where you can input related items by clicking  and selecting from a drop down menu of options. Then specify any remaining information in the table relating the items in the property table to the selected item.
 - For those properties with a : Click inside the box to check or uncheck the box.
 - Continue editing until all project specific item and property changes have been made.

STEP FOUR: Import 28 Day Bioaccumulation Reference Data

- In the main menu, select File → Import → Import Bioaccumulation Results.

- The Open Excel window will then appear. Locate and select the Bioaccumulation Test Result Excel file containing project reference data and click *Open*.
- The Import Mode window will then appear, click *Yes* to import the data.
- Reference site data within the imported Bioaccumulation Test Result Excel file should now appear in the 28-days Bioaccumulation Test properties for each Invertebrate included in the test and general project properties should appear in the Project Properties pane.

STEP FIVE: Name and save the reference site project

- From the main menu select File → Save Project As or click  to name and save the project. Be careful not to overwrite the template file.
- The Save Project As... window will appear prompting the user to assign a name and location to save the new BEST reference project. Select the desired location and name the project, then click *Save*. This will save the project and return you to the Main Window.

STEP SIX: Import 28 Day Bioaccumulation Test Data

- In the main menu, select File → Import → Import Bioaccumulation Results.
- The Open Excel window will then appear. Locate and select the Bioaccumulation Test Result Excel file containing project test site data and click *Open*.
- The Import Mode window will then appear, click *Yes* to import the data.
- Test site data within the imported Bioaccumulation Test Result Excel file should now appear in the 28-days Bioaccumulation Test properties for each Invertebrate included in the test and general project properties should appear in the Project Properties pane.

STEP FIVE: Name and save the test site project

- From the main menu select File → Save Project As or click  to name and save the project. Be careful not to overwrite the reference site file.
- The Save Project As... window will appear prompting the user to assign a name and location to save the new BEST reference project. Select the desired location and name the project, then click *Save*. This will save the project and return you to the Main Window.

STEP SEVEN: Specify Reference Project

- In the Explorer pane, click the main Project category (the first category in the Explorer Pane).
- In the Properties Pane, click  to the right of Reference Project in the Reference section.
- The Open window will appear where you can search for and select the file corresponding to the reference site, then click *Open*.
- The reference project file should now appear in the Reference project input box.

STEP EIGHT: Save the completed test site project

- From the main menu select File → Save Project or click  to overwrite the previous file and save the current project.

STEP NINE: Calculate and display results

- Click  to run the model calculations and view the detailed report or click  to run the model calculations and view the summary report. After the calculation has completed, the Report window will appear showing risk assessment results for the project.

STEP TEN: Save Results

- In the Report window, save the project risk assessment results by clicking .

2. Trophic Trace Model

This section presents simple, step by step instructions to create and run a TT model. In this example, the user will develop an entirely new TT model. Alternatively, if an appropriate template model is available, the user should begin with a template model similar to the method in the BEST model step by step example above.

STEP ONE: Getting Started

- Open the BRAMS software by running the executable file BRAMS.jar.
- The StartUp window will then appear while BRAMS is loading.
- If this is the first time the program has been opened, once BRAMS has finished loading, the User Identification window will appear prompting the user to enter their User Name. Enter your User Name and click *Continue* to continue to the main BRAMS window.
- If BRAMS has been previously opened on this computer, the Main Window will appear and the previously entered User Name will be used.

- From the Main Window, the user is now ready to create, open, edit, and run BRAMS models.

STEP TWO: Open a new TT project

- Click  to open a new Trophic Trace project. The blank Trophic Trace framework will then appear in the BRAMS panes.
- As mentioned previously, the user can also begin with an appropriate template model when available. To load a template model, simply click  in the toolbar and select the template file in the Open window.

STEP THREE: Add Items and Properties

Add items and their properties to the project in by navigating the Explorer, Table and Properties Panes within the Main Window.

- Add the items you wish to include in the project to each of the item categories (Invertebrates, Fishes, Birds, Mammals, Human, Chemicals, Environment) in the Explorer Pane.
 - In the Explorer Pane, click and highlight the item category you wish to edit. Items in this category will then appear in the Table Pane.
 - In the Table Pane, Click  to create a new item in the selected category. To delete an item, select it and click .
 - In the Properties Pane, enter the name of the item in the Name text box.
 - Continue adding and naming items until all model items have been entered into the project.
- Enter the properties of each item in the Properties Pane.
 - In the Explorer Pane, select the category of the item you wish to enter properties for.
 - In the Table Pane, select the item you wish to add properties to.
 - In the Properties Pane, add all properties.
 - For General and Specific properties:
 - For those properties with a : Click the  and select an item from the drop down menu.
 - For those properties with a : If the input value is known with certainty, simply enter the known value in the text box. If the input value is uncertain, click the  and enter four values representing the range of possibilities according to trapezoidal fuzzy numbering (See section Part V section 3).
 - For Toxicity and Diet properties:
 - Click the  next to the property. A table will appear where you can input related items by clicking  and selecting from a drop

down menu of options. Then specify any remaining information in the table relating the items in the property table to the selected item.

- Continue selecting items and adding properties until all properties have been specified.

STEP FOUR: Save Completed Project

- Click  to name and save the project. The Save Project As... window will appear prompting the user to assign a name and location to save the new TT project. Select the desired location and name the project, then click *Save*. This will save the project and return you to the Main Window.

STEP FIVE: Calculate and display results

- Click  to run the model calculations and view the report. After the calculation has completed, the ReportViewer window will appear showing risk assessment results for the project.

STEP SIX: Save Results

- In the ReportViewer window, save the project risk assessment results by clicking .

Part V: BRAMS Modeling Framework

This part summarizes the theoretical foundation of the Trophic Trace and BEST models in terms of input parameters, assumptions, and risk calculations. The information also provides a basis for comparison between the two models in BRAMS.

1. Modeling Framework in Trophic Trace *

1.1 Gobas Model for organics

The model used to estimate fish body burdens for hydrophobic organic compounds relies on a steady-state uptake model based on the approach of Gobas (1993 and 1995):

$$C_f = \frac{k_1 * C_{wd} + k_d * C_{diet}}{k_2 + k_e + k_m + k_g} \quad (1)$$

Where:

k_1	=	gill uptake rate (L/Kg/d)
C_{wd}	=	freely dissolved concentration in water (ng/L)
k_d	=	dietary uptake rate (d^{-1})
C_{diet}	=	concentration in the diet ($\mu\text{g}/\text{kg}$)
k_2	=	gill elimination rate (d^{-1})
k_e	=	fecal egestion rate (d^{-1})
k_m	=	metabolic rate (d^{-1})
k_g	=	growth rate (d^{-1})
C_f	=	concentration in fish ($\mu\text{g}/\text{kg}$)

Several sources provide equations for the rate constants (k_2 , k_e , k_m and k_g) and these are described in greater detail in von Stackelberg et al. (2002).

Biota-sediment accumulation factor (BSAF)

Biota-sediment accumulation factors (BSAFs) used in the model are ratios that describe the relationship between the concentration of a nonpolar organic chemical in the lipid phase in tissue of a sediment-dwelling organism to the concentration in the sediment organic carbon phase to which the organism is exposed. BSAFs are defined as:

$$BSAF = (C_B / f_L) / (C_S / f_{OC}) \quad (2)$$

* This section is adapted from the TrophicTrace 4.0 Users Manual. von Stackelberg, K. and A. Burmistrova. 2004. TrophicTrace 4.0 Users Manual: A Tool for Assessing Risks from Trophic Transfer of Sediment-Associated Contaminants. January 28, 2009. 34 pp.

Where:

C_B = concentration of contaminant in biota, mg/kg wet weight
 f_L = the fraction lipid of the biota, kg lipid/kg wet weight
 C_S = the concentration of contaminant in sediment, mg/kg dry weight
 f_{OC} = the fraction organic carbon in sediment, kg organic carbon/kg dry weight

$$C_B = C_S * (f_L / f_{OC}) * BSAF \quad (3)$$

Where:

C_B = concentration of contaminant in biota, mg/kg wet weight
 f_L = the fraction lipid of the biota, kg lipid/kg wet weight
 C_S = the concentration of contaminant in sediment, mg/kg dry weight
 f_{OC} = the fraction organic carbon in sediment, kg organic carbon/kg dry weight
BSAF = biota-sediment accumulation factor (typical assumption is 1.0) obtained from site-specific measurements or literature sources

The model can also accept a measured invertebrate concentration resulting from the standard Tier 3 28-day bioaccumulation test results. To account for the fact that these measured concentrations may not have achieved steady-state, a K_{ow} -dependent adjustment is made (McFarland, 1984; Connell and Hawker, 1988) automatically within BRAMS based on the following formula:

$$\log t_{ss} = 6.9 \times 10^{-3}(\log K_{ow})^4 - 1.85 \times 10^{-1}(\log K_{ow})^3 + 1.65(\log K_{ow})^2 - 5.34(\log K_{ow}) + 5.93 \quad (4)$$

Where:

t_{ss} = time required to reach steady-state

1.2 Trophic Transfer Factor (TTF) and Bioconcentration Factor (BCF) for inorganic and hydrophilic organic compounds

Estimates of fish burdens for inorganic and hydrophilic organic compounds rely on two different approaches, depending on data availability. The first approach is a trophic transfer factor (TTF) from prey to predator approach, and the second is a bioconcentration factor (BCF) approach. For some chemicals, there are data available on bioaccumulation from invertebrates to fish (Dillon, 1995). Currently, TTF are available for copper, cadmium, lead, zinc, and arsenic. In the BCF approach, water concentrations are multiplied by a bioconcentration factor to estimate fish body burdens. Water concentrations can either be provided by the user or estimated by the model assuming equilibrium partitioning from sediment.

Both the food web model for hydrophobic organic compounds and the BCF approach for inorganic and hydrophilic organic compounds require a freely dissolved water concentration as an input. Trophic Trace incorporates two approaches for estimating a freely dissolved water

concentration: 1) a user-specified freely dissolved water concentration from site-specific data; 2) from a subroutine (equation 5) using either a user-specified whole water concentration or an estimated whole water concentration (calculated by assuming equilibrium partitioning from a user-specified sediment concentration). The subroutine that estimates a freely dissolved water concentration is shown in equation 5:

$$C_{wd} = \frac{1}{(1 + 0.1 * DOC * DE_{oc} * K_{oc} + POC * DE_{oc} * K_{oc})} * C_{ww} \quad (5)$$

Where:

- C_{wd} = freely dissolved concentration in water (ng/L)
- DOC = dissolved organic carbon (mg/L)
- DE_{oc} = density of organic carbon (0.041 mg OC/mg)
- K_{oc} = organic carbon/water partition coefficient (L/kg OC)
- POC = particulate organic carbon (mg/L)
- C_{ww} = whole water concentration (ng/L)

If a whole water concentration is not available, the program uses equilibrium partitioning with sediment to estimate a freely dissolved water concentration. The equation for organic contaminants is:

$$C_w = \left(\frac{C_{oc}}{K_{oc}} \right) \quad (6)$$

Where:

- C_w = concentration of freely dissolved chemical in the water ($\mu\text{g/L}$)
- C_{oc} = the organic carbon-normalized sediment concentration ($\mu\text{g/kg}$ dry wt sediment) and
- K_{oc} = organic carbon-water partition coefficient (L/kg organic carbon)

The K_{oc} for each chemical can be estimated from its octanol-water partition coefficient, K_{ow} , according to the following regression relationship (Connell and Hawker, 1988):

$$\log K_{oc} = 0.00028 + 0.983 \log_{10} K_{ow} \quad (7)$$

1.3 Risk Assessment Formulas

Human Health Risk

The estimates of fish body burdens represent point estimates of concentrations to which humans are exposed via fish ingestion. These fish tissue concentrations are used along with exposure

assumptions specific to each human receptor population to calculate carcinogenic risk and non-carcinogenic hazard indices. Carcinogenic risk is calculated as follows:

$$Risk = \frac{CSF * IR_f * C_f * ED}{BW * 1000000 * AT} \quad (8)$$

Where:

- Risk = incremental lifetime cancer risk
- CSF = cancer slope factor (mg/kg-day)⁻¹
- IR_f = annualized fish ingestion rate (g/day)
- C_f = concentration in fish (µg/kg)
- ED = exposure duration (days)
- BW = body weight (kg)
- AT = averaging time (days)

Non-carcinogenic hazard indices are calculated as follows:

$$HI = \frac{IR_f * C_f * ED}{RfD * BW * 1000000 * AT} \quad (9)$$

Where:

- HI = hazard index
- RfD = Reference dose (mg/kg-day)
- IR_f = annualized fish ingestion rate (g/day)
- C_f = concentration in fish (µg/kg)
- ED = exposure duration (days)
- BW = body weight (kg)
- AT = averaging time (days)

Ecological risk

Potential ecological risks are evaluated by comparing predicted contaminant concentrations in tissue and/or daily dose estimates to appropriate toxicity reference values (TRVs). These comparisons are based on predicted tissue concentrations in mg/kg for fish, and on predicted daily dose estimates for the higher order ecological receptors.

TRVs are levels of exposure associated with either Lowest Observed Adverse Effects Levels (LOAELs) or No Observed Adverse Effects Levels (NOAELs). They provide a basis for judging the potential effects of measured or predicted exposures that are above or below these levels. TRVs are contaminant- and species-specific and are developed based on laboratory or field studies.

Use of both LOAELs and NOAELs provides perspective on the potential for risk as a result of exposure to contaminants in dredged materials. LOAELs are values at which effects have been observed in either laboratory or field studies, while the NOAEL represents the lowest dose or body burden at which an ecologically relevant effect was not observed. Exceedance of a LOAEL indicates a greater potential for risk.

Some studies examine toxicity endpoints (such as lethality, growth, and reproduction) that are thought to have greater potential for adverse effects on populations of organisms than other studies. Other studies examine toxicity endpoints such as behavior, disease, cell structure, or biochemical changes that affect individual organisms, but may not result in adverse effects at the population level. For example, toxic effects such as enzyme induction may or may not result in adverse effects to individual animals or populations. The procedure in Trophic Trace is to develop TRVs from studies that examine the effects of contaminants on lethality, growth or reproduction. Studies that examined the effects of contaminants on other sublethal endpoints are not used to select TRVs unless no other studies are available. Lethality, growth, and reproductive-based endpoints typically present the greatest risk to the viability of the individual organism and therefore of the population's survival. Thus, these are considered to be the endpoints of greatest concern.

When exposures are expected to be long-term, data from studies of chronic exposure are preferable to data from medium-term (subchronic), short-term (acute), or single-exposure studies (USEPA, 1997c). Bioaccumulative substances are by definition persistent, and exposure of ecological receptors to these contaminants from dredged materials is expected to be long-term, and therefore studies of chronic exposure are preferentially used to select TRVs. Long-term studies are also preferred since reproductive effects of contaminants are typically studied after long-term exposure.

Dose-response studies compare the response of organisms exposed to a range of doses to that of a control group. Ideally, doses that are below and above the threshold level that causes adverse effects are examined. Toxicity endpoints determined in dose-response and other studies include:

- NOAEL (No-Observed-Adverse-Effect-Level) is the highest exposure level shown to be without adverse effect in organisms exposed to a range of doses. NOAELs may be expressed as dietary doses (e.g., mg contaminant consumed/kg body weight/d), as concentrations in external media (e.g., mg contaminant/kg food), or as concentrations in tissue of the affected organisms (e.g., mg chemical/kg egg).
- LOAEL (Lowest-Observed-Adverse-Effect-Level) is the lowest exposure level shown to produce adverse effect in organisms exposed to a range of doses. LOAELs may also be expressed as dietary doses (e.g., mg contaminant consumed/kg body weight/d), as concentrations in external media (e.g., mg contaminant/kg food), or as concentrations in tissue of the effected organisms (e.g., mg chemical/kg egg).
- LD₅₀ is the Lethal Dose that results in death of 50% of the exposed organisms. Expressed in units of dose (e.g., mg contaminant administered/kg body weight of test organism/d).

- LC₅₀ is the Lethal Concentration in some external media (e.g., food, water, or sediment) that results in death of 50% of the exposed organisms. Expressed in units of concentration (e.g., mg contaminant/kg wet weight food).
- ED₅₀ is the Effective Dose that results in a sublethal effect in 50% of the exposed organisms (mg/kg/d).
- EC₅₀ is the Effective Concentration in some external media that results in a sublethal effect in 50% of the exposed organisms (mg/kg).
- CBR or Critical Body Residue is the concentration in the organism (e.g., whole body, liver, or egg) that is associated with an adverse effect (mg contaminant/kg wet wt tissue).
- EL-effect is the effect level that results in an adverse effect in organisms exposed to a single dose, rather than a range of doses. Expressed in units of dose (mg/kg/d) or concentration (mg/kg).
- EL-no effect is the effect level that does not result in an adverse effect in organisms exposed to a single dose, rather than a range of doses. Expressed in units of dose (mg/kg/d) or concentration (mg/kg).

Most USEPA risk assessments typically estimate risk by comparing the exposure of receptors of concern to TRVs that are based on NOAELs. Example TRVs included in Trophic Trace are developed on the basis of both NOAELs and LOAELs to provide perspective on the range of potential effects relative to measured or modeled exposures.

Differences in the feeding behavior of aquatic and terrestrial organisms determine the type of toxicity endpoints that are most easily measured and most useful in assessing risk. For example, the dose consumed in food is more easily measured for terrestrial animals than for aquatic organisms since uneaten food can be difficult to collect and quantify in an aqueous environment. Therefore, for aquatic organisms, toxicity endpoints are more often expressed as concentrations in external media (e.g., water) or as accumulated concentrations in the tissue of the exposed organism (also called a “body burden”). In some studies, doses are administered via gavage, intraperitoneal injection into an adult, or injection into a fish or bird egg. If appropriate studies are available, TRVs in Trophic Trace are selected on the basis of the most likely route of exposure, as described below:

- TRVs for fish are expressed as critical body residues (CBR) (e.g., mg/kg whole body weight and mg/kg lipid in eggs).
- TRVs for terrestrial receptors (e.g., birds and mammals) are expressed as daily dietary doses (e.g., mg/kg whole body wt/d).
- TRVs for birds are also expressed as concentrations in eggs (e.g. mg/kg wet wt egg).

The toxicity quotient in ecological risk assessments is calculated as follows:

$$TQ = \frac{\sum IR_f * C_f * frac}{TRV * BW} \quad (10)$$

Where:

- TQ = Toxicity Quotient
- IR_f = annualized ingestion rate (kg/day)
- C_f = concentration in prey (mg/kg)
- frac = fraction in diet
- TRV = toxicity reference value (mg/kg/day)
- BW = body weight (kg)

2. Framework for BEST Model

The BEST model framework is based on the 1999 EPA Region 1 Bioaccumulation Risk Assessment Model.

2.1 Invertebrate tissue concentration

The BEST model predicts invertebrate tissue concentration using 28-day bioaccumulation test results and chemical properties in the following equations for metals and organics respectively.

Equation 1: BEST Formula for Invertebrate Edible Tissue Concentration (Metals)

$$[\text{Edible Tissue}_{\text{Invertebrate, Metal}}] \text{ (mg/kg)} = [\text{Cprey}] \times \text{SSCF}$$

Where:

$[\text{Edible Tissue}_{\text{Invertebrate, Metal}}]$ = Concentration of metal contaminant in edible tissue of invertebrate species ($\mu\text{g/g}$)

$[\text{Cprey}]$ = concentration of contaminant in the invertebrate in the maximum replicate of five replicates from the 28-day bioaccumulation test data depending on the user's choice ($\mu\text{g/g}$)

SSCF = steady state correction factor (unitless)

Equation 2: BEST Formula for Invertebrate Edible Tissue Concentration (Organics)

$$[\text{Edible Tissue}_{\text{Invertebrate, Organic}}] \text{ (mg/kg)} = \frac{[\text{Cprey}] \times \text{SSCF}}{1000}$$

Where:

$[\text{Edible Tissue}_{\text{Invertebrate, Organic}}]$ = Concentration of organic contaminant in edible tissue of invertebrate species (mg/kg)

$[\text{Cprey}]$ = concentration of contaminant in the invertebrate in the maximum replicate of five replicates from the 28-day bioaccumulation test data (ng/g)

SSCF = steady state correction factor (unitless)

1000 = Unit Normalization Factor $[\text{Edible Tissue}_{\text{Invertebrate, Organic}}]$ (ng/g \rightarrow $\mu\text{g/g}$)

2.2 Trophic Transfer

The BEST model predicts the chemical concentrations in predator species by applying a trophic transfer model to the measured contaminant concentrations in the benthic invertebrate test species using the following equation:

Equation 3: BEST Formula for Body Burdens in Predator Tissue

$$[\text{EdibleTissue}_{\text{Predator}}] \text{ (mg/kg)} = [\text{Edible Tissue}_{\text{Invertebrate}}] \times \text{BMF} \times \left(\frac{\text{Lipid}_{\text{Pred}}}{\text{Lipid}_{\text{Prey}}} \right)$$

Where:

[Edible Tissue_{Predator}] = Concentration of contaminant in edible tissue of predator (mg/kg)

[Edible Tissue_{Invertebrate}] = Concentration of contaminant in edible tissue of invertebrate species (mg/kg)

Lipid_{Pred} = predator mean lipid fraction (g lipid/g tissue)

Lipid_{Prey} = invertebrate mean lipid fraction (g lipid/g tissue)

BMF = biomagnification factor (unitless)

2.3 Human Health Risk

Once the edible tissue concentration is calculated using the trophic transfer model, the result is used to determine the dose to humans that consume these species. The lifetime average daily dose (LADD) is calculated for cancer risks and non-cancer risks.

The LADD is calculated using the following equation:

Equation 4: BEST Lifetime Average Daily Dose Equation

$$\text{LADD (mg/kg-day)} = \frac{\text{ETC} \times \text{FI} \times \text{F} \times \text{IR} \times \text{ED}}{\text{BW} \times \text{LT}}$$

Where:

LADD = Lifetime Average Daily Dose (mg/kg-day)

ETC = Edible Tissue Concentration of diet species (mg/kg)

FI = Fraction Ingested (unitless)

F = Frequency (days/year)

IR = Fish/shellfish Ingestion Rate (kg/day)

ED = Exposure Duration (years)

BW = Body Weight (kg)

LT = Lifetime (days)

To determine the carcinogenic risk level, the LADD is multiplied by an oral cancer slope factor (CSF) according to the following equation:

Equation 5: Standard Cancer Risk Equation

$$\text{Cancer Risk} = \text{LADD} \times \text{CSF}$$

Where:

LADD = Lifetime Average Daily Dose (mg/kg-day)

CSF = Oral Cancer Slope Factor (mg/kg)

To determine the non-carcinogenic hazard (i.e., hazard quotient), the LADD is divided by a

reference dose (RfD) according to the following equation:

Equation 6: Standard Non-cancer Risk Equation

$$\text{Non-cancer Risk} = \text{LADD}/\text{RfD}$$

Where:

LADD = Lifetime Average Daily Dose (mg/kg-day)

RfD = Oral Reference Dose (mg/kg-day)

Non-cancer risks greater than 1 are considered indicative of potential health effects. For cancer risks, an acceptable risk range of 1×10^{-6} to 1×10^{-4} is typically applied. Risk thresholds can be set in the Risk Thresholds section of the General properties.

2.4 Model Assumptions

Trophic Transfer

As previously described, the BEST risk model predicts edible tissue concentrations in predator species by applying a trophic transfer model to the measured concentrations in invertebrate test species (Equation 1) based on the results of the 28-day bioaccumulation testing. This approach assumes that the test species represent the prey species typically consumed by predators, and that 100 percent of the organisms consumed are exposed to the dredged material.

Steady State Correction Factor

A steady state correction factor (SSCF) is used to correct for underestimates of prey tissue concentrations in standard 28-day bioaccumulation testing. Because the standard testing period (28 days) might not be long enough for the exposed organisms to reach a state of equilibrium with their environment, the SSCF is applied to further estimate prey tissue concentrations under natural exposure periods that are longer than the standard testing duration.

Biomagnification Factor

The biomagnification factor (BMF) accounts for accumulation of chemicals in predator tissues from consumption of invertebrate prey. Chemicals that biomagnify, or increase concentration up the food chain, will have BMFs >1 while those that do not biomagnify will have BMFs ≤ 1 .

Toxicity Equivalency Factor

To address potential toxicity for dioxin compounds and for selected PCBs and PAHs, a toxicity equivalency factor (TEF) approach should be applied by the user. In this approach, specific compounds for which toxicity information are uncertain or unavailable are assigned a TEF value that estimates their toxicity relative to a compound of known toxicity (called a TEF Reference Chemical in BEST). For example, individual dioxin congeners, as well as coplanar PCB compounds, should each be assigned a value ranging from 0 to 1 indicating their toxicity relative to 2,3,7,8-TCDD. The measured concentrations of these compounds are multiplied by the risk

factors (CSF and RfD) of the TEF Reference Chemical they are related to in order to determine their cancer and non-cancer risks.

Risks

As previously discussed, the BEST model estimates the carcinogenic and non-carcinogenic risk to human health based on the consumption of species directly exposed to contaminants in the sediment and their predators using standard risk equations (EPA, 1989b) based on the lifetime average daily dose (LADD) and average daily dose (ADD), respectively.

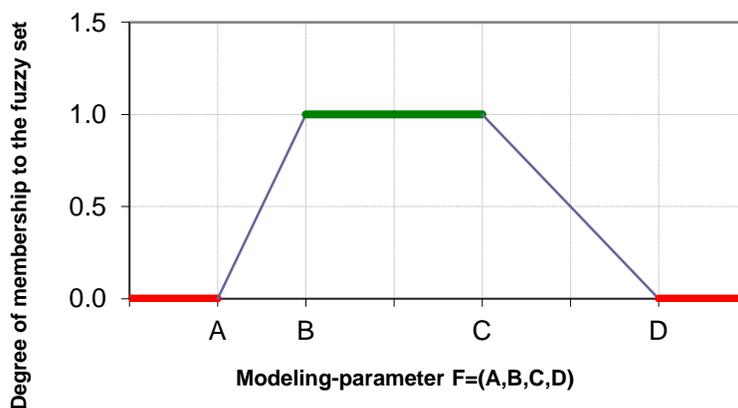
3. Interval Analysis of “Fuzzy Math” to Characterize Parameter Uncertainty In Trophic Trace*

3.1 Trapezoidal fuzzy numbers

A trapezoidal fuzzy number is simply four numerical values [A, B, C, D] where A is less than or equal to B, B is less than or equal to C, and C is less than or equal to D. For the fuzzy parameter $F=[A, B, C, D]$ the interval [A,D] represents the plausible range of the parameter. The number A is the minimum possible value of the parameter, and D is the maximum possible value of the parameter. The range [B,C] is the most likely range of the parameter F. So, fuzzy results yield both “worst case” and “best estimates” simultaneously.

Trapezoidal fuzzy numbers is an example of a fuzzy set and could be represented via its membership function showing the degree of membership for each value of the parameter (see Figure 20).

Figure 20: Membership Function for Trapezoidal Fuzzy Number $F=(A,B,C,D)$



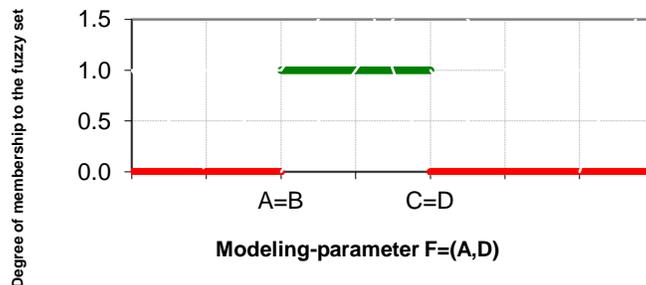
* This section is adapted from the TrophicTrace 4.0 Users Manual. von Stackelberg, K. and A. Burmistrova. 2004. TrophicTrace 4.0 Users Manual: A Tool for Assessing Risks from Trophic Transfer of Sediment-Associated Contaminants. January 28, 2009. 34 pp.

Degree of membership is a number between 0 and 1. The range of certain values of the parameter have a membership level equal to one (green line on Figure 19 corresponding to the interval $[B,C]$), restricted values with a degree of membership equal to zero are shown in red. All other values are more or less possible in proportion to their membership degree. This approach allows us to consider the fuzzy set as a measure for possibility (Zimmermann, 1991). Note that the y-axis does not represent a probability or likelihood. The degree of membership in the fuzzy set is proportional, however, such that if the degree of membership = 1 (B to C, also called the likeliest or probable range), then the parameter value, given the inputs, will definitely be within that range. The parameter may take on values from the sides of the trapezoid (A to B and C to D, also called the full or possible range), but these values are only “possibilities” with the degree of possibility reflected in the degree of membership. For example, a value that has a degree of membership of 0.8 is much more possible than a value with a degree of membership that is only 0.1.

3.2 Example: Interval

In the case when all possible values of the parameter are equally plausible (e.g., equivalent to a uniform distribution), then the range of the parameter can be described by an interval and interval analysis is used to analyze a model with such parameters. The membership function for an interval is a stepped function (see Figure 21).

Figure 21: Membership Function for Interval $F=(A,D)$



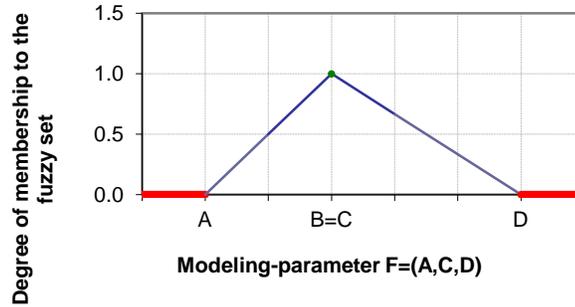
This approach also provides the possibility to consider the interval $[A,D]$ as a trapezoidal fuzzy number $[A,B,C,D]$ with $B=A$ and $C=D$, i.e. as the fuzzy number $[A,A,D,D]$, and to use such parameters in modeling. In this case, the short representation $[A,D]$ can be used instead of $[A,A,D,D]$.

3.3 Triangular Fuzzy Numbers as a Particular Case of Trapezoidal Fuzzy Numbers

Trapezoidal fuzzy numbers also include fuzzy numbers with a triangular shape for the membership function. A triangular fuzzy number is evaluated as a trapezoidal fuzzy number

$[A,B,C,D]$ with $B=C$, i.e. $[A,B,B,D]$. Such a fuzzy number could be used for a quantitative description of a parameter for which a possible range is known together with a single most likely value. This is shown graphically in Figure 22. The short notation for a triangular fuzzy number is $[A,B,D]=[A,B,D,D]$

Figure 22: Triangular Fuzzy Number $F=(A,C,D)$



3.4 Exact Parameter Value

It might be possible to know or only have information for one value for some parameters in the model. The approach to treat them as a trapezoidal fuzzy number $[A,B,C,D]$ with $A=B=C=D$: $[A,A,A,A]$ allows the model to include such parameters simultaneously with other parameters that are more uncertain. Zadeh (1965) provides an implementation for processing of fuzzy numbers by the extension principle. Note, that all following notations are equivalent: $A=[A]=[A,A]=[A,A,A]=[A,A,A,A]$; all denote standard (not fuzzy) numbers as the particular case of the fuzzy number.

Trophic Trace performs the extension principle for the model equation process, but approximates results by trapezoidal shapes, too. The approximation approach uses the vertex method (Dong and Shah, 1987) for computing a function of fuzzy variables.

3.5 Arithmetic of Trapezoidal Fuzzy Numbers

3.5.1 Addition

According to the extension principle, the sum of two trapezoidal fuzzy numbers is also a trapezoidal number. The following formula provides the exact value used by Trophic Trace.

$$[A_1, B_1, C_1, D_1] + [A_2, B_2, C_2, D_2] = [A_1 + A_2, B_1 + B_2, C_1 + C_2, D_1 + D_2] \quad (10)$$

3.5.2 Subtraction

As for subtraction, the extension principle provides an exact solution for this operation, as shown in the following formula.

$$[A_1, B_1, C_1, D_1] - [A_2, B_2, C_2, D_2] = [A_1 - A_2, B_1 - B_2, C_1 - C_2, D_1 - D_2] \quad (11)$$

3.5.3 Multiplication

Trophic Trace uses the following approximate formula for multiplication of fuzzy numbers.

$$[A_1, B_1, C_1, D_1] * [A_2, B_2, C_2, D_2] \sim [A_1 * A_2, B_1 * B_2, C_1 * C_2, D_1 * D_2] \quad (12)$$

The vertex method is based on α -cut conception and interval analysis. It can be shown that the exact solution of multiplying trapezoidal fuzzy numbers has a curvilinear trapezium shape (so the result of multiplication of trapezoidal fuzzy numbers is not trapezoidal itself: this is the purpose of using the “approximate” sign “~”). We approximate the result by the trapezoidal fuzzy number anyway. The vertexes of this curvilinear relationship are calculated using formula (12) from above.

3.5.4 Division

α -cut conception and interval analysis provides the following formula used in the Trophic Trace model for operation of division of positive trapezoidal fuzzy numbers.

$$[A_1, B_1, C_1, D_1] / [A_2, B_2, C_2, D_2] \sim [A_1 / D_2, B_1 / C_2, C_1 / B_2, D_1 / A_2] \quad (13)$$

As in interval analysis, the multiplication and division of fuzzy numbers are inverse to each other only for the case when all fuzzy parameters are exact values (all four components are equal). If parameter F has plausible range $[A_1, D_1]$ and the plausible range for parameter Y is $[A_2, D_2]$, then to obtain the minimum value for the parameter F/Y one needs to divide the minimum value of the parameter F by the maximum value of the parameter Y. The maximum value of F/Y is obtained by dividing maximum F by minimum Y.

3.5.5 Power operations

The extension principle provides an exact solution for extending the exponent function for fuzzy numbers.

$$\text{EXP} [A_1, B_1, C_1, D_1] = [\text{EXP} (A_1), \text{EXP} (B_1), \text{EXP} (C_1), \text{EXP} (D_1)] \quad (14)$$

This function is the particular case of a power function for which the extension principle also provides the exact solution, as shown below.

$$[A_1, B_1, C_1, D_1]^{[A_2, B_2, C_2, D_2]} = [A_1^{A_2}, B_1^{B_2}, C_1^{C_2}, D_1^{D_2}] \quad (15)$$

PART VI: Appendices

APPENDIX A: REFERENCES

- Abraham, B.J. (1985). Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic) – Mummichog and Killifish. (FWS/OB2-82/11.40, US Fish and Wildlife Service, Washington, D.C., 1985).
<http://www.nwrc.usgs.gov/publications/specintro.htm>
- Agency for Toxic Substances and Disease Registry (ATSDR). (2000). Draft Toxicological Profile for DDT, DDE, and DDD. U.S. Department of Health and Human Services, Atlanta, GA.
- Battelle. 2005. Evaluation of EPA Region 1 Bioaccumulation Risk Assessment Model, EPA/OCPD 68-C-03-041. States Environmental Protection Agency: Ocean and Coastal Protection Division.
- Bleavins, M R. and R. J. Aulerich. (1981). Feed consumption and food passage time in mink (*Mustela vison*) and European ferrets (*Mustela putorius furo*). *Lab. Anim. Sci.* 31 268-269.
- Bridges, T.S., K. von Stackelberg. 2002. A Management Guide for a Tiered Risk Assessment Procedure for Evaluating Bioaccumulation Data Collected during Regulatory Evaluations of Dredged Material. Menzie-Cura & Associates, Inc. and USACE Engineer and Development Research Center.
- Burkhard, L. 1995. Memorandum dated June 9, 1995, Biomagnification of NY Bight Apex, to Alex Lechich, US EPA Region II. Environmental Research Laboratory, Office of Research and Development, Duluth MN.
- Byron, W.R., G.W. Bierbower, J.B. Brouwer, and W.H. Hansen. (1967). Pathologic changes in rats and dogs from two-year feeding of sodium arsenite or sodium arsenate. *Toxicology and Applied Pharmacology* 10:132-147.
- California EPA. 2004. Office of Environmental Health Hazard Assessment Toxicity Criteria Database. <http://www.oehha.ca.gov/risk/chemicalDB//index.asp>. Accessed January 29, 2009.
- Connell, D.W. and D.W. Hawker. (1988). Use of polynomial expressions to describe the bioconcentration of hydrophobic chemicals by fish. *Ecotoxicol Environ Saf*, 16(3):242-57
- Cura, J.J., Heiger-Bernays, W., Bridges, T.S., and D.W. Moore. (1999). Ecological and human health risk assessment guidance for aquatic environments. Technical Report DOER-4, US Army Corps of Engineers, Engineer Research and Development Center, Dredging Operations and Environmental Research Program, December.

Dahlgren, R.B., R. L. Linder, and C.W. Carlson. (1972). Polychlorinated biphenyls: their effects on penned pheasants. *Environmental Health Perspectives* 1:89-101.

Dillon, T.M., Suedel, B.C., Peddicord, R.K., Clifford, P.A., and J.A. Boraczek. (1995). Trophic transfer and biomagnification potential of contaminants in aquatic ecosystems. *Environmental Effects of Dredging Technical Notes*, EEDP-01-33, US Army Corps of Engineers, January.

Dixon, D.G. and J.B. Sprague. (1981). *J. Fish Biol.* 18: 579-589

Dong, W. and H.C. Shah. (1987). Vertex method for computing functions of fuzzy variables. *Fuzzy Sets and Systems*, 24:65-78.

Fitzhugh O. (1948). Use of DDT insecticides on food products. *Indust Eng Chem* 40:704-705.

Giesy, J.P., W.W. Bowerman, M.A. Mora, D.A. Verbrugge, R.A. Othoutd, J.L. Newsted, C.L. Summer, R.J. Aulerich, S.J. Bursian, J.P. Ludwig, G.A. Dawson, T.J. Kubiak, D.A. Best, and D.E. Tillitt. (1995). Contaminants in fishes from Great Lakes-influenced sections and above dams of three Michigan rivers: III. Implications for health of bald eagles. *Archives of Environmental Contamination and Toxicology* 29:309-321.

Gobas, F.A.P.C. (1993). A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food-webs: application to Lake Ontario. *Ecol. Modelling* 69:1-17.

Gobas, F.A.P.C., M.N. Z'Graggen and X. Zhang. (1995). Time response of the Lake Ontario ecosystem to virtual elimination of PCBs. *Env. Science Technol.* 29(8):2038-2046.

Grimes, B.H., M.T. Huish, J.H. Kerby, J.S. Fish, and D. Moran. (1989). Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic) – Summer and Winter Flounder. (FWS/OB2-82/11.112, US Fish and Wildlife Service, Washington, D.C., 1989). <http://www.nwrc.usgs.gov/publications/specintro.htm>

Hamelink JL, Waybrant R.C., Ball RC. (1971). A proposal: Exchange equilibria control the degree chlorinated hydrocarbons are biologically magnified in lentic environments. *Transactions of the American Fisheries Society* 100:207-214.

Hansen, D.J., S.C. Schimmel, and J. Forester. (1974). Aroclor 1254 in eggs of sheepshead minnows: Effect on fertilization success and survival of embryos and fry. *Proceedings of Southeastern Game Fish Commission*. 1974.

Hoffman, D. J., G. J. Smith and B.A. Ratner. (1993). Biomarkers of contaminant exposure in common terns and black-crowned night herons in the Great Lakes. *Environmental Toxicology and Chemistry*. 12:1095-1103.

Lincer J.L. (1972). DDE- induced eggshell thinning in the American kestrel: a comparison of the field situation and laboratory results. *J Appl Ecol* 12:781-793.

Lyman, W.J., W.F. Reehl and D.H. Rosenblatt. (1990). *Handbook of Chemical Property Estimation Methods, Environmental Behavior of Organic Compounds*. American Chemical Society, Washington, DC

Mackay, D., W.Y. Shiu and K.C. Ma. (1992). *Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals; Volume 1-Monoaromatic Hydrocarbons, Chlorobenzenes, and PCBs*. Lewis Publishers, Boca Raton, Florida.

McFarland, V. F. (1984). "Activity-based evaluation of potential bioaccumulation from sediments." Dredging and dredged material disposal: Proceedings of the Conference Dredging '84, Clearwater Beach, FL, November 14-16, 1984. Raymond L. Montgomery and Lamie W. Leach, eds. American Society of Civil Engineers, New York, 1, 461-467.

McFarland, V.A. 1994. Evaluation of Field-Generated Accumulation Factors Predicting the Bioaccumulation Potential of Sediment-Associated PAH compounds. Ph.D. Dissertation. Northeast Louisiana University Monroe, L.A.

McFarland, V.F., and P.W. Ferguson. (1995). TBP revisited: a ten year perspective on a screening test for dredged sediment bioaccumulation potential. In Dredging '94: Proceedings of the Second International Conference on Dredging and Dredged Material Placement, Volume 1. McNair, E.C., Jr., Ed., sponsored by the Waterways Committee of the Waterway, Port, Coastal, and Ocean Division of the American Society of Civil Engineers.

New Jersey Marine Sciences Consortium (NJMSC) and New Jersey Department of Agriculture (NJDA). (1994). Fish consumption patterns by New Jersey Consumers and Anglers. Prepared for New Jersey Department of Environmental Protection and Energy, Division of Science and Research. August.

Parsons, T.R., M. Takahashi and B. Hargrave. (1984). *Biological Oceanographic Processes* (Pergamon Press, Oxford, 1984).

Restum, J.C., S.J. Bursian, J.P. Giesy, J.A. Render, W.G. Helferich, E.B. Shipp, and D.A. Verbrugge. (1998). Multigenerational study of the effects of consumption of PCB-contaminated carp from Saginaw Bay, Lake Huron, on mink. 1. Effects on mink reproduction, kit growth and survival, and selected biological parameters. *Journal of Toxicology and Environmental Health*, Part A, 54:343-375.

Rubinstein, N. I., Lake, J. L., Pruell, R. J., Lee, H., II, Taplin, B., Helshe, J., Bowen, R., and Pavignano, S. (1987). "Predicting bioaccumulation of sediment associated organic contaminants: Development of a regulatory tool for dredged material evaluation." Technical Report D-87 prepared by the U.S. Environmental Protection Agency, Narragansett, RI, for the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 59 pp.

Sample, B.E., D.M. Opresko, G.W. Suter II. Toxicological Benchmarks for Wildlife: 1996 Revision. U.S. Dept. of Energy, Office of Environmental Management. ES/ER/TM-86/R3.

Stackelberg, von K., Vorhees, D., Linkov, I., Burmistrov, D., and T. Bridges. (2002). Importance of uncertainty and variability to predicted risks from trophic transfer of contaminants in dredged sediments. *Risk Analysis* 22(3):499-512.

Stackelberg, von K. and T.S. Bridges. (2002). A management guide for a tiered risk assessment procedure for evaluating bioaccumulation data collected during regulatory evaluations of dredged material. Menzie-Cura & Associates, Inc. and US Engineer and Development Research Center.

Stackelberg, von K. and A. Burmistrova. 2004. *TrophicTrace* 4.0 Users Manual: A Tool for Assessing Risks from Trophic Transfer of Sediment-Associated Contaminants. January 28, 2009. 34 pp.

Stephan, C.W. (1993). Derivation of proposed human health and wildlife bioaccumulation factors for the Great Lakes Initiative. Environmental Research Laboratory, Office of Research and Development, US Environmental Protection Agency, Duluth, MN. March.

USEPA/USACE. United States Environmental Protection Agency and United States Army Corps of Engineers. (1991). Evaluation of dredged material proposed for ocean disposal: testing manual. EPA-503/8-91/001.

USEPA/USACE United States Environmental Protection Agency and United States Army Corps of Engineers. (1998). Evaluation of dredged material proposed discharge in waters of the U.S. testing manual: inland testing manual. EPA 823-B-98-004.

United States Environmental Protection Agency (USEPA). (1989). Risk Assessment Guidance for Superfund, Volume 1 – Human Health Evaluation Manual, Part A, Interim Final. EPA/540/1-89/0002. Publication 9285.7-01A. Office of Emergency and Remedial Response, Washington, D.C.

United States Environmental Protection Agency (USEPA). (1993). Wildlife Exposure Factors Handbook. Office of Research and Development, Washington, DC. EPA/600/R-93/187a. December, 1993.

United States Environmental Protection Agency (USEPA). (1997a). Exposure Factors Handbook, Volume I: General Factors. Office of Research and Development. Washington D.C.: Government Printing Office. EPA/600/P-95/002Fa.

United States Environmental Protection Agency (USEPA). (1997b). Exposure Factors Handbook, Volume II: Food Ingestion Factors. Office of Research and Development. Washington D.C.: Government Printing Office. EPA/600/P-95/002Fb.

United States Environmental Protection Agency (USEPA). (1997c). Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final. Environmental Response Team, Edison, NJ. EPA 504/R-97/006. June 5, 1997.

- United States Environmental Protection Agency (USEPA). (1999a). Integrated Risk Information System Database (IRIS). <http://www.epa.gov/iris>.
- United States Environmental Protection Agency (USEPA). (1999b). Partition Coefficients for Metals in Surface Water, Soil, and Waste [s0524.pdf] Prepared by HydroGeoLogic, Inc., and Allison Geoscience Consultants, Inc. for the Office of Solid Waste. June. <http://www.epa.gov/epaoswer/hazwaste/id/hwirwste/risk.htm>
- United States Environmental Protection Agency (USEPA). (1999c). Data Collection for the Hazardous Waste Identification Rule, Section 11: Aquatic Food Web Data [s0041.pdf] Prepared by the Center for Environmental Analysis for the Office of Solid Waste. October. <http://www.epa.gov/epaoswer/hazwaste/id/hwirwste/risk.htm>
- United States Environmental Protection Agency (USEPA). (2000). Proposed changes to the bioaccumulation testing evaluation framework and response to scientific peer reviewers comments on the existing framework for determining the suitability of dredged material to be placed at the Historic Area Remediation Site (HARS). USEPA, Region 2, New York, October.
- United States Environmental Protection Agency (USEPA). (2004). U.S. EPA Integrated Risk Information System (IRIS) Database. U.S. Environmental Protection Agency, Washington, D.C. Updated January 30, 2009.
- Vorhees, D.J., Kane Driscoll, S.B., von Stackelberg, K., and T.S. Bridges. (1998). Improving dredged material management decisions with uncertainty analysis. Dredging Operations and Environmental Research Program, Technical Report DOER-3, December.
- Wiemeyer, S.N., C.M. Bunck, and C.J. Stafford. (1993). Environmental Contaminants in bald eagle eggs – 1980-84- and further interpretations of relationships to productivity and shell thickness. *Archives of Environmental Contamination and Toxicology* 24:213-227.
- Wiemeyer, S.N., T.G. Lamont, C.M. Bunck, C.R. Sindelar, F.J. Gramlich, J.D. Fraser, and M.A. Byrd. (1984). Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagle eggs-1969-79- and their relations to shell thinning and reproduction. *Archives of Environmental Contamination and Toxicology* 13:529-549.
- Wilson, Jr., W.H. and R.E. Ruff. (1988). Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North-Atlantic) – Sandworm and Bloodworm. (FWS/OB2-82/11.80, US Fish and Wildlife Service, Washington, D.C., 1988). <http://www.nwrc.usgs.gov/publications/specintro.htm>
- Zadeh, L.A. (1965). Fuzzy Sets. *Inform. and Control*, 8:338-353.
- Zimmermann, H.J. (1991). Fuzzy Set Theory and its Application. Boston: 2nd Edition, Kluwer Academic Publisher.

APPENDIX B: ACRONYMS

ADDAMS	USACE fate and transport modeling system
BEST	Bioaccumulation Evaluation Screening Tool
BCF	Bioconcentration Factor
BSAF	Biota Sediment Accumulation Factor (here used only as a benthic sediment accumulation factor)
BRAMS	Bioaccumulation Risk Assessment Modeling Software
CSF	Cancer Slope Factor (mg/kg-day) ⁻¹
DOC	Dissolved Organic Carbon
ITM	Inland Testing Manual
K _{oc}	Log
K _{ow}	Log-octanol water partitioning coefficient
LADD	Lifetime Average Daily Dose
LOAEL	Lowest Observed Adverse Effect Level for ecological receptors
NJDA	New Jersey Department of Agriculture
NOAEL	No Observed Adverse Effect Level for ecological receptors
NY/NJ	New York/New Jersey
OTM	Ocean Testing Manual
PCBs	Polychlorinated Biphenyls
POC	Particulate Organic Carbon
RfD	Reference Dose (mg/kg-day)
TBP	Theoretical Bioaccumulation Potential
TT	Trophic Trace
TTF	Trophic Transfer Factor (from invertebrates to fish)
TRV	Toxicity Reference Value for ecological receptors
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency